August 22, 2018

# Dr. Albert M. Green

## Patent Portfolio

| Dr. Albert M. Green<br>Patent Portfolio<br>August 22, 2018 | | | |
|---|---|---|---|
| **Count** | **Patent #** | **Publication Date** | **Title** |
| 1. | 6,166,756 | 12/26/2000 | Multiple channel data writing device |
| 2. | 6,341,118 | 1/22/2002 | Multiple channel scanning device using oversampling and image processing to increase throughput |
| 3. | 6,545,422 | 4/8/2003 | Socket for use with a micro-component in a light-emitting panel |
| 4. | 6,570,335 | 5/27/2003 | Method and system for energizing a micro-component in a light-emitting panel |
| 5. | 6,612,889 | 9/2/2003 | Method for making a light-emitting panel |
| 6. | 6,620,012 | 9/16/2003 | Method for testing a light-emitting panel and the components therein |
| 7. | 6,646,388 | 11/11/2003 | Socket for use with a micro-component in a light-emitting panel |
| 8. | 6,762,566 | 7/13/2004 | Micro-component for use in a light-emitting panel |
| 9. | 6,764,367 | 7/20/2004 | Liquid manufacturing processed for panel layer fabrication |
| 10. | 6,791,264 | 9/14/2004 | Light-emitting panel and a method for making |
| 11. | 6,796,867 | 9/28/2004 | Use of printing and other technology for micro-component placement |
| 12. | 6,801,001 | 10/5/2004 | Method and apparatus for addressing micro-components in a plasma display panel |
| 13. | 6,822,626 | 11/23/2004 | Design, fabrication, testing and conditioning of micro-components for use in a light-emitting panel |
| 14. | 6,902,456 | 6/7/2005 | Socket for use with a micro-component in a light-emitting panel |
| 15. | 6,975,068 | 12/13/2005 | Light-emitting panel and a method for making |
| 16. | 7,005,793 | 2/28/2006 | Socket for use with a micro-component in a light-emitting panel |
| 17. | 7,125,305 | 10/24/2006 | Light-emitting panel and a method for making |
| 18. | 7,137,857 | 11/21/2006 | Method for manufacturing a light-emitting panel |
| 19. | 7,236,151 | 6/26/2007 | Liquid crystal display |
| 20. | 7,288,014 | 10/30/2007 | Design, fabrication, testing, and conditioning of micro-components for use in a light-emitting panel |
| 21. | 7,420,445 | 9/2/2008 | Phase change control devices and circuits for guiding electromagnetic waves employing phase change control devices |
| 22. | 7,789,725 | 9/7/2010 | Manufacture of light-emitting panels provided with texturized micro-components |
| 23. | 7,796,103 | 9/14/2010 | Drapable liquid crystal transfer display films |
| 24. | 8,043,137 | 10/25/2011 | Light-emitting panel and a method for making |
| 25.. | 8,246,409 | 8/21/2012 | Light-emitting panel and a method for making |
| 26. | 9,651,813 | 5/16/2017 | Liquid crystal paper |

US006166756A

# United States Patent [19]

White et al.

[11] **Patent Number:** **6,166,756**

[45] **Date of Patent:** **Dec. 26, 2000**

[54] **MULTIPLE CHANNEL DATA WRITING DEVICE**

[75] Inventors: **Robert Courtney White**, Fairfax; **Adam Thomas Drobot**, Annandale; **Newell Convers Wyeth**, Oakton; **Albert Myron Green**, Alexandria, all of Va.

[73] Assignee: **Science Applications International Corporation**, San Diego, Calif.

[21] Appl. No.: **09/089,136**

[22] Filed: **Jun. 2, 1998**

[51] **Int. Cl.**[7] ........ **B41J 2/47**

[52] **U.S. Cl.** ........ **347/239**; 347/238

[58] **Field of Search** ........ 347/239, 238, 347/255, 242, 129; 385/29; 355/1, 40; 359/127, 290, 291; 369/100, 103, 112

[56] **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,112,360 | 11/1963 | Gregg . | |
| 3,220,013 | 11/1965 | Harris | 347/239 |
| 3,892,468 | 7/1975 | Dunguay . | |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| 0 092 420 | 10/1983 | European Pat. Off. . |
| 0 784 314 | 7/1997 | European Pat. Off. . |
| 37 17 604 | 11/1987 | Germany . |

OTHER PUBLICATIONS

Abstract of D.E. Brei and J. Blechschmidt, "Design and Static Modeling of a Semicircular Polymeric Piezoelectric Microactuator", (JMEMS, vol. 1, No. 3, p. 106) Sep. 1992.

Abstract of K. Minami, S. Kawamura, and M. Esashi, "Fabrication of Distributed Electrostatic Micro Actuator (DEMA)", (JMEMS, vol. 2, No. 3, p. 121 et. seq.) Sep. 1993.

Abstract of Q. Meng, M. Mehregany, and R. L. Mullen, "Theoretical Modeling of Microfabricated Beams with Elastically Restrained Supports", (JMEMS, vol. 2, No. 3, p. 128 et. seq.) Sep. 1993.

Abstract of M. Ataka, A. Omodaka, N. Takeshima, and H. Fujita, "Fabrication and Operation of Polyimide Bimorph Actuators for a Ciliary Motion System", (JMEMS, vol. 2, No. 4, p. 146) Dec. 1993.

Abstract of J.G. Smits and A. Ballato, "Dynamic Admittance Matrix of Piezoelectric Cantilever Bimorphs", (JMEMS, vol. 3, No. 3, p. 105 et. seq.) Sep. 1994.

Abstract of J.W. Judy, R.S. Muller, and H.H. Zappe, "Magnetic Microactuation of Polysilicon Flexure Structures", (JMEMS, vol. 4, No. 4, p. 162) Dec. 1995.

Abstract of T.S. Low and W. Guo, "Modeling of a Three–Layer Piezoelectric Bimorph Beam with Hysteresis", (JMEMS, vol. 4, No. 4, p. 230) Dec. 1995.

(List continued on next page.)

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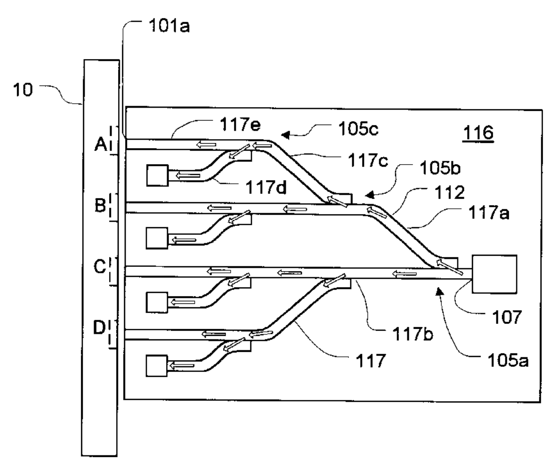
[57] **ABSTRACT**

An integrated optoelectronic chip **116** produces multiple modulatable outputs in a read write head. An array of light guides in a light guide switchyard has some terminations at output apertures and some at beam dumps within the read/write head. The beam dumps absorb and dissipate any light conveyed to them. The beam switches allow control of the direction of light emitted from an on-board laser **106** which enters the array of light guides. By switching between a respective beam dump and a respective output aperture, the beam switch is used to modulate the output from the aperture. The light emitted can be imaged onto a target surface by a lens system or a single holographic element. In an alternative embodiment, instead of dumping the light to a beam dump, it can also be directed away from the target surface. An optoelectronic chip for modulating multiple outputs can be formed without an embedded laser. Instead, a separate laser may be connected to a chip having light guides, optoelectronic switches, and beam dumps, only.

**36 Claims, 9 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 4,058,736 | 11/1977 | Takahashi et al. . | |
| 4,135,083 | 1/1979 | Van Alem et al. . | |
| 4,193,091 | 3/1980 | Kleuters et al. . | |
| 4,234,788 | 11/1980 | Palmer et al. . | |
| 4,337,531 | 6/1982 | Willemsen . | |
| 4,482,986 | 11/1984 | Noda et al. . | |
| 4,507,765 | 3/1985 | Suzuki et al. . | |
| 4,544,259 | 10/1985 | Kanaoka et al. | 355/1 |
| 4,564,268 | 1/1986 | Tatsuno et al. . | |
| 4,572,949 | 2/1986 | Bowers et al. . | |
| 4,737,946 | 4/1988 | Yamashita et al. . | |
| 4,744,073 | 5/1988 | Sugiki . | |
| 4,755,668 | 7/1988 | Davis . | |
| 4,763,973 | 8/1988 | Inoue et al. . | |
| 4,767,210 | 8/1988 | Kashyap . | |
| 4,771,415 | 9/1988 | Taki . | |
| 4,815,807 | 3/1989 | Kaneko et al. . | |
| 4,858,215 | 8/1989 | Yano et al. . | |
| 4,991,160 | 2/1991 | Premji . | |
| 5,001,338 | 3/1991 | Boero . | |
| 5,010,346 | 4/1991 | Hamilton et al. . | |
| 5,070,488 | 12/1991 | Fukushima et al. . | |
| 5,109,459 | 4/1992 | Eibert et al. . | |
| 5,121,449 | 6/1992 | Shiba et al. . | |
| 5,128,915 | 7/1992 | Yamashita et al. . | |
| 5,144,604 | 9/1992 | Sugiura . | |
| 5,144,616 | 9/1992 | Yasukawa et al. . | |
| 5,195,152 | 3/1993 | Gupta . | |
| 5,278,812 | 1/1994 | Adar et al. . | |
| 5,289,454 | 2/1994 | Mohapatra et al. . | |
| 5,293,291 | 3/1994 | Ohki et al. . | |
| 5,317,148 | 5/1994 | Gray et al. . | |
| 5,390,157 | 2/1995 | Revelli, Jr. . | |
| 5,414,785 | 5/1995 | Bergmann | 385/24 |
| 5,416,881 | 5/1995 | Ikeda . | |
| 5,422,469 | 6/1995 | Bard et al. . | |
| 5,444,689 | 8/1995 | Ohki et al. . | |
| 5,452,382 | 9/1995 | Shionoya et al. . | |
| 5,661,591 | 8/1997 | Lin et al. . | |
| 5,802,222 | 9/1998 | Rasch et al. | 385/14 |
| 5,940,564 | 8/1999 | Jewell | 385/93 |

OTHER PUBLICATIONS

Abstract of Yuji Uenishi, Hidenao Tanaka, and Hiro Ukita, "AlGaAs/GaAs micromachining for monolithic integration of optical and mechanical components", (Proc. SPIE vol. 2291, p. 82–91, Integrated Optics and Microstructures II, Massood Tabib–Azar; Dennis L. Polla; Ka–Kha Wong; Eds. Oct. 1994).

Scanning Device Using Fiber Optic Bimorph (Adam Thomas Drobot, Robert Courtney White). Our reference: 00479.02150, U.S. Application Serial No. 09/089,138, filed Jun. 2, 1998.

Multiple Parallel Source Scanning Device (Adam Thomas Drobot, Robert Courtney White, Newel Convers Wyeth). Our Reference: 00479.02151, U.S. Application Serial No. 09/089,137, filed Jun. 2, 1998.

Method and Apparatus for Controlling the Focus of a Read/Write Head for an Optical Scanner (Edward Alan Phillips, Newel Convers Wyeth). Our Reference: 00479.02154, U.S. Application Serial No. 09/088,781, filed Jun. 2, 1998.

Multiple Channel Scanning Device Using Optoelectronic Switching (Adam Thomas Drobot, Robert Courtney White, Newel Convers Wyeth). Our Reference: 00479.02153, U.S. Application Serial No. 09/088,782, filed Jun. 2, 1998.

Multiple Channel Scanning Device using Oversampling and Image Processing to Increase Throughput (Adam Thomas Drobot, Robert Courtney White, Newel Convers Wyeth, Albert Myron Green, Edward Alan Phillips). Our Reference: 00479.02155, U.S. Application Serial No. 09/088,780, filed Jun. 2, 1998.

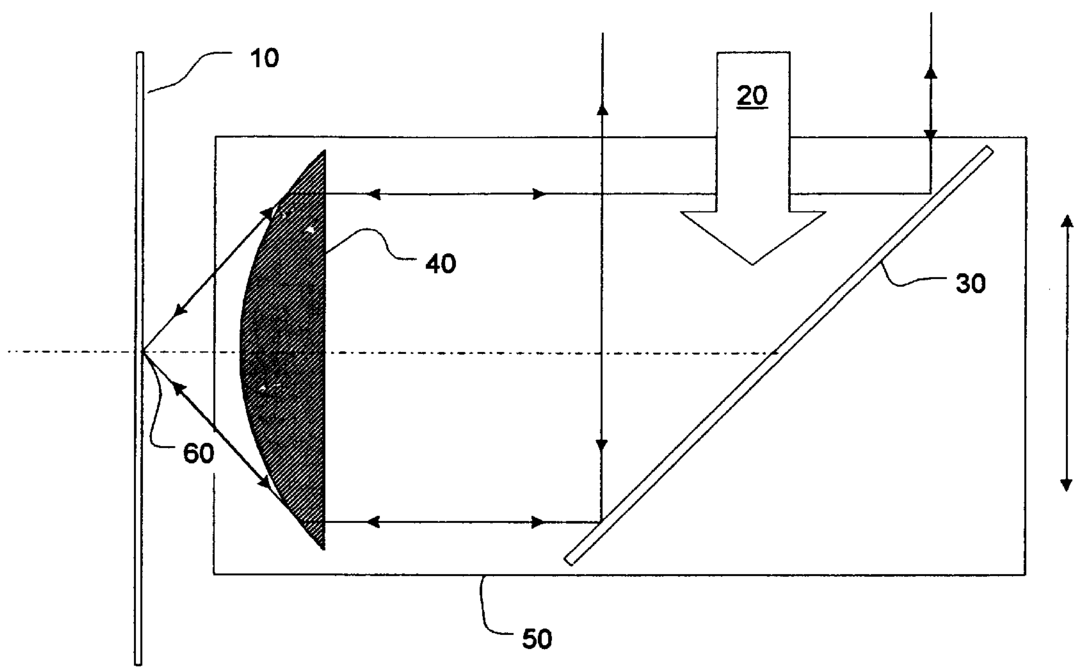
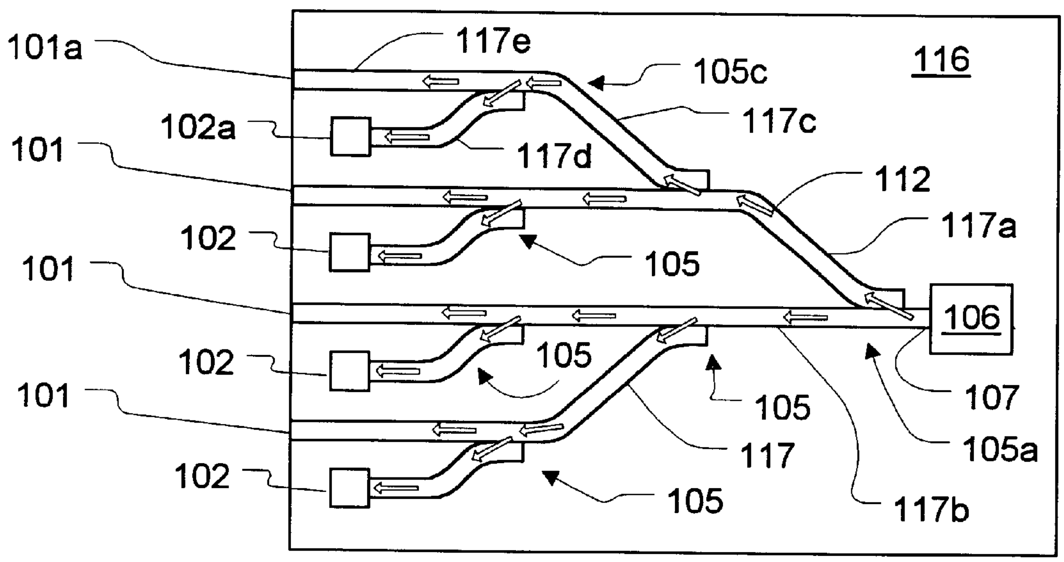



Fig. 1

PRIOR ART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105c
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117c
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117d
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102
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107
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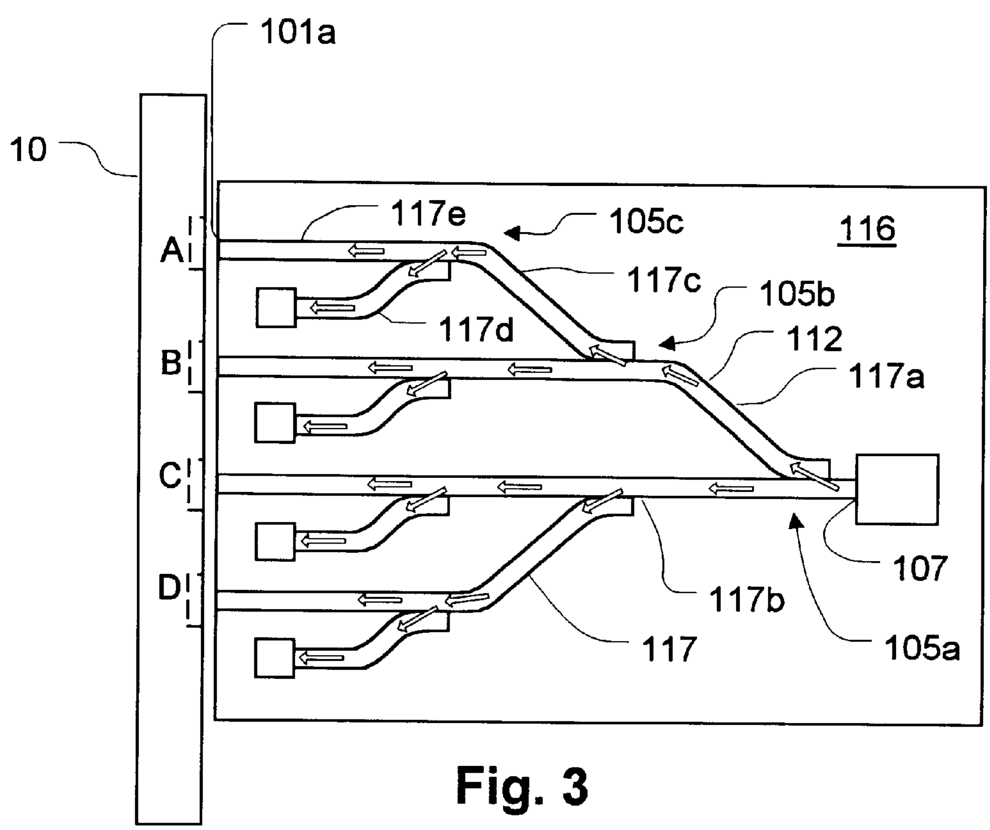
117
105a
102
105
117b

Fig. 2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A
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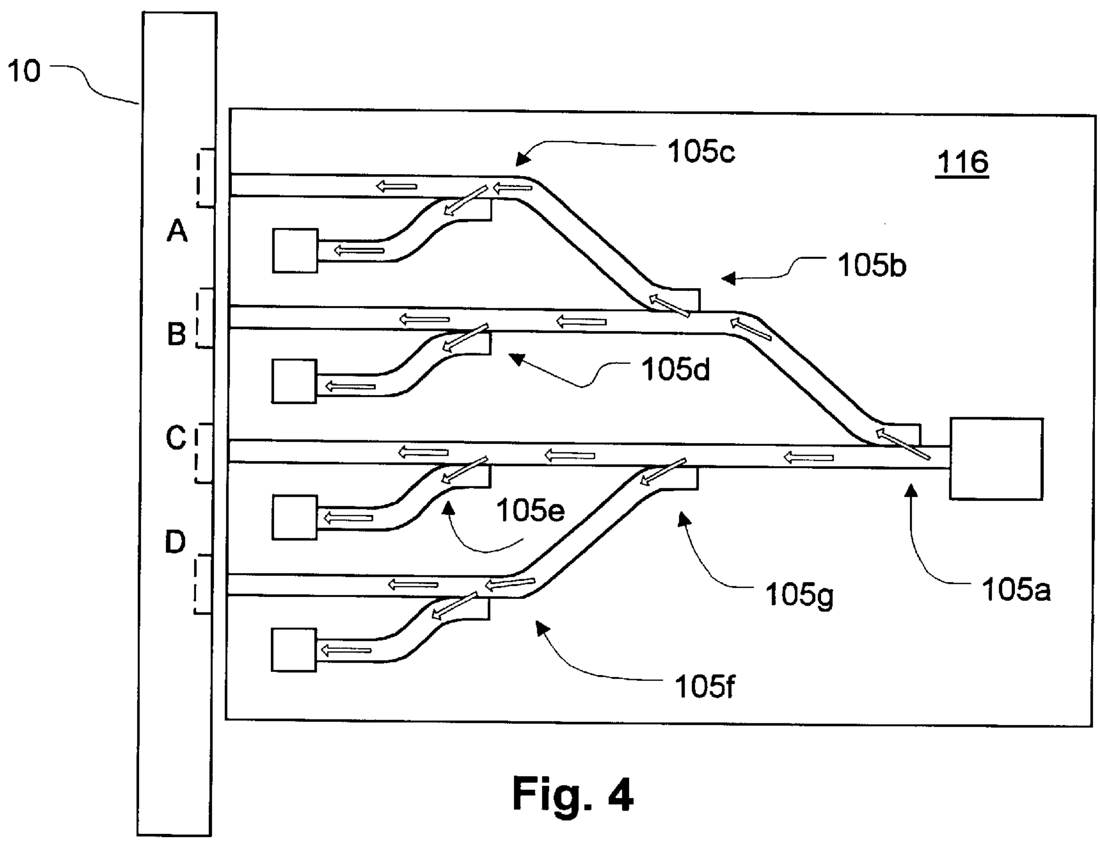
C
107
D
117b
117
105a

Fig. 3

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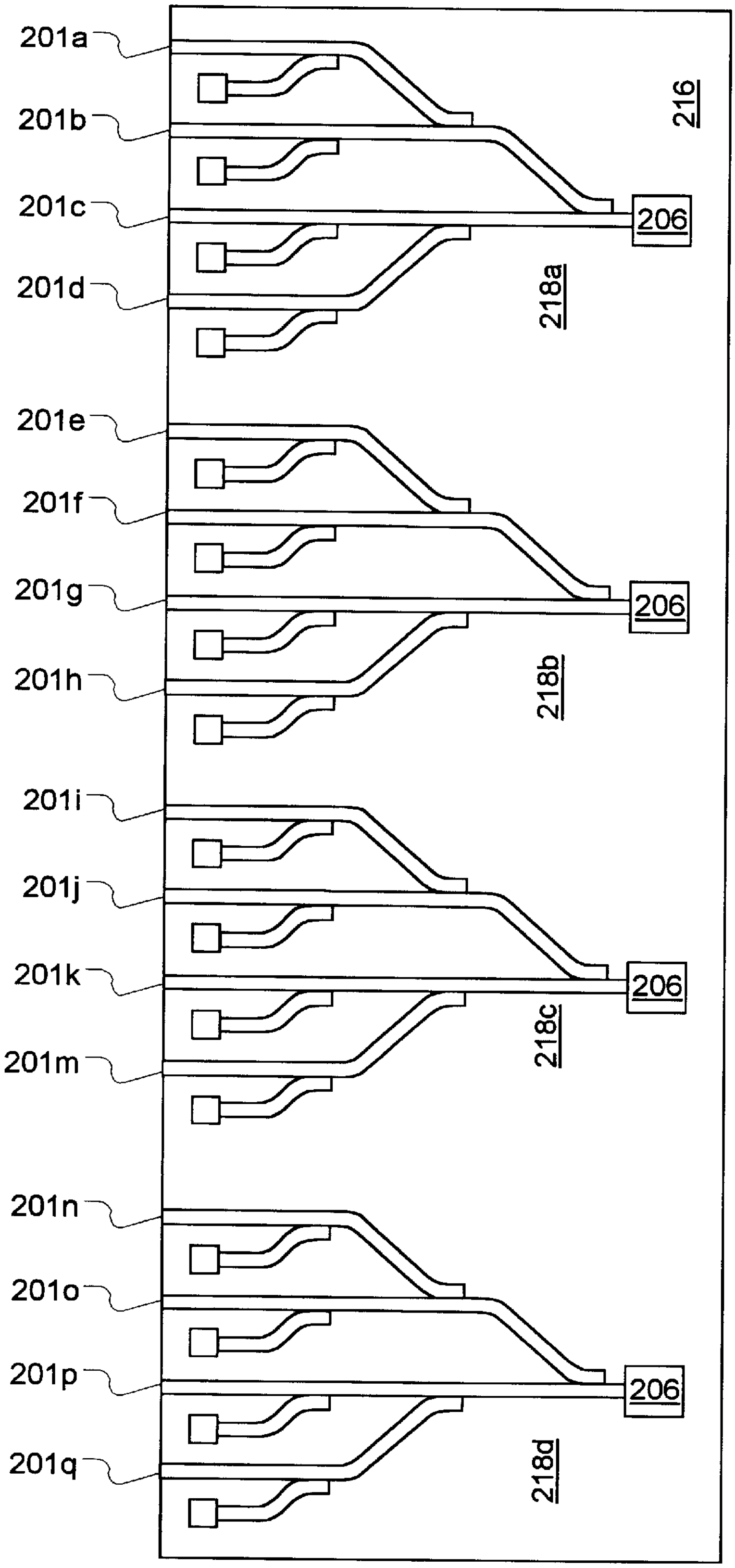
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218a
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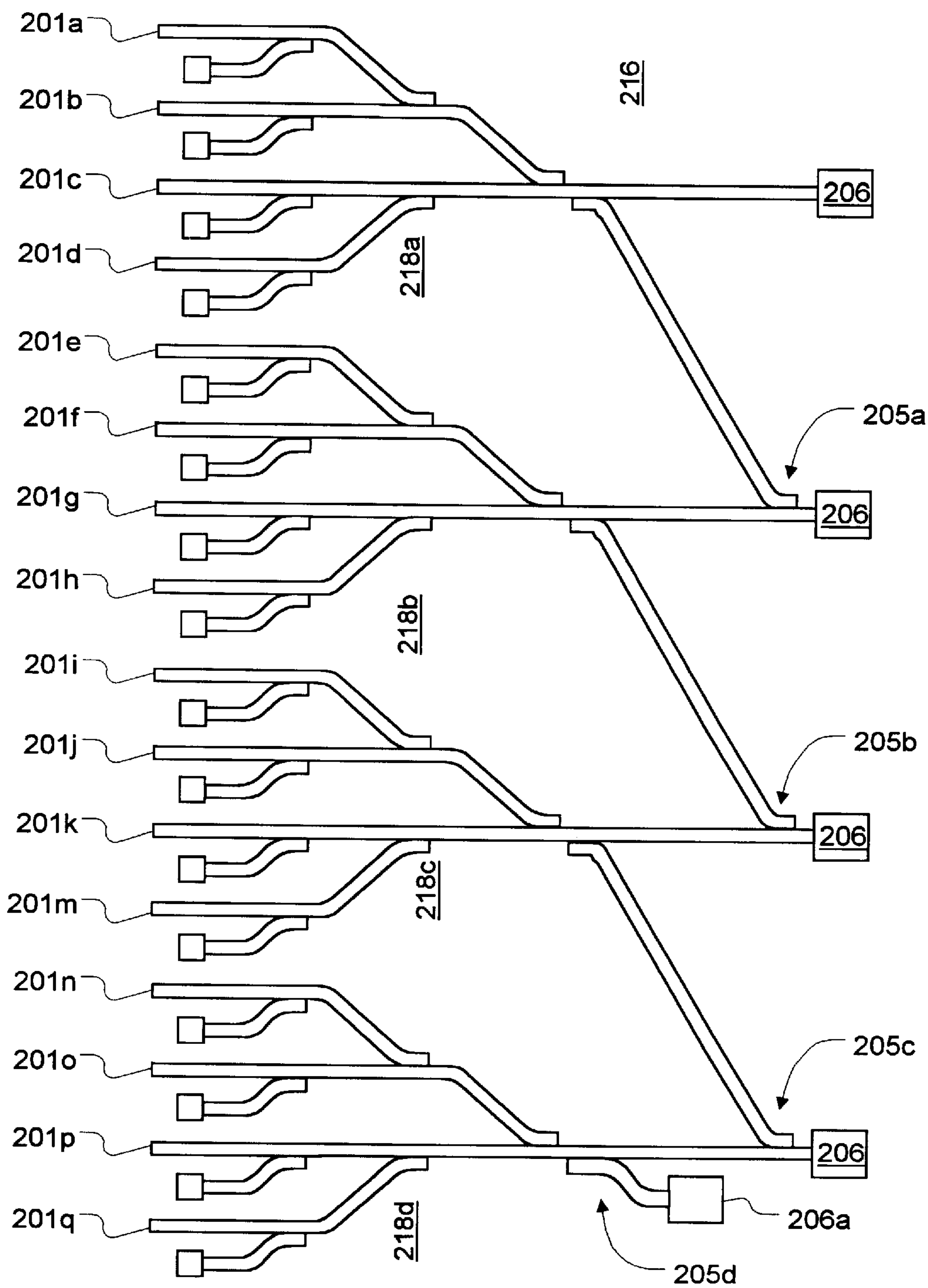
218c
218d

Fig. 5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205c
205d

Fig. 6

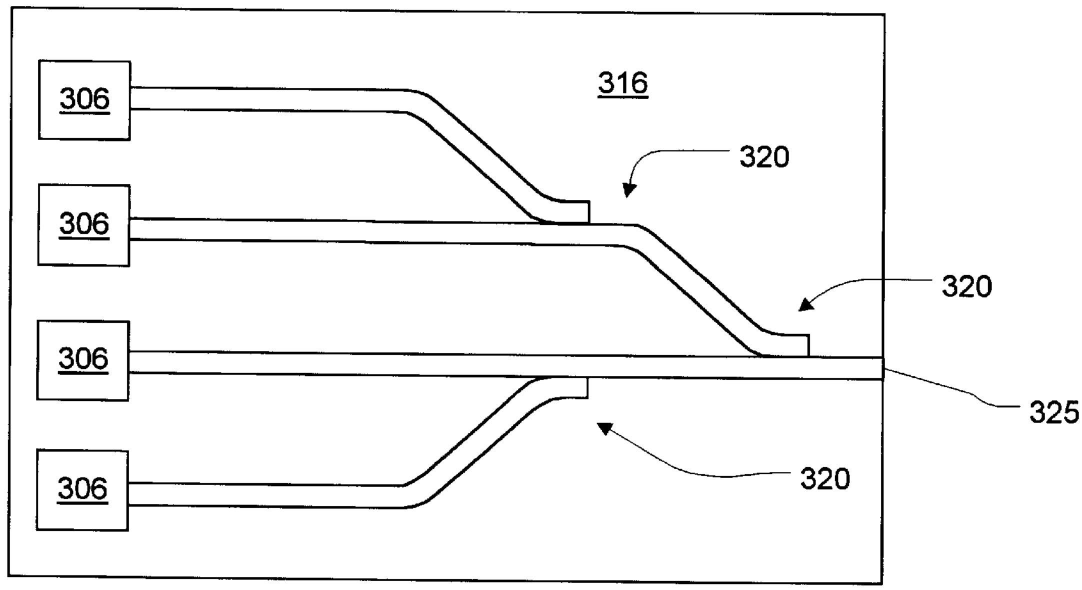
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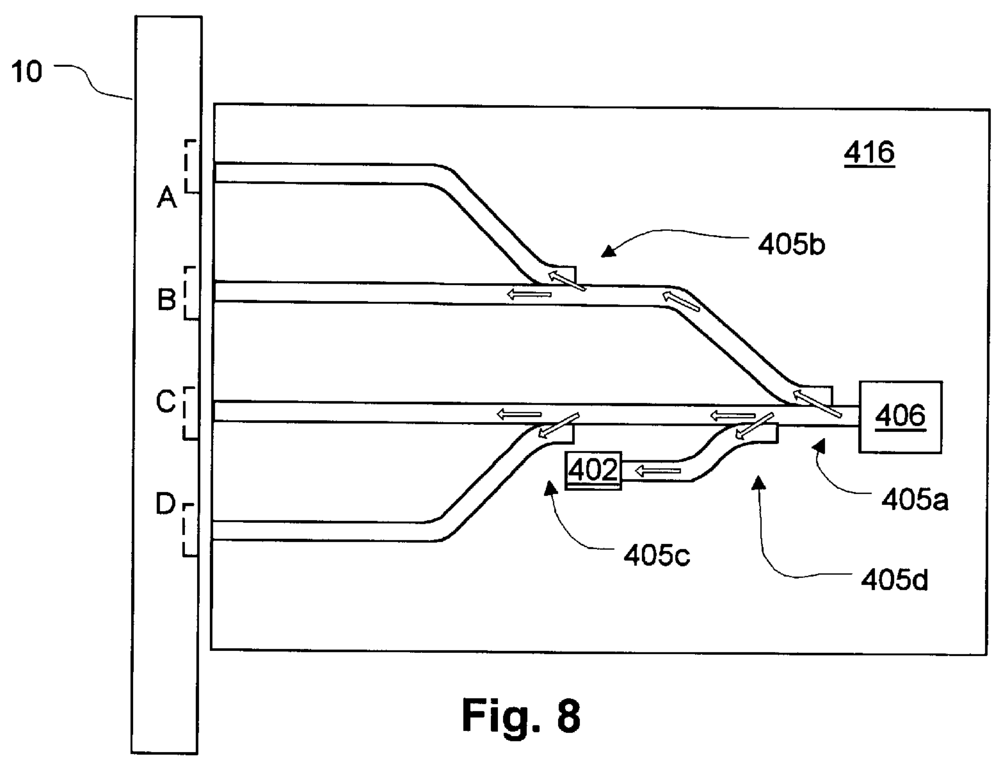
Fig. 7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C
D
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402
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405c
405d

Fig. 8

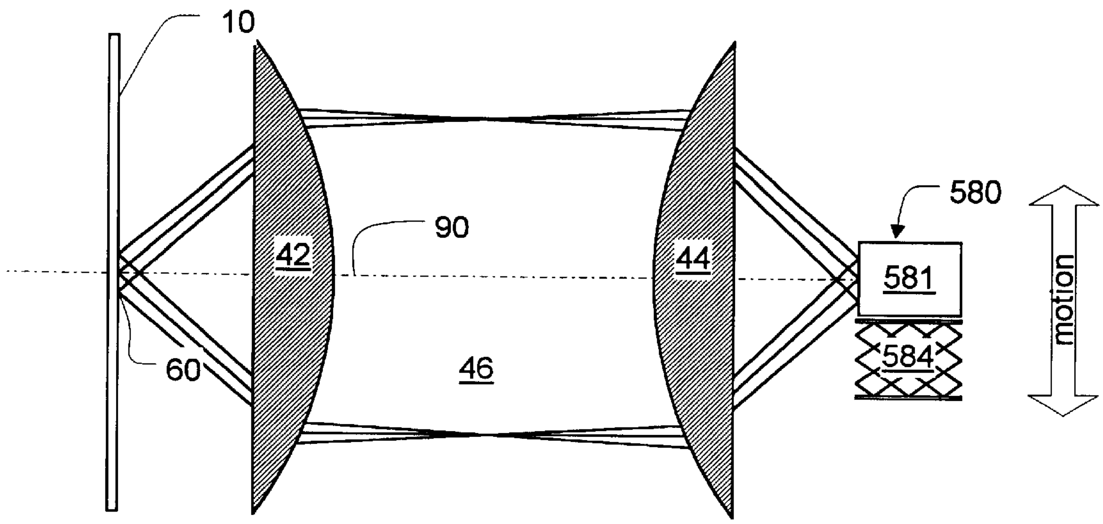


Fig. 9

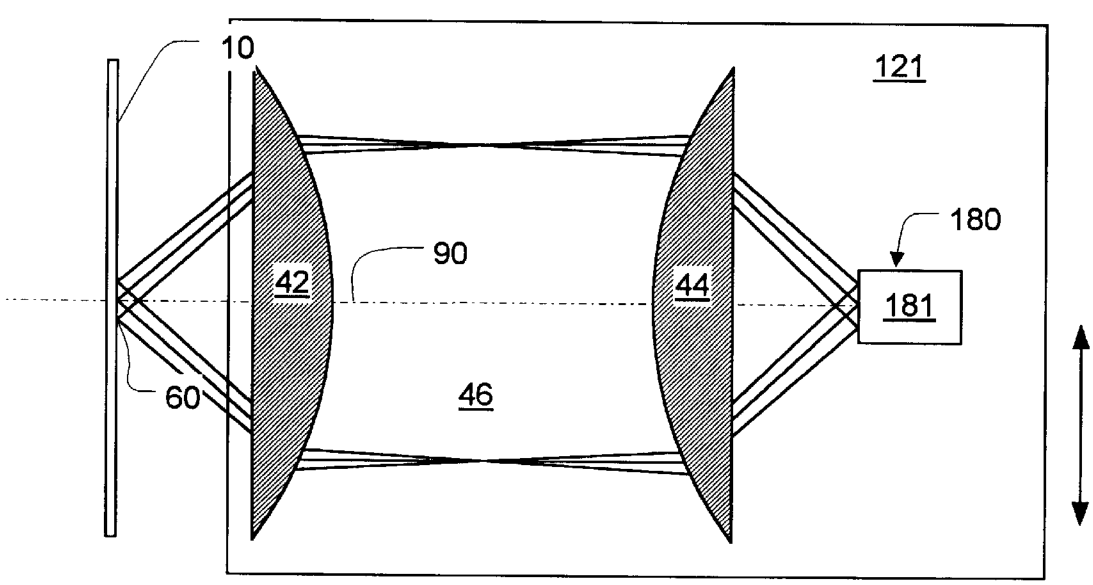


Fig. 10

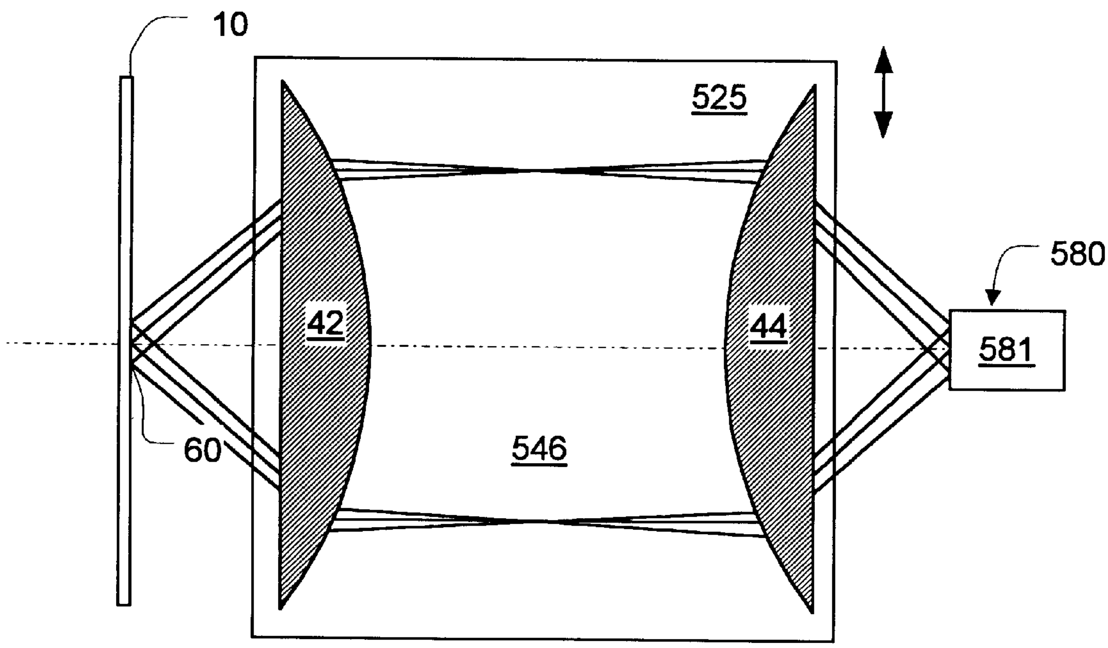


Fig. 11

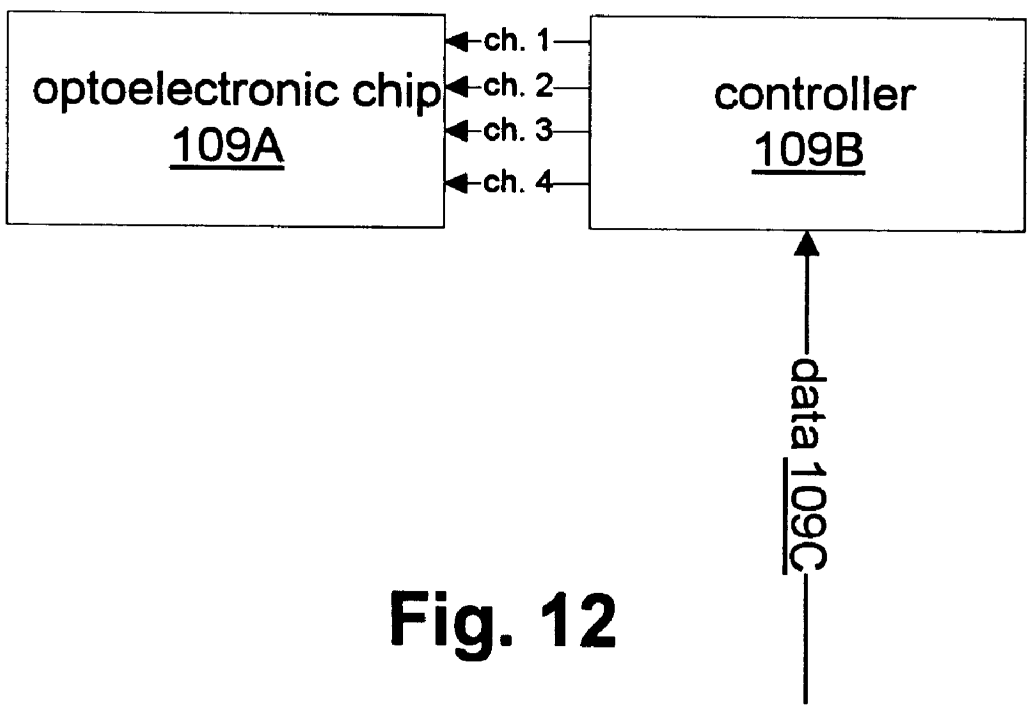
optoelectronic chip
109A
ch. 1
ch. 2
ch. 3
ch. 4
controller
109B
data 109C

Fig. 12

# MULTIPLE CHANNEL DATA WRITING DEVICE

## BACKGROUND OF THE INVENTION

Various optical scanners are known for such applications as data storage, bar code reading, image scanning (surface definition, surface characterization, robotic vision), and lidar (light detection and ranging). Referring to FIG. **1**, a prior art scanner **50** generates a moving spot of light **60** on a planar target surface **10** by focusing a collimated beam of light **20** through a focusing lens **40**. If the assembly is for reading information, reflected light from the constant intensity spot **60** is gathered by focusing lens **40** and returned toward a detector (not shown). To write information, the light-source is modulated. To cause the light spot **60** to move relative to the surface **10**, either the surface **10** is moved or the scanner **50** is moved. Alternatively, the optical path could have an acousto-optical beam deflector, a rotating prism-shaped mirror, or a lens driven galvanometrically or by piezoelectric positioners. Scanners also fall into two functional groups, raster and vector. Both types generally use the same types of beam deflection techniques.

Higher-speed raster scanners use either spinning prism-shaped (polygonal cross-sectioned) mirrors or multifaceted spinning holograms (hologons). Performance parameters for these conventional beam deflection techniques are listed in Table 1. The discrete optics in these devices are generally associated with high costs for mass manufacture, assembly and alignment.

TABLE 1

Performance of Conventional Beam Deflectors for Optical Scanning.

| Parameter | Polygonal Mirrors | Galvano-Driven Mirrors | Hologons Trans-mission) | Acousto-Optic Deflectors |
|---|---|---|---|---|
| Wavefront Distortion | λ/8 at 0.55 μm | λ/8 at 0.55 μm | λ/6 at 0.55 μm | λ/2 at 0.55 μm |
| area resolution (spot-widths/sec | 25,000 (scan lens limited) | 25,000 (scan lens limited) | 25,000 (scan lens limited) | 1,000 (scan lens limited) |
| Cross-axis error | 1 0 arc sec (uncorrected) | 1–2 arc sec (uncorrected) | 10 arc sec | 0 |
| Speed (spot widths/sec) | $1 \times 10^8$ | $2 \times 10^6$ | $2 \times 10^7$ | $2.8 \times 10^7$ |
| Bandwidth | 0.3–20 μm | 0.3–20 μm | Mono-chromatic | mono-chromatic |
| Scan efficiency | 80–1 00% | 65–90% | 90% | 60–80% |

(from The Phoionics Design and Applications Handbook 1993, Laurin Publishing Co., Inc., p.H-449)

The performance parameters listed in Table 1 assume different levels of importance depending on the optical scanning application. For raster scanning to cover extended surface areas, the emphasis is on speed, area resolution, and scan efficiency. Wide bandwidth is needed if the surface is to be color scanned. For applications requiring vector scanning of precise paths at high resolution, the optical system typically uses a monochromatic, focused spot of light that is scanned at high speed with low wavefront distortion and low cross-axis error. Optical data storage has been a prime application of this type of optical scanning.

In optical data storage media, information is stored as an array of approximately wavelength-size dots (bit cells) in which some optical property has been set at one of two or more values to represent digital information. Commercial read/write heads scan the media with a diffraction-limited spot, typically produced by focusing a collimated laser beam with fast objective lens system as shown in FIG. **1**. A fast objective lens, one with a high numerical aperture, achieves a small spot size by reducing Fraunhofer-type diffraction. The spot is scanned by moving an assembly of optical components (turning mirror, objective lens, position actuators) over the optical medium, either along a radius of a disc spinning under the spot or across the width of a tape moving past the head. The assembly moves in one dimension along the direction of the collimated laser beam. As the disk spins or the tape feeds, the line of bit cells must be followed by the spot with sufficient precision to avoid missing any bit cells. The fine tracking is achieved by servo mechanisms moving the objective lens relative to the head assembly. An auto-focus servo system is also necessary to maintain the diffraction limited spot size because the medium motion inevitably causes some change in the mean/medium separation with time. Proper focus adjustment is possible because the medium is flat and smooth. Such a surface reflects incident light in well-defined directions like a mirror. Light reflected from the medium is collected by focusing optics and sent back along the collimated beam path for detection.



Scanning by several spots simultaneously is used to achieve high data rates through parallelism in one known system called the CREO® optical tape system. One scanning device that avoids reliance on discrete optical elements to achieve scanning is described in U.S. Pat. No. 4,234,788. In this scanner, an optical fiber is supported rigidly at one end in a cantilevered fashion. The supported end of the fiber is optically coupled to a light emitting diode or photo diode for transmitting or receiving light signals, respectively. The fiber is free to bend when a force is exerted on it. The fiber can thus be made to scan when light from the light-emitting diode emanates from the tip of the fiber ss the fiber is forced back and forth repeatedly. To make the fiber wiggle back and forth an alternating electric field, generally perpendicular to the axis of the fiber, is generated. The fiber is coated with a metallic film. A charge is stored on the film, especially near the tip, by forming a capacitance with a metallized plate oriented perpendicularly to the fiber axis (optically at least partly transparent). The stored charge makes the fiber responsive to the electric field.

A drawback of this device is the limit on the speeds with which the fiber can be made to oscillate. The device requires a series of elements to move the fiber: an external field-generating structure, a DC voltage source to place charge on the fiber coating, an AC source to generate the external field. Another drawback of this prior art mechanism is the inherent problem of stress fractures in the fiber optics. Bending the fiber repeatedly places serious demands on the materials. Problems can arise due to changes in optical properties, changes in the mechanical properties causing unpredictable variation in the alignment of the plane followed by the bending fiber, the amplitude of vibration, the natural frequency of vibrations, and structural failure. Still another limitation is imposed by the need to place a conductor between the fiber tip and the optical medium to form the capacitance. This places another optical element between the fiber tip and the scanned surface and makes it impossible to sweep the tip very close to the scanned surface as may be desired for certain optical configurations.

Another prior art scanning device is described in U.S. Pat. No. 5,422,469. This patent specification describes a number of different devices to oscillate the end of an optical light guide or optical fiber. One embodiment employs a piezoelectric bimorph connected to the free end of a device to which the free end of an optical fiber and a focusing lens are attached. Reflected light is directed back through the fiber to a beam splitter which directs the reflected light out of the bidirectional (outgoing/return) path at some point along the fiber remote from the source of light. The above embodiment uses a simpler prime mover, a piezo-electric bimorph. However, the need for a focusing lens attached to the end of the fiber, by increasing the mass, imposes difficult practical requirements for high speed oscillation of the fiber. In addition, to achieve very small projected spot size requires a high numerical aperture at the output end of the focusing optics. It is difficult to achieve this with the conventional optics contemplated by the '469 disclosure. Furthermore, the reciprocation of the fiber as described in the '469 patent requires a multiple-element device. Friction between the motor and the fiber can cause changes in the optical properties of the fiber, and mechanical changes in the motor, the fiber, or the interface, that result in changes (which may be unpredictable) in the amplitude of oscillation or the resonant frequency of the motor-fiber combination (which might generate, or be susceptible to, undesired harmonics). Also, the process of assembly of such a combination of a motor and a fiber presents problems. Ideally, for high frequency operation, the device would be very small.

Common to all storage/retrieval devices is the need for greater and greater data rates. Increases in speed have been achieved by increasing the speed of scanning. However, there are practical limits, particularly with regard to the writing operation, relating to physical properties inherent in the optical media.

Also common to the applications of optical scanning technology is the need for great precision in the focus of the scanning light source and the return signal.

## SUMMARY OF THE INVENTION

According to an embodiment, the invention provides an optical scanner employing an array of optical fibers driven by a micro electro-mechanical systems (MEMS) motor. The fibers are held on a stage which is oscillated by a MEMS motor. The light collected from the tips of the fibers is captured and focused to an array of small spots by imaging optics which, in this embodiment, are fixed relative to the scanned surface. This generates a rapidly sweeping array of light spots on the scanned surface. In alternative embodiments, the focusing optics are oscillated and the fiber array is held fixed. In another embodiment, the focusing optics and the fiber array are oscillated as a single assembly. Other motors may be used with the invention.

According to another embodiment, the invention provides a device for writing data to a target surface of a piece of media. The structure of the media can be modified by impingement of light. The device has a base element with a light source, light guides, optical switches, multiple output apertures, and at least one beam dump interconnected in such a way that light from the light source is selectively conveyed to the output apertures and/or to the at least one beam dump. The output apertures are arranged relative to the target surface such that the light emitted from the apertures impinges on the target surface. The device has a controller connectable to a data source to receive data signals. The controller is connected to control the switches. The controller is programmed to control the switches to selectively convey light to the output apertures or to the beam dump such that the light is impinged on the target surface in such a way as to result in a modulation of the surface that represent the data signals. In a variation, the base element is an optoelectronic chip. In another variation, the device has a frame connected to the base element. The piece of media is attachable to the frame such that the piece of media is movable relative to the base element. As a result, the target surface moves in a first direction relative to the base element. An oscillating motor connected between the frame and the base element oscillates the base element relative to the target surface. In another variant, the target surface is moved continuously in the first direction at a constant speed. In still another variant, a direction of an oscillation of the base element has a component substantially perpendicular to the first direction. In still another variant, the controller is programmed to convey substantially all of the light from the light source sequentially toward each of the multiple output apertures. A feature is provided in another embodiment, wherein the controller is programmed to interrupt, selectively, a final conveyance of the light to a respective one of the apertures by switching the light from a path connecting to one of the output apertures to a beam dump in response to the data signals. In this way, an output from the multiple output apertures is modulated without modulating the laser source. According to another feature the controller is programmed to modulate light emitted from the multiple output apertures by selectively conveying the light from the light source to the beam dump to prevent light from being emitted from at least one of the multiple apertures and conveying the light from the light source to the multiple output apertures to emit light from the output apertures. A variant provides that the light source is a laser and the base element is an optoelectronic chip with the laser built into the chip. Another variant provides that the light source directs all of the light into a first of the light guides which connects with second and third light guides through a first of the switches. The light is directed through the second light guide, which leads to a first output aperture, when the first switch is in a first position and the light is directed through the third light guide when the first switch is in a second position. Another alternative provides that the first light guide has a second switch capable of directing the all of the light to the (at least one) beam dump. Alternatively, the second light guide has a second switch while the third light guide has a third switch, and they are configured to direct the all of the light to the at least one beam dump, selectively. Another feature provides a focusing element between the output apertures and the target surface to image light from the output apertures onto the target surface.

According to still another embodiment, the invention provides a multiple, parallel-channel data writing device for writing on media. The device has a write head with output apertures, each corresponding to an output channel. Further, the device provides imaging optics between the media and the write head to focus light emitted from the output apertures simultaneously on the media. As a result, a state of the media is altered and the media is written on. A controller is programmed and connected to modulate light emitted from the output apertures responsively to an external data stream. An oscillating motor, mechanically connected between the media and the write head, oscillates the write head along a first direction at least partly perpendicular to a unidirectional feed direction of the media. As a result of this feature, the oscillation of the write head combined with a modulation of the modulated light emitted from the output apertures, causes data derived from the external data stream onto the media to be written over an area substantially proportional to a cross product of the first direction and the unidirectional feed direction. In a variant, the area is substantially proportional to a number of the output apertures.

In another variant, the rate of data writing of the write head is proportional to a rate of feed of the media relative to the write head. Another variant provides that the write head contain a laser which is run continuously and provides that the device include at least one optoelectronic switch. The light from the output apertures is modulated by switching the optoelectronic switch between the output apertures and a beam dump in the write head. In another variant the write head has two lasers connected by an optoelectronic switch to a light guide leading to the output apertures. The switch may connect one of the two lasers to a given output aperture by default and the other of the two lasers to the given output aperture when the default laser fails. In a further variation, the write head oscillates relative to the media and the imaging optics. Alternatively, the imaging optics are fixed relative to the write head. A further option provides that the write head is an optoelectronic chip with integrally formed waveguides and switches formed photo-lithographically therein.

According to still another embodiment, the invention provides a multiple parallel-channel data writing device for writing on media. The device has a write head with output apertures, each corresponding to an output channel. Imaging optics between the media and the write head focus light emitted from the output apertures simultaneously on the media. This alters a state of the media resulting in a writing operation. A controller is programmed and connected to modulate light emitted from the output apertures responsively to an external data stream. An oscillating motor, mechanically connected to the imaging optics between the media and the write head, oscillates the imaging optics in such a way that images of light emitted from the output apertures are oscillated on the media along a first direction at least partly perpendicular to a unidirectional feed direction of the media with respect to the write head. As a result of an oscillation of the write head and a modulation of the modulated light emitted from the output apertures, the device writes data derived from the external data stream onto the media over an area substantially proportional to a cross product of the first direction and the unidirectional feed direction. According to a variation the area is substantially proportional to a number of the output apertures. According to another variation, a rate of data writing of the write head is proportional to a rate of feed of the media relative to the write head. Another variant provides that the write head contains a laser which is run continuously and at least one optoelectronic switch. The light from the output apertures is modulated by switching the optoelectronic switch between the output apertures and a beam dump in the write head. In another variant, the write head has two lasers connected by an optoelectronic switch to a light guide leading to the output apertures. The switch connects to one of the two lasers to the output apertures by default and to another of the two lasers when the one of the two lasers fails.

## BRIEF DESCRIPTION OF THE DRAWING

In the drawing,

FIG. **1** is a ray trace diagram showing a scanning device according to the prior art.

FIG. **2** is an illustration of an optoelectronic chip with integral waveguides, beam switches, a laser source, and beam dumps to allow the generation of a modulated signal using one laser source through multiple channels simultaneously.

FIGS. **3** and **4** are diagrams for discussing the operation of the embodiment of FIG. **2**.

FIG. **5** is an illustration of another optoelectronic chip with more elements including, as in the embodiment of FIG. **2**, integral waveguides, beam switches, a laser source, and beam dumps to allow the generation of a modulated signal using one laser source through multiple channels simultaneously.

FIG. **6** is an illustration of an embodiment similar to that of FIG. **5** in which lasers sources are supplied with crossover backup connections by means of light guides and additional switching.

FIG. **7** is an illustration of a group of lasers formed in an optoelectronic chip interconnected by combiners to combine the energy of the lasers into one source.

FIG. **8** is an embodiment similar to that of FIG. **2** except that a single beam dump is used for modulation instead of multiple beam dumps.

FIG. **9** is a ray trace diagram showing a multiple channel scanning head according an embodiment of the invention, where the imaging optics are fixed and the scanning head is oscillated by a MEMS motor to scan a region of a target surface.

FIG. **10** is a ray trace diagram showing a multiple channel scanning head according an embodiment of the invention, where the imaging optics and scanning head are fixedly interconnected and oscillated as a unit by a MEMS motor to scan a region of a target surface.

FIG. **11** is a ray trace diagram showing a multiple channel scanning head according an embodiment of the invention, where the imaging optics are oscillated as a unit by a MEMS motor to scan a region of a target surface.

FIG. **12** is an illustration of a controller that controls an optoelectronic chip.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to FIG. **2**, an integrated optoelectronic chip **116** produces multiple modulatable outputs at **101**. Beam dumps **102** absorb and dissipate any light signal applied to them. Beam switches at **105** (including **105***a*, **105***b*, and **105***c*) allow control of the direction of light emitted from an on-board laser **106** which enters an array of light guides **117** (including branches **117***a*–**117***e*) formed in the chip **116** at an entry point **107**. By switching between a respective beam dump **102** and a respective output **101**, beam switch **105** is used to modulate the outputs **101** of the chip **116**. The light emitted can be imaged onto a target surface by a lens system or a single holographic element. In an alternative embodiment, instead of dumping the light to a beam dump, it can also be directed away from the target surface.

An optoelectronic chip for modulating multiple outputs can be formed as shown in FIG. **2** without an embedded laser **106**. Instead, a separate laser (not shown) may be connected to a chip having light guides **117**, optoelectronic switches **105**, and beam dumps **102**, only.

The light guides **117** (or optical wave guides) are formed directly in the chip **116** using fabrication techniques similar to those employed in the manufacture of integrated circuits. Optoelectronic chips are formed in a layer-by-layer process beginning with a suitable substrate such as silicon or glass wafer. A thin metal film is applied to the substrate and patterned to define electrodes and conductors. Next, a layer of material is added to form the optical waveguides and the material is patterned using photolithography. Switches may be formed by doping the material (or by other known methods) to create non-linear optical effects in the switching regions. In a purely additive process, additional material layers can be applied sequentially, on each of which additional optical paths, electrodes, and conductors can be formed.

Referring now also to FIG. **3**, light enters the array of light guides **117** through entry port **107**. Thereafter, light travels as indicated by arrows **112**. At each optical switch, light is directed along one of two possible paths or can be divided by some percentage between guides. For example, light entering switch **105***a* can be switched to transmit the light entering through entry port **107** along branch **117***a* or branch **117***b*. If, for example, at a particular time, a datum is to be written at a position A on the medium **10** by impinging light energy at a first time and then, subsequently, at a second time, preventing any light from falling on region A and assuming no light is to impinge on any of the regions A through D during the second time interval, then the various switches would be controlled as follows. During the first time interval, optical switches **105***a,* **105***b,* and **105***c* would be set to direct light along the path **117***a*-**117***c*-**117***e* so that light is emitted from an output **101***a*. At the beginning of the second time interval, switches **105***a* and **105***b* can remain in their positions and switch **105***c* is switched to direct light along path **117***d* causing the light to be absorbed in beam dump **102***a*. The above is only an example. By extension, it is apparent that through appropriate control of the various switches **105**, light can be emitted from any of the ports, one at a time, and during any time required, the switches **105** can be controlled so that no light is emitted at all. Through this configuration, a single light source can be used to write multiple tracks of data which saves the cost of parts and the power required to operate the light source. In addition, power does not have to be cycled to the light source to control it and this can result in lower stress on the light source component. For a laser, this means it can operate in a continuous wave (CW) long lifetime, stable mode.

The utility of the invention is apparent in the following scenario. Assume that the maximum output power from a single laser is enough (after system losses), to supply several (e.g., four) optical scanning channels. A read/write head with the chip **116** would use the switching functions to direct the laser output to the four output channels in parallel (meaning dividing power between the guides) with precise synchronization to address each channel at any time when its output was positioned to write. If a channel is writing to the scanned surface, modulation of that channel is done using the last switch (e.g. **105***c*) before the output aperture **101***a*. The chip **116** uses the last switch in a series to divert the laser output to a respective beam dump. For example, if a "zero" is written by modulating the light output to zero output, the respective switch (e.g., **105***a*) is controlled to direct the light to a beam dump **102**. A control regime might control all of the switches **105** except the final ones, to direct the light cyclicly toward the four outputs **101**. The final switches would be used synchronously with the cyclic control of the non-final switches, to modulate the pulses of light directed toward them.

Referring to FIG. **4**, the following table summarizes the switching aspect of such a control regime to cyclicly direct the light toward the four target regions.

| target | Switch positions | | |
|---|---|---|---|
| region | 105a | 105b | 105g |
| A | Bypass | bypass | no effect |
| B | Bypass | through | no effect |
| C | Through | no effect | through |
| D | Through | no effect | bypass |

The following table indicates how the switches are set to direct light toward a particular region ("on") or modulate light off when light is directed toward that region ("off").

| | Switch positions | | | | | | |
|---|---|---|---|---|---|---|---|
| Target region | 105c | 105d | 105e | 105f | 105a | 105b | 105g |
| A-on | Through | no effect | no effect | no effect | bypass | bypass | no effect |
| B-on | no effect | through | no effect | no effect | bypass | through | no effect |
| C-on | no effect | no effect | through | no effect | through | no effect | through |
| D-on | no effect | no effect | no effect | through | through | no effect | bypass |
| A-off | Bypass | no effect | no effect | no effect | bypass | bypass | no effect |
| B-off | no effect | bypass | no effect | no effect | bypass | through | no effect |
| C-off | no effect | no effect | bypass | no effect | through | no effect | through |
| D-off | no effect | no effect | no effect | bypass | through | no effect | bypass |

Referring now to FIG. **5**, an example of a chip **216** with sixteen outputs **201***a*–**201***q* and employing four inputs each connected to a respective laser **206**. In the embodiment of FIG. **5**, four devices **218***a*–**218***d,* essentially the same as shown in FIG. **4** are ganged on one chip. A more elaborate design that includes more extensive crossover is shown in FIG. **6**. In this embodiment, when one light source fails, at least one other can be used to permit continued operation. Additional switches **205***a*–**205***d* can be used to supply light from adjacent lasers **206** into a given path. An additional laser **206***a* is included to provide backup for an orphaned set of outputs. Note that the crossing light guides could be used if they are fabricated on separate layers with the junctions formed deep enough to permit connections.

Referring now to FIG. **7**, the outputs of multiple lasers **306** can be combined for an application that requires an output intensity greater than a single laser can produce alone. In an optoelectronic chip **316**, multiple optical rail taps **320** are used to combine the outputs of more than one laser **306**. In this embodiment, four lasers combine to generate one combined output **325**. This embodiment is particularly useful for use with laser devices such as vertical cavity surface emitting lasers (VCSELs) when used to write on materials requiring several milliwatts of power.

Using combinations of features of the embodiments of FIGS. **6** and **7**, a many sources-to-many outputs device could be constructed. In that case, the frequency of writing could be increased because, if one laser is occupied during a writing phase and a second output needs a light source during that time period, it can be supplied by another unoccupied laser.

Referring to FIG. **8**, another embodiment is similar to that of FIG. **4**. However, instead of using multiple local beam dumps **102***a*–**102***d*, a single beam dump **402** is used. For this embodiment, during a cycle when no data is to be written, the switch **405***d* is set to bypass and the beam is dumped.

Referring to FIG. **9**, the small size of the embodiments discussed above lends itself to scanning using small motors such as microelectromechanical systems (MEMS) technology motors. In an embodiment of the invention, a multiple output scanning head, optoelectronic (OE) chip **581** according to any of the previous embodiments discussed, has multiple outputs, as described. Although the drawings only indicate ray traces for three beams, it is understood that the drawing is compatible with any number of outputs. OE chip **581** is oscillated by a motor **584**, based on MEMS technology. A scanning motion of multiple spots **60** can be obtained with this arrangement. The multiple focused spots **60** will scan over the surface **10** when the source array **580** is oscillated relative to the optical axis **90** of the lens system. In the embodiment of FIG. **9**, the lens system **46** is held fixed and the OS chip **581** is oscillated. In a nominal lens system with 1:1 magnification, the spots move along the surface **10** the same distance as the stage **581**.

Referring to FIG. **10**, in an alternative embodiment, similar to that of FIG. **9**, the focusing optics **46**, as well as the light guide array **180**, is oscillated. The focusing optics **46** and the light guide array **180** are supported on a large stage **121** which is oscillated by a motor (not shown). Referring to FIG. **11**, in still another embodiment, lens system **46** is supported on stage **125** that is oscillated relative to both the scanned surface **10** and the source array **180**. With a magnification of 1:1, the light spot is displaced twice the displacement of the focusing device.

Referring to FIG. **12**, a controller **109**B controls any of the optoelectronic chips, represented by **109**A and discussed above, by controlling various optoelectronic switches (discussed above). Synchronization of the timing of the control signals, which modulate according to an input data stream **109**C to control the optoelectronic switches, could be achieved by reading fiducial marks formed in the media in advance and sending timing signals to the controller, by having the controller write fiducial marks on the media using timing information based on the rate of movement of the media with respect to the writing device. Such techniques are known in the prior art. Controller **109**B controls which channels receive light and whether those channels are modulated on or off for writing a given media area. Note the controller **109**B may also control light source power.

Using the invention, laser light can be allocated among several output channels with very fast switching rates for optimum use of power for both reading and writing applications. Furthermore, using this approach of lithography, high accuracy spacing and positioning of the output apertures can also be achieved independently of any limits on laser fabrication. Cost savings can also be achieved. Single laser outputs requiring more power than can be achieved with single laser can be supported by using the output-combining feature described. In addition, laser output can be modulated without directly varying laser output power, thus allowing the laser to operate in a continuous wave (CW), long-lifetime, stable mode.

The best MEMS scanning method depends on the practical engieering tradeoffs attending the specific application. For example, the mass of the moving element, the amplitude of the oscillation, and the frequency. One optimization goal might be to opt for high frequency and therefore favor minimum mass of the moving element. This would suggest an individual fiber is best. Engineering, however, places other constraints on the application, for example, the actual position of the surface emitting the light relative to the focal point of the optics. See for example, Brei et. al, incorporated herein by reference below.

Regarding the manufacturing of MEMS devices, for example, the light emitting aperture, shape and surface treatment, manufacturing issues are not a problem. For example methods have been developed to apply metals to glass fibers to enable capacitive coupling for driving the fiber motion. Individual methods of fabrication and then manufacture may be addressed depending on the availability of resources, e.g. metallization of a polymer "fiber" or waveguide, or application of piezoelectric material to a polymer. Regarding the optical properties of the fiber output, particularly with regard to numerical aperture (NA), some trial and error experimentation may be required to achieve an optimum configuration. If constructed layer by layer, the fiber tip construction is totally conventional. The optical quality and properties of the exit aperture as mentioned above are critical, and therefore exact recipes may require some trial and error experimentation. For example, a graded index clad may be necessary, or new process methods due to required design considerations. In embodiment employing an optical fiber, the exit aperture may be defined by cleaving. In embodiment employing a multilayer (e.g. polymer) structure, processing at the end of the fiber is important. Conventional methods at present include ion beam "polishing" of the tip or exit aperture.

The cantilever "style" vibrating fiber structure requires a waveguiding "core," as with any optical fiber. Also a cladding is required to confine the optical energy. The fiber, or, more generally, light guide, can have a round, square, or rectangular cross section depending on design considerations for the purpose of light "piping." A square or rectangular cross section is easiest to deal with from a manufacturing and fabrication point of view, as well as from the point of view of driving oscillations. Planar "capacitive" plates are easily implemented in a layered, bimorph configuration that optimizes energy transfer for driving oscillation while minimizing the required power. However, this puts severe constraints on optical design due to the need for polarization conservation elsewhere in the system, as well as mode conservation and balance. A layer by layer fabrication process is the best approach; in that case, the "fixed end" of the fiber is on top of the underlying structural and functional layers. The quality checks necessary are both optical and mechanical. Longevity will be related to mechanical work, with frequency, total number of oscillations, material, composite structures, adhesion, etc. also being contributing factors.

Note, regarding a fundamental mechanism of failure in stressed single crystal materials, such as Si, defects in single crystals diffuse thermally and aggregate in the material. This is well known (see for example Silicon Processing for the VLSI Era, S. Wolf and R. N. Tauber, Lattice Press and other books addressing the processes in Si fabrication, particularly crystal growth).

The electro-optical switch and the optical railtap (directional coupler) are both components that have been developed in other integrated optics material systems (e.g. lithium niobate). They have also been developed in polymer-based integrated optics.

Note that various embodiments could make use of the same lasers for both reading and writing, as discussed above. In such a case, a head could have separate exit apertures for reading and for writing, or have one set of apertures serving both functions.

The respective entireties of the following United States patent applications, filed concurrently herewith, are hereby incorporated by reference in the present application:

Scanning Device Using Fiber Optic Bimorph (Adam Thomas Drobot, Robert Courtney White)

Multiple Parallel Source Scanning Device (Adam Thomas Drobot, Robert Courtney White, Newel Convers Wyeth)

Multiple Channel Scanning Device Using Optoelectronic Switching (Adam Thomas Drobot, Robert Courtney White, Newel Convers Wyeth)

Method and Apparatus for Controlling the Focus of a Read/Write Head for an Optical Scanner (Edward Alan Phillips, Newel Convers Wyeth)

Multiple Channel Scanning Device Using Oversampling and Image Processing to Increase Throughput (Adam Thomas Drobot, Robert Courtney White, Newel Convers Wyeth, Albert Myron Green, Edward Alan Phillips)

The respective entireties of the following references are hereby incorporated by reference in the present application:

M. Ataka, A. Omodaka, N. Takeshima, and H. Fujita, "Fabrication and Operation of Polyimide Bimorph Actuators for a Ciliary Motion System", JMEMS, Volume 2, No. 4, page 146.

D. E. Brei and J. Blechschmidt, "Design and Static Modeling of a Semicircular Polymeric Piezoelectric Microactuator", JMEMS, Volume 1, No. 3, page 106.

J. W. Judy, R. S. Muller, and H. H. Zappe, "Magnetic Microactuation of Polysilicon Flex-ure Structures", JMEMS, Volume 4, No. 4, page 162.

T. S. Low and W. Guo, "Modeling of a Three-Layer Piezoelectric Bimorph Beam with Hysteresis", JMEMS. Piezoelectric actuators are usually stacked or bimorph in configu-ration. In this paper the mechanics of a three-layer piezoelectric bimorph is discussed and its dynamic model with hysteresis is presented. The results can be used to analyze piezoe-ectric actuators constructed with three-layer piezoelectric bimorphs.

Q. Meng, M. Mehregany, and R. L. Mullen, "Theoretical Modeling of Microfabricated Beams with Elastically Restrained Supports", JMEMS, Volume 2, No. 3, page 128 et. seq.

K. Minami, S. Kawamura, and M. Esashi, "Fabrication of Distributed Electrostatic Micro Actuator (DEMA)", JMEMS, Volume 2, No. 3, page 121 et. seq.

J. G. Smits, and A. Ballato, "Dynamic Admittance Matrix of Piezoelectric Cantilever Bi-morphs", JMEMS, Volume 3, No. 3, page 105 et. seq.

Yuji Uenishi, Hedeno Tanaka, and Hiroo Ukita, NTT Interdisciplinary Research Laborato-ries (Tokyo, Japan), "AlGaAs/GaAs micromachining for monolithic integration of optical and mechanical components", Optical power driven cantilever resonator. Proceedings SPIE et. seq.

What is claimed is:

**1**. A device for writing data to a target surface of a piece of media whose structure can be modified by impingement of light, comprising:

a base element with a light source, light guides, optical switches, multiple output apertures, and at least one beam dump interconnected such that light from said light source is selectively conveyed to said multiple output apertures and to said at least one beam dump;

said multiple output apertures being arranged relative to said target surface such that light emitted from said multiple output apertures impinges on said target surface;

a controller connectable to receive data signals;

said controller being connected to control said switches; and

said controller being programmed to control said switches to selectively convey light to said multiple output apertures and said at least one beam dump such that said light is impinged on said target surface in such a way as to result in a modulation of said surface that represent said data signals.

**2**. A device as in claim **1**, wherein said switches distribute light from said light source to more than one of said multiple output apertures according to a percentage determined by said controller.

**3**. A device as in claim **1**, wherein said base element comprises an optoelectronic chip formed by lithography.

**4**. A device as in claim **1**, further comprising:

a frame connected to said base element; and

said piece of media being attachable to said frame such that said piece of media is movable relative to said base element, whereby said target surface moves in a first direction relative to said base element;

an oscillating motor connected between said frame and said base element to oscillate said base element relative to said target surface.

**5**. A device as in claim **4**, wherein said target surface is moved continuously in said first direction at a constant speed.

**6**. A device as in claim **5**, wherein a direction of an oscillation of said base element has a component substantially perpendicular to said first direction.

**7**. A device as in claim **4**, wherein said controller is programmed to convey substantially all of the light from said light source sequentially toward each of said multiple output apertures.

**8**. A device as in claim **7**, wherein said controller is programmed to interrupt, selectively, a final conveyance of said substantially all of said light to a respective one of said multiple apertures by switching said light from a path connecting to said respective one of said multiple output apertures to said at least one beam dump, responsively to said data signals, whereby an output from said multiple output apertures is modulated without modulating said light source.

**9**. A device as in claim **1**, wherein said controller is programmed to modulate light emitted from said multiple output apertures by selectively conveying said light from said light source to said beam dump to prevent light from being emitted from at least one of said multiple apertures and conveying said light from said light source to said multiple output apertures to emit light from said output apertures.

**10**. A device as in claim **1**, wherein said light source comprises a laser and said base element comprises an optoelectronic chip with said laser built into said chip.

**11**. A device as in claim **1**, wherein:

said light source directs all of said light into a first of said light guides which connects with second and third of said light guides through a first of said switches; and said light being directed through said second of said light guides, which leads to a first of said multiple output apertures, when said first of said switches is in a first position and said light being directed through said third of said light guides when said first of said switches is in a second position.

**12**. A device as in claim **11**, wherein, said first of said light guides has a second of said switches capable of directing said all of said light to said at least one beam dump.

**13**. A device as in claim **11**, wherein:

said second of said light guides has a second of said switches;

said third of said light guides has a third of said switches; and

said second and said third is capable of directing said all of said light to said at least one beam dump.

**14**. A device as in claim **11**, further comprising a focusing element between said output apertures and said target surface to image light from said output apertures onto said target surface.

**15**. A device as in claim **1**, further comprising a focusing element between said output apertures and said target surface to image light from said output apertures onto said target surface.

**16**. A device as in claim **15**, wherein said focusing element is in a fixed position relative to said base element.

**17**. A device as in claim **1**, wherein:

said light source comprises a first laser for selectively conveying light to a first group of said multiple output apertures in a default mode and a second laser for selectively conveying light to a second group of said multiple output apertures in a default mode; and

a switching means for selectively conveying light from said first laser to said first and said second groups of output apertures when said second laser fails.

**18**. A device as in claim **1**, wherein said light source comprises a continuous wave laser.

**19**. A device for writing data to a target surface of a piece of media supported by a frame and whose structure can be modified by impingement of light, comprising:

a base element with a light source, light guides, optical switches, multiple output apertures, and at least one beam dump interconnected such that light from said light source is selectively conveyed to said multiple output apertures and to said at least one beam dump;

said multiple output apertures being arranged relative to said target surface such that light emitted from said multiple output apertures impinges on said target surface;

a controller connectable to receive data signals;

said controller being connected to control said switches;

said controller being programmed to control said switches to selectively convey light to said multiple output apertures and said at least one beam dump such that said light is impinged on said target surface in such a way as to result in a modulation of said surface that represent said data signals; and

a means for moving said base element relative to said frame.

**20**. A device as in claim **19**, wherein said switches distribute light from said light source to more than one of said multiple output apertures according to a percentage determined by said controller.

**21**. A device as in claim **19**, wherein said base element comprises an optoelectronic chip formed by lithography.

**22**. A device as in claim **19**, wherein:

said piece of media is attachable to said frame such that said piece of media is movable relative to said base element, whereby said target surface moves in a first direction relative to said base element; and

said means for moving said base element relative to said frame comprises an oscillating motor.

**23**. A device as in claim **22**, wherein said target surface is moved continuously in said first direction at a constant speed.

**24**. A device as in claim **23**, wherein a direction of an oscillation of said base element has a component substantially perpendicular to said first direction.

**25**. A device as in claim **22**, wherein said controller is programmed to convey substantially all of the light from said light source sequentially toward each of said multiple output apertures.

**26**. A device as in claim **25**, wherein said controller is programmed to interrupt, selectively, a final conveyance of said substantially all of said light to a respective one of said multiple apertures by switching said light from a path connecting to said respective one of said multiple output apertures to said at least one beam dump, responsively to said data signals, whereby an output from said multiple output apertures is modulated without modulating said laser source.

**27**. A device as in claim **19**, wherein said controller is programmed to modulate light emitted from said multiple output apertures by selectively conveying said light from said light source to said beam dump to prevent light from being emitted from at least one of said multiple apertures and conveying said light from said light source to said multiple output apertures to emit light from said output apertures.

**28**. A device as in claim **19**, wherein said light source comprises a laser and said base element comprises an optoelectronic chip with said laser built into said chip.

**29**. A device as in claim **19**, wherein:

said light source directs all of said light into a first of said light guides which connects with second and third of said light guides through a first of said switches;

said light being directed through said second of said light guides, which leads to a first of said multiple output apertures, when said first of said switches is in a first position and said light being directed through said third of said light guides when said first of said switches is in a second position.

**30**. A device as in claim **29**, wherein, said first of said light guides has a second of said switches capable of directing said all of said light to said at least one beam dump.

**31**. A device as in claim **29**, wherein:

said second of said light guides has a second of said switches;

said third of said light guides has a third of said switches; and

said second and said third is capable of directing said all of said light to said at least one beam dump.

**32**. A device as in claim **29**, further comprising a focusing element between said output apertures and said target surface to image light from said output apertures onto said target surface.

**33**. A device as in claim **19**, further comprising a focusing element between said output apertures and said target surface to image light from said output apertures onto said target surface.

**34**. A device as in claim **33**, wherein said focusing element is in a fixed position relative to said base element.

**35**. A device as in claim **19**, wherein:

said light source comprises a first laser for selectively conveying light to a first group of said multiple output apertures in a default mode and a second laser for selectively conveying light to a second group of said multiple output apertures in a default mode; and

a switching means for selectively conveying light from said first laser to said first and said second groups of output apertures when said second laser fails.

**36**. A device as in claim **1**, wherein said light source comprises a continuous wave laser.

* * * * *

US006341118B1

(12) **United States Patent**
**Drobot et al.**

(10) **Patent No.: US 6,341,118 B1**
(45) **Date of Patent: Jan. 22, 2002**

(54) **MULTIPLE CHANNEL SCANNING DEVICE USING OVERSAMPLING AND IMAGE PROCESSING TO INCREASE THROUGHPUT**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/088,780**

(22) Filed: **Jun. 2, 1998**

(51) **Int. Cl.**[7] .................................................. **G11B 7/00**

(52) **U.S. Cl.** ............... **369/118**; 369/44.37; 369/112.27; 369/121

(58) **Field of Search** ............................... 369/44.12, 45, 369/44.34, 44, 44.37, 112, 118, 108, 110, 121, 122, 112.23, 112.27, 112.09; 250/227.11, 227.14, 227.21, 573, 201.5; 385/33, 14, 115, 8, 11, 135; 372/102, 101, 50, 96

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,112,360 A | 11/1963 | Gregg | 369/112 |
| 3,220,013 A | 11/1965 | Harris | 347/260 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| DE | 37 17 604 | 4/1990 |
| DE | 44 01 972 | 7/1995 |
| EP | 0 092 420 | 10/1983 |
| EP | 0 646 908 A | 4/1995 |
| EP | 0 784 314 A | 7/1997 |
| WO | WO 88/03293 | 5/1988 |
| WO | WO 95/25971 | 9/1995 |

OTHER PUBLICATIONS

"Miniature Micro–Optical Scanners", Optical Engineering, vol. 33, No. 11, Nov. 1, 1994, pp. 3616–3623 (Motamedi, M.E. et al).

Abstract of D.E. Brei and J. Blechschmidt, "Design and Static Modeling of a Semiconductor Polymeric Piezoelectric Microactuator", (JMEMS, vol. 1, No. 3, p. 106).

Abstract of K. Minami, S. Kawamura, and M. Esashi, "Fabrication of Distributed Electrostatic Micro Actuator (DEMA)", (JMEMS, vol. 2, No. 3, p. 121 et. seq.).

Abstract of Q. Meng, M. Mehregany, and R. L. Mullen, "Theoretical Modeling of Microfabricated Beams with Elastically Restrained Supports," (JMEMS, vol. 2, No. 3, p. 128 et. seq.).

Abstract of M. Ataka, A. Omodaka, N. Takeshima, and H. Fujita, "Fabrication and Operation of Polyimide Bimorph Actuators for a Cillary Motion System", (JMEMS, vol. 2, No. 4, p. 146).

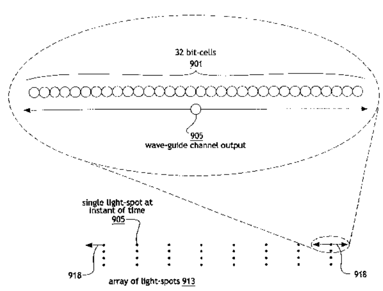
(List continued on next page.)

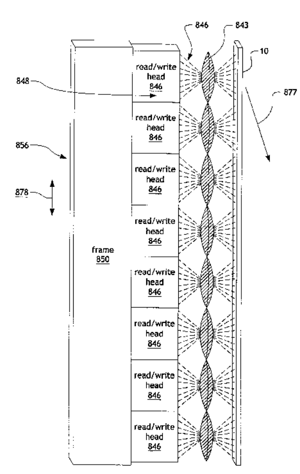
*Primary Examiner*—David Hudspeth
*Assistant Examiner*—Kim-Kwok Chu
(74) *Attorney, Agent, or Firm*—Banner & Witcoff, Ltd.

(57) **ABSTRACT**

A multiple channel scanning device has a scanning head with multiple columns of apertures that emit light which is projected to a small spot on the surface of a recorded medium. Light returned from the medium reenters the apertures and is conducted to detectors. In a preferred embodiment, the scanning head is rapidly oscillated (may be on the order of 100 kHz rate), in a direction parallel to the columns. The medium is moved in a direction perpendicular to the columns so that the same recorded regions pass beneath successive columns of apertures. The data from the detectors is image-processed to improve the quality of data reading using the successive readings of the same data regions. This allows errors to be corrected and throughput to be improved.

**26 Claims, 11 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 3,892,468 | A | | 7/1975 | Dunguay | 250/227.11 |
| 3,941,927 | A | | 3/1976 | Russell | 359/196 |
| 4,058,736 | A | | 11/1977 | Takahashi et al. | 250/573 |
| 4,090,206 | A | | 5/1978 | Pfeiffer et al. | 347/244 |
| 4,135,083 | A | | 1/1979 | Van Alem et al. | 250/201.5 |
| 4,193,091 | A | | 3/1980 | Kleuters et al. | 369/112 |
| 4,234,788 | A | | 11/1980 | Palmer et al. | 250/227 |
| 4,283,777 | A | | 8/1981 | Miyazawa | 369/32 |
| 4,286,145 | A | | 8/1981 | Palmer | 235/462 |
| 4,337,531 | A | | 6/1982 | Willemsen | 369/45 |
| 4,460,989 | A | * | 7/1984 | Russell | 369/110 |
| 4,482,986 | A | | 11/1984 | Noda et al. | 369/44 |
| 4,500,204 | A | | 2/1985 | Ogura | 356/318 |
| 4,507,765 | A | | 3/1985 | Suzuki et al. | 369/45 |
| 4,544,259 | A | | 10/1985 | Kanaoka et al. | 355/1 |
| 4,564,268 | A | | 1/1986 | Tatsuno et al. | 372/101 |
| 4,566,015 | A | | 1/1986 | MacKenzie | 347/242 |
| 4,572,949 | A | | 2/1986 | Bowers et al. | 250/227 |
| 4,660,094 | A | | 4/1987 | Yoshimoto et al. | 358/406 |
| 4,737,946 | A | | 4/1988 | Yamashita et al. | 369/45 |
| 4,744,073 | A | | 5/1988 | Sugiki | 369/112 |
| 4,755,668 | A | | 7/1988 | Davis | 250/227 |
| 4,763,973 | A | | 8/1988 | Inoue et al. | 385/12 |
| 4,764,738 | A | * | 8/1988 | Fried | 385/8 |
| 4,765,703 | A | * | 8/1988 | Suzuki et al. | 385/8 |
| 4,767,210 | A | | 8/1988 | Kashyap | 356/345 |
| 4,771,415 | A | | 9/1988 | Taki | 369/112 |
| 4,815,807 | A | | 3/1989 | Kaneko et al. | 385/33 |
| 4,858,215 | A | | 8/1989 | Yano et al. | 369/45 |
| 4,991,160 | A | | 2/1991 | Premji | 369/44.12 |
| 5,001,338 | A | | 3/1991 | Boero | 250/227.21 |
| 5,010,346 | A | | 4/1991 | Hamilton et al. | 250/227.14 |
| 5,031,187 | A | * | 7/1991 | Orenstein et al. | 372/50 |
| 5,070,488 | A | | 12/1991 | Fukushima et al. | 369/103 |
| 5,095,472 | A | | 3/1992 | Uchino et al. | 369/44.14 |
| 5,109,459 | A | | 4/1992 | Eibert et al. | 385/115 |
| 5,121,449 | A | | 6/1992 | Shiba et al. | 385/14 |
| 5,128,915 | A | | 7/1992 | Yamashita et al. | 369/44.12 |
| 5,144,604 | A | | 9/1992 | Sugiura | 369/44.12 |
| 5,144,616 | A | | 9/1992 | Yasukawa et al. | 369/122 |
| 5,195,152 | A | | 3/1993 | Gupta | 369/44.12 |
| 5,220,450 | A | | 6/1993 | Iizuka | 359/205 |
| 5,278,812 | A | | 1/1994 | Adar et al. | 369/44.12 |
| 5,289,454 | A | | 2/1994 | Mohapatra et al. | 369/112 |
| 5,293,291 | A | | 3/1994 | Ohki et al. | 369/44.12 |
| 5,317,148 | A | | 5/1994 | Gray et al. | 250/227.26 |
| 5,354,985 | A | | 10/1994 | Quate | 250/234 |
| 5,390,157 | A | | 2/1995 | Revelli, Jr. | 369/44.12 |
| 5,414,785 | A | | 5/1995 | Bergmann | 385/24 |
| 5,416,881 | A | | 5/1995 | Ikeda | 385/135 |
| 5,422,469 | A | | 6/1995 | Bard et al. | 250/227.26 |
| 5,444,689 | A | | 8/1995 | Ohki et al. | 369/109 |
| 5,452,382 | A | | 9/1995 | Shionoya et al. | 385/11 |
| 5,465,243 | A | | 11/1995 | Boardman et al. | 369/53.29 |
| 5,483,515 | A | * | 1/1996 | Cheng et al. | 369/124 |
| 5,508,990 | A | * | 4/1996 | Nagasaki et al. | 369/44.37 |
| 5,564,268 | A | | 10/1996 | Thompson | 57/3 |
| 5,602,863 | A | * | 2/1997 | Itagaki | 372/50 |
| 5,661,591 | A | | 8/1997 | Lin et al. | 359/290 |
| 5,727,098 | A | | 3/1998 | Jacobson | 385/31 |
| 5,802,222 | A | | 9/1998 | Rasch et al. | 385/1 |
| 5,940,564 | A | | 8/1999 | Jewell | 385/93 |
| 6,084,848 | A | * | 7/2000 | Goto | 369/121 |

OTHER PUBLICATIONS

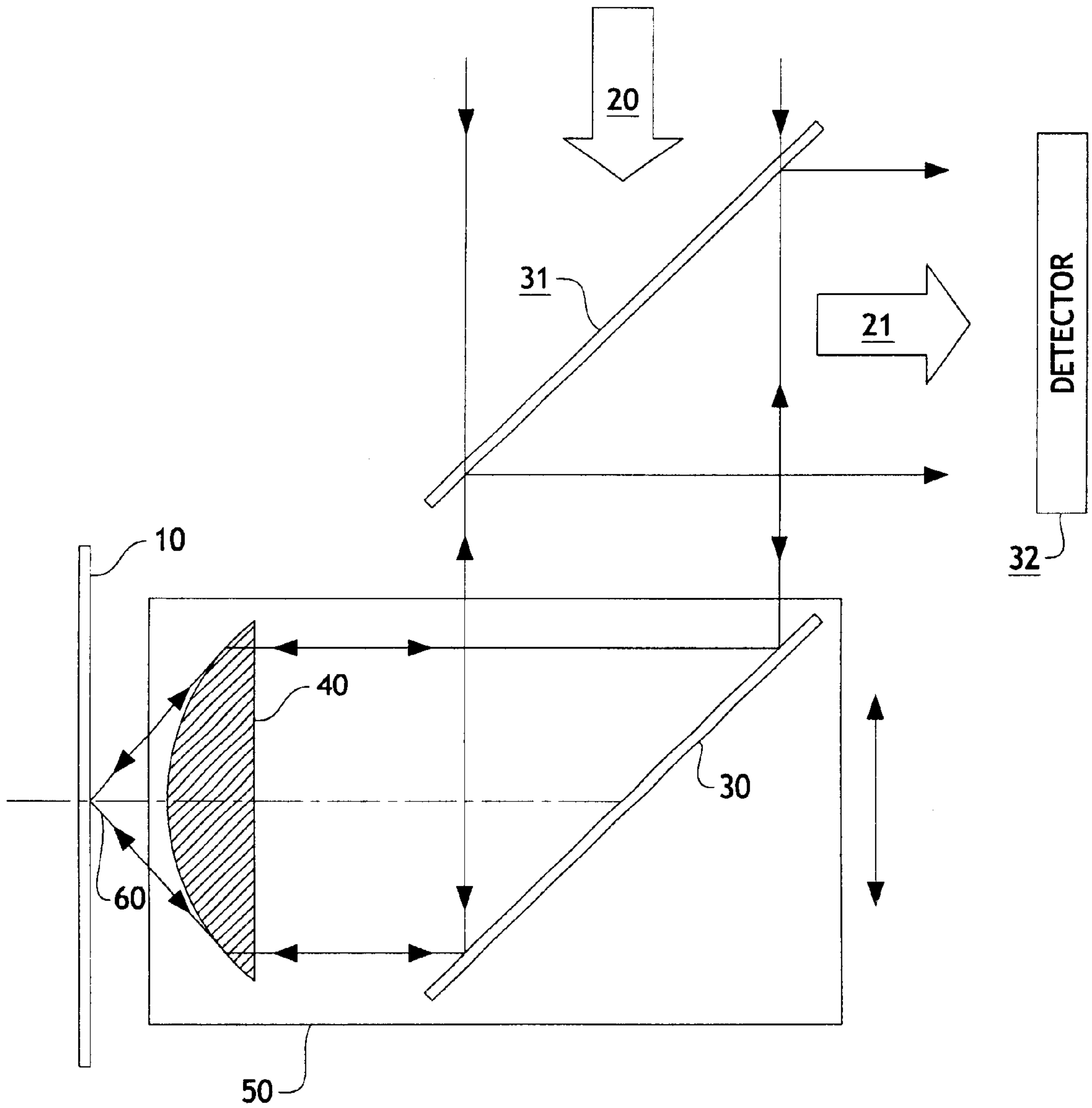
Abstract of J.G. Smits and A. Ballato, "Dynamic Admittance Matrix of Piezoelectric Cantilever Bimorphs", (JMEMS, vol. 3, No. 3, p. 105 et. seq.).

Abstract of J.W. Judy, R.S. Muller, and H.H. Zappe, "Magnetic Microactuation of Polysilicon Flexure Structures", (JMEMS, vol. 4, No. 4, p. 162).

Abstract of T.S. Low and W. Guo, "Modeling of a Three–Layer Piezoelectric Bimorph Beam with Hysteresis", (JMEMS, vol. 4, No. 4, p. 230).

Abstract of Yuji Uenishi, Hidenao Tanaka, and Hiro Ukita, "AlGaAs/GaAs micromachining for monolithic integration of optical and mechanical components", (Proc. SPIE vol. 2291, p. 82–91, Integrated Optics and Microstructures II, Massood Tabib–Azar; Dennis L. Polla; Ka–Kha Wong; Eds. Oct. 1994).

* cited by examiner




PRIOR ART

Fig. 1

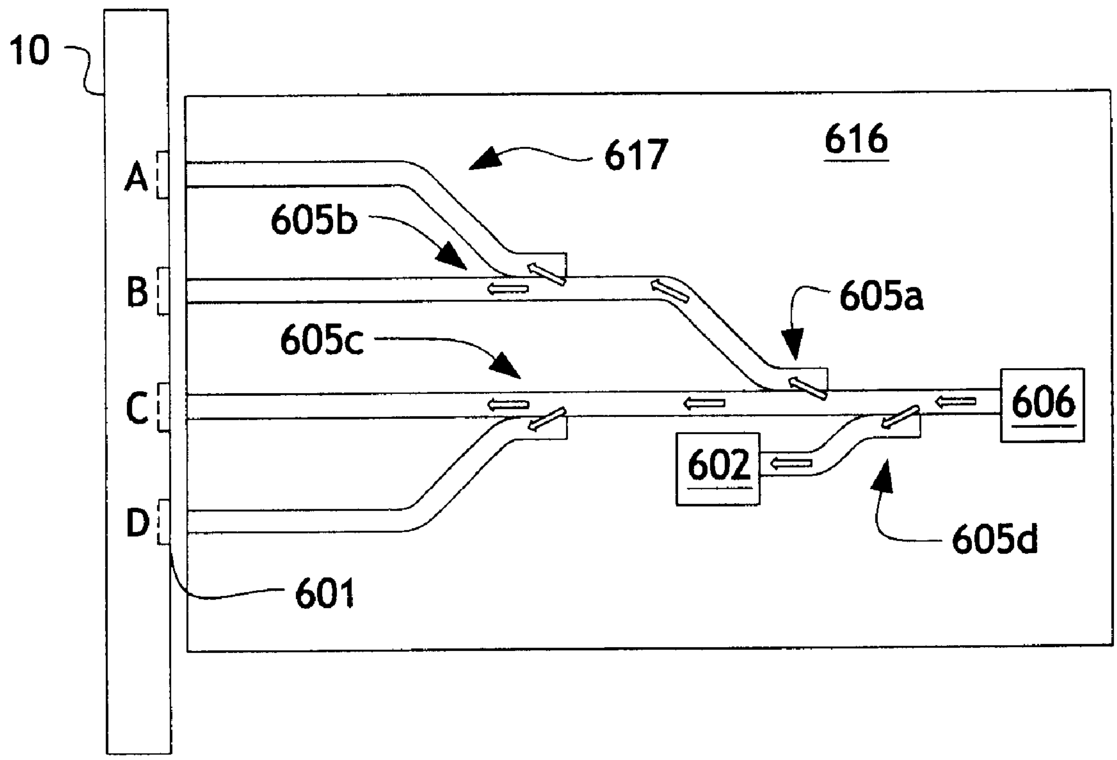
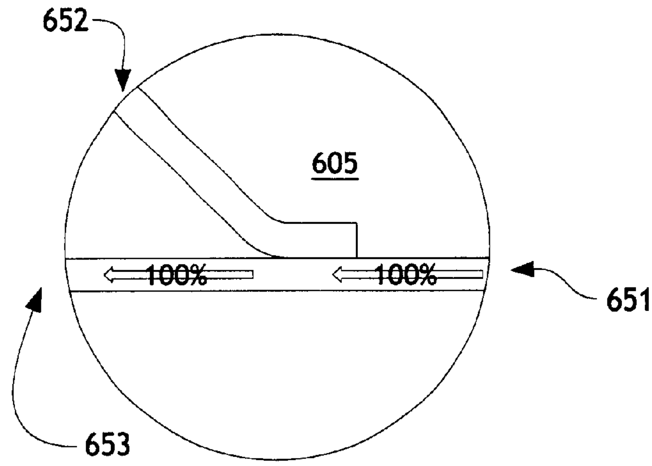



Fig. 2

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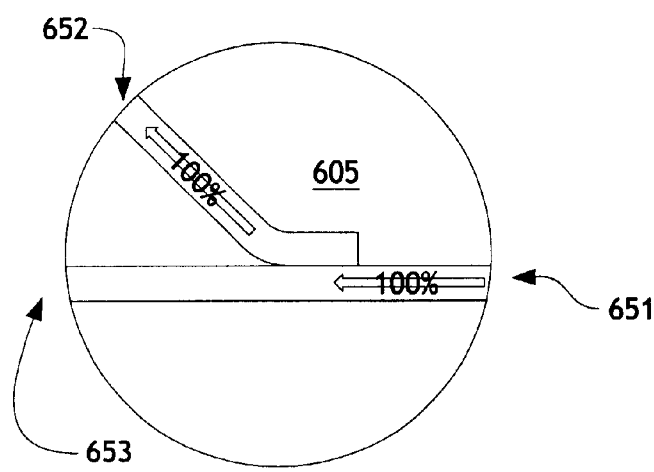


Fig. 4

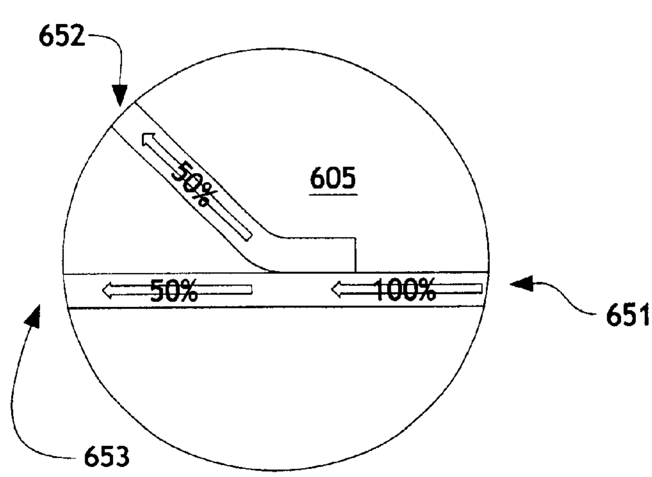


Fig. 5

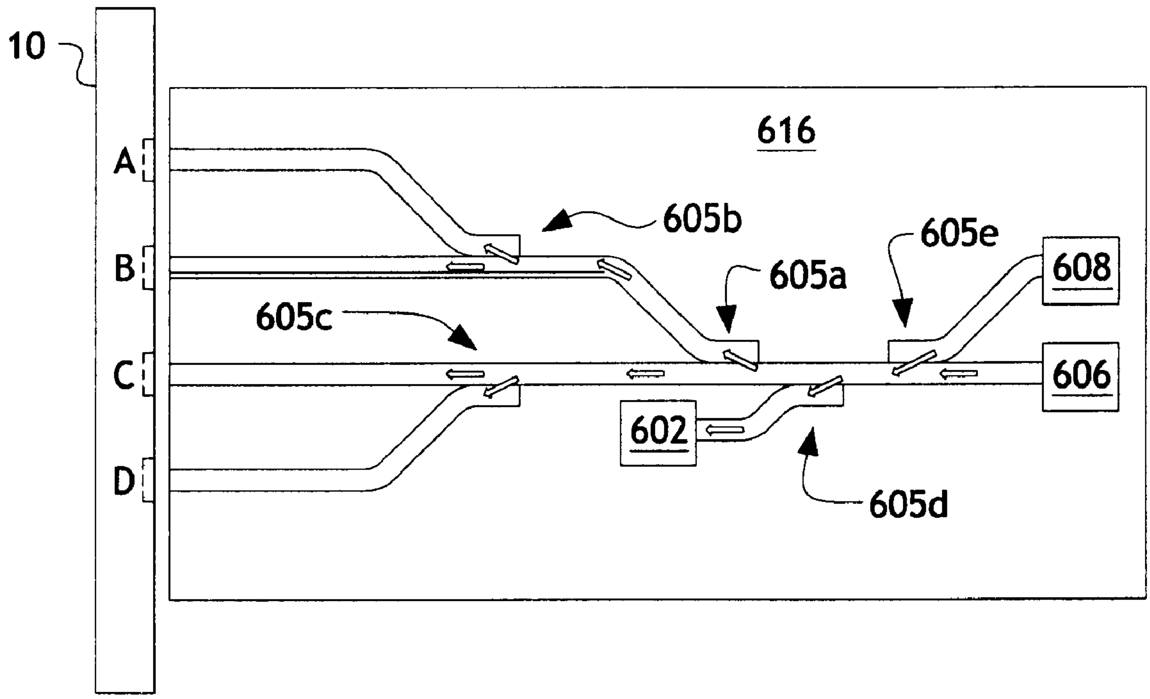


Fig. 6

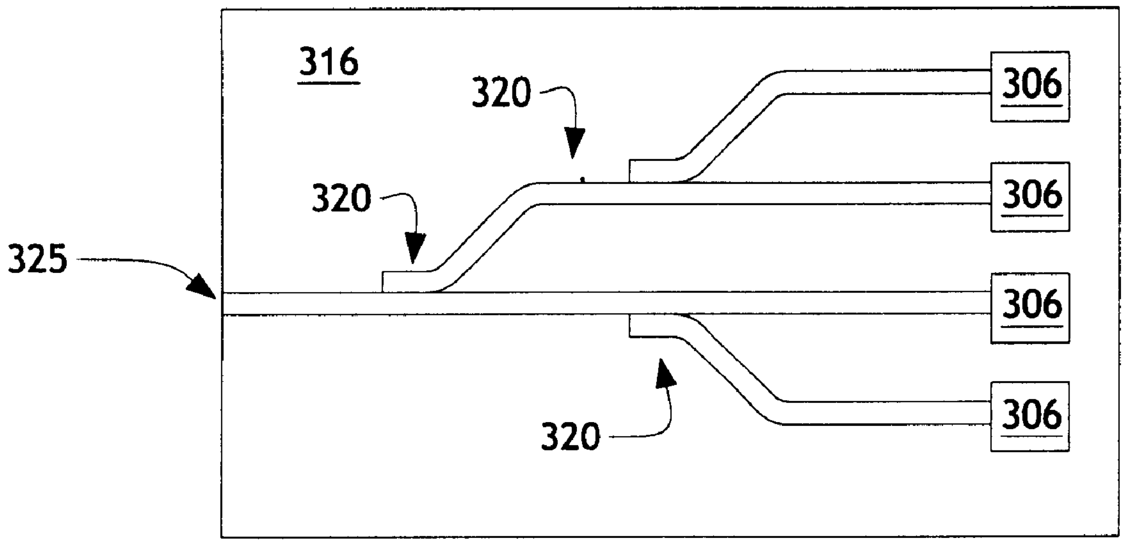


Fig. 7

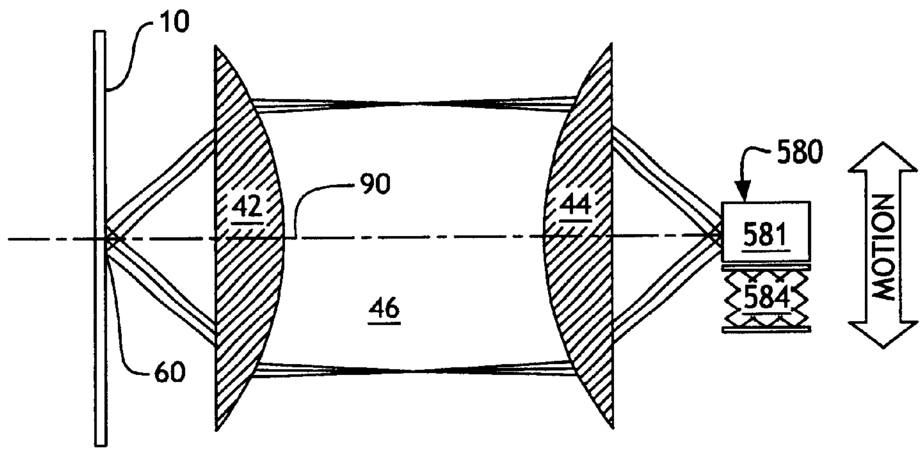


Fig. 8

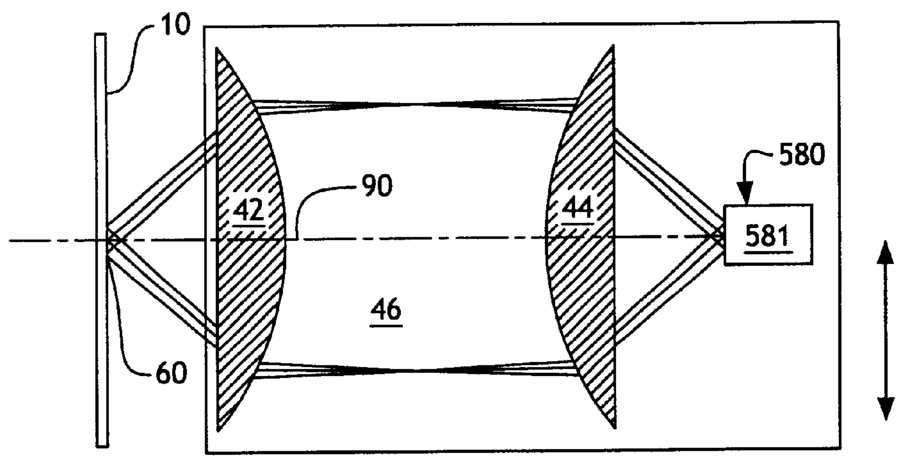


Fig. 9

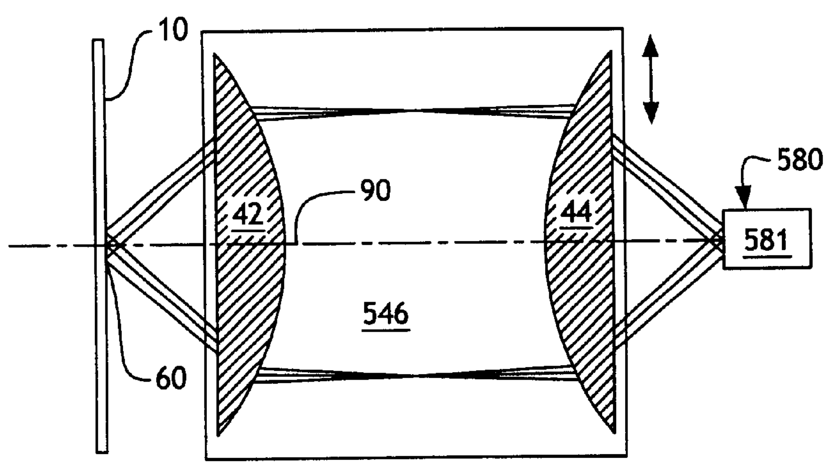


Fig. 10

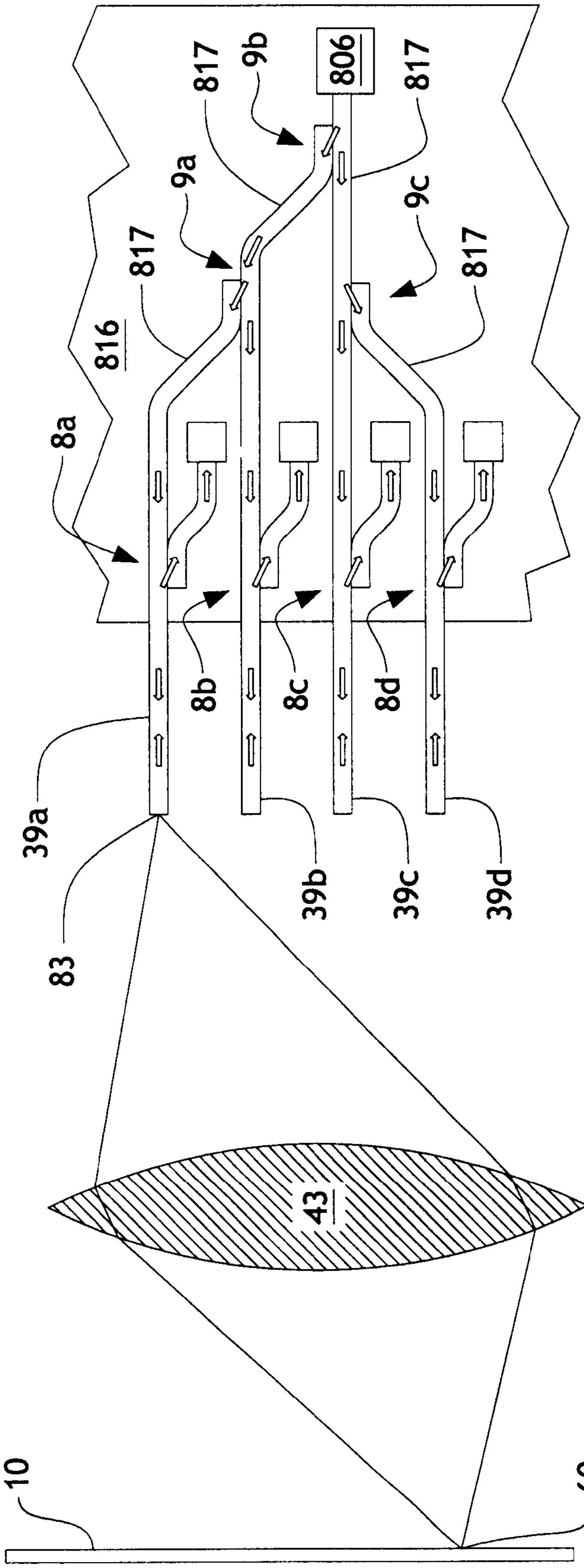

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Fig. 11

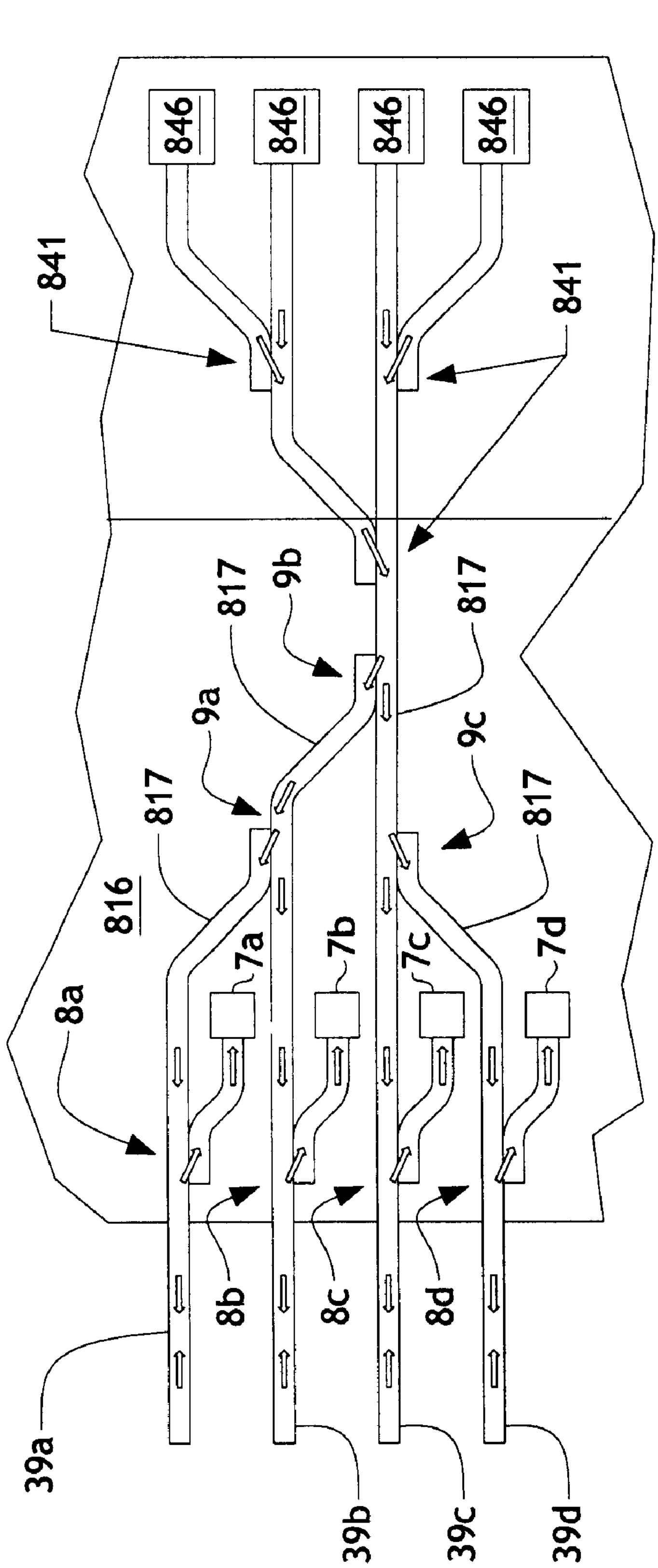
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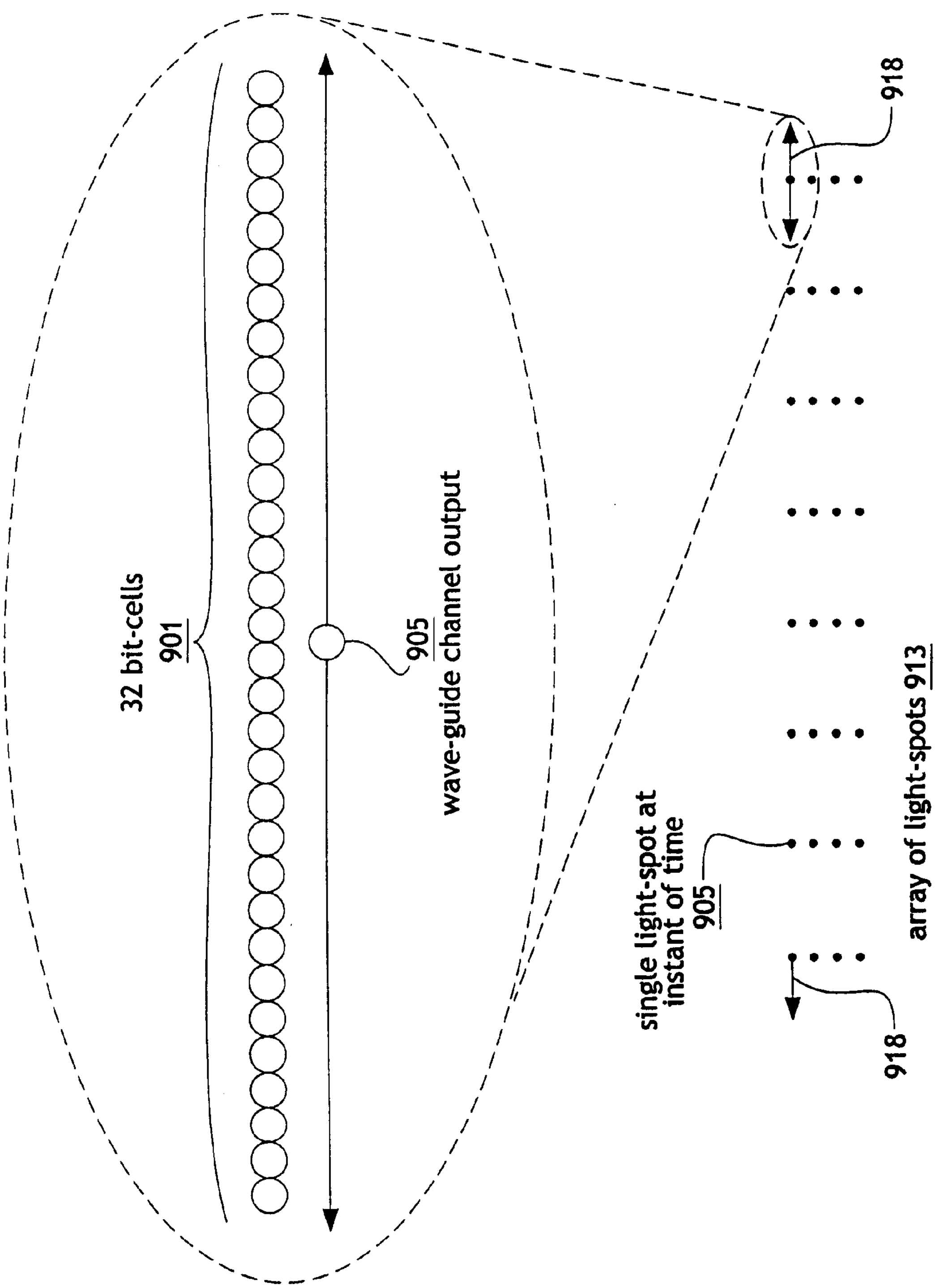
Fig. 12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905
wave-guide channel output
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single light-spot at
instant of time
905
array of light-spots 913
918

Fig. 13

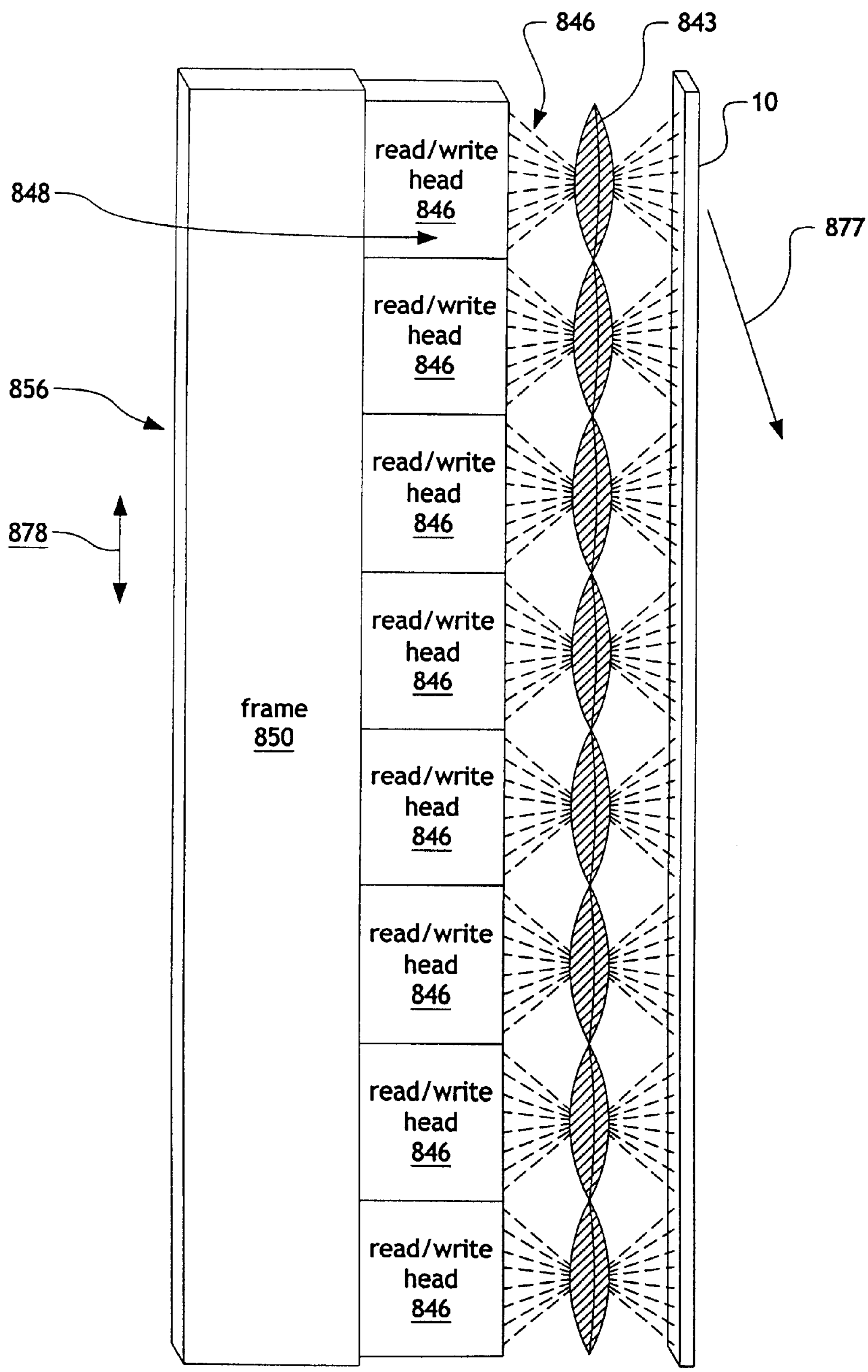


Fig. 14

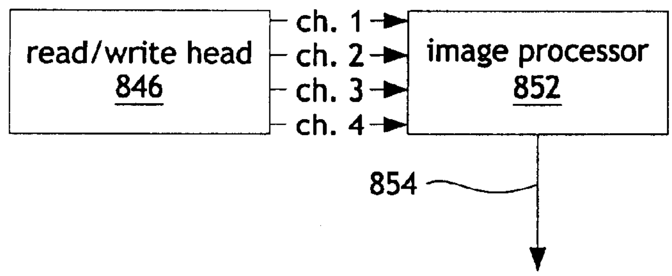


Fig. 15

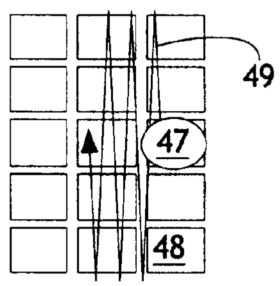


Fig. 16

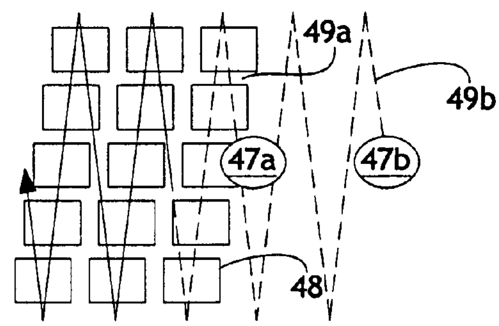


Fig. 17

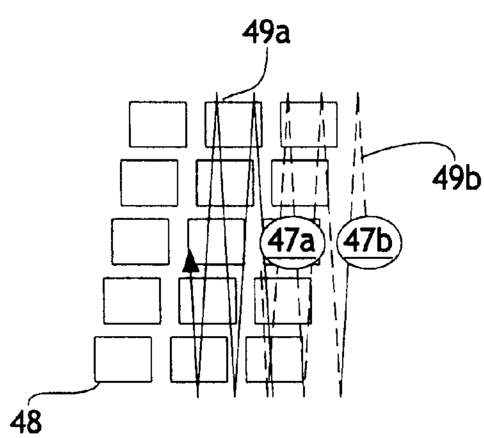


Fig. 18

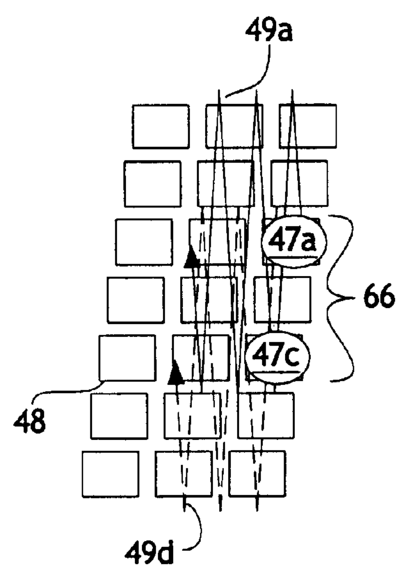


Fig. 19

# MULTIPLE CHANNEL SCANNING DEVICE USING OVERSAMPLING AND IMAGE PROCESSING TO INCREASE THROUGHPUT

## CROSS REFERENCE TO RELATED APPLICATIONS

The respective entireties of the following United States patents and patent applications, filed concurrently herewith, are hereby incorporated by reference: U.S. Pat. No. 6,091,067 (Scanning Device Using Fiber Optic Bimorph), U.S. Pat. No. 6,137,105 (Multiple Parallel Source Scanning Device), U.S. application Ser. No. 09/088,781 (Method and Apparatus for Controlling the Focus of a Read/Write Head for an Optical Scanner), U.S. Pat. No. 6,246,658 (Multiple Channel Scanning Device Using Optoelectronic Switching), U.S. Pat. No. 6,166,756 (Multiple Channel Data Writing Device).

## BACKGROUND OF THE INVENTION

Various optical scanners are known for such applications as data storage, bar code reading, image scanning (surface definition, surface characterization, robotic vision), and lidar (fight detection and ranging). Referring to FIG. **1**, a prior art scanner **50** generates a moving spot of light **60** on a planar target surface **10** by focusing a collimated beam of light **20** through a focusing lens **40**. If the assembly is for reading information, reflected light from the constant intensity spot **60** is gathered by focusing lens **40** and returned toward a detector **32**. To write information, the light-source is modulated. To cause the light spot **60** to move relative to the surface **10**, either the surface **10** is moved or the scanner **50** is moved. Alternatively, the optical path could have an acousto-optical beam deflector, a rotating prism-shaped mirror, or a lens driven galvanometrically or by piezoelectric positioners. Scanners also fall into two functional groups, raster and vector. Both types generally use the same types of beam deflection techniques.

Higher-speed raster scanners use either spinning prism-shaped (polygonal cross-sectioned) mirrors or multifaceted spinning holograms (hologons). Performance parameters for these conventional beam deflection techniques are listed in Table 1. The discrete optics in these devices are generally attended by high costs for mass manufacture, assembly, and alignment.

TABLE 1

Performance of Conventional Beam Deflectors for Optical Scanning

| Parameter | Polygonal Mirrors | Galvano-Driven Mirrors | Hologons (Transmission) | Acousto-Optic Deflectors |
|---|---|---|---|---|
| Wavefront Distortion | $\lambda/8$ at 0.55 $\mu m$ | $\lambda/8$ at 0.55 $\mu m$ | $\lambda/6$ at 0.55 $\mu m$ | $\lambda/2$ at 0.55 $\mu m$ |
| Area resolution (spot-widths/sec) | 25,000 (scan lens limited) | 25,000 (scan lens limited) | 25,000 (scan lens limited) | 1,000 (scan lens limited) |
| Cross-axis error | 10 arc sec (uncorrected) | 1–2 arc sec (uncorrected) | 10 arc sec | 0 |
| Speed (spot widths/sec) | $1 \times 10^8$ | $2 \times 10^6$ | $2 \times 10^7$ | $2.8 \times 10^7$ |
| Bandwidth | 0.3–20 $\mu m$ | 0.3–20 $\mu m$ | Monochromatic | monochromatic |
| Scan efficiency | 80–100% | 65–90% | 90% | 60–80% |

(from The Photonics Design and Applications Handbook 1993, Laurin Publishing Co., Inc., p. H449)

The performance parameters listed in Table 1 assume different levels of importance depending on the optical



scanning application. For raster scanning to cover extended surface areas, the emphasis is on speed, area resolution, and scan efficiency. Wide bandwidth is needed if the surface is to be color-scanned. For applications requiring vector scanning of precise paths at high resolution, the optical system typically uses a monochromatic, focused spot of light that is scanned at high speed with low wavefront distortion and low cross-axis error. Optical data storage has been a prime application of this type of optical scanning.

In optical data storage media, information is stored as an array of approximately wavelength-size dots (cells) in which some optical property has been set at one of two or more values to represent digital information. Commercial read/write heads scan the media with a diffraction-limited spot, typically produced by focusing a collimated laser beam with a fast objective lens system as shown in FIG. **1**. A fast objective lens, one with a high numerical aperture, achieves a small spot size by reducing Fraunhofer-type diffraction. The spot is scanned by moving an assembly of optical components (turning mirror, objective lens, position actuators) over the optical medium, either along a radius of a disc spinning under the spot or across the width of a tape moving past the head. The assembly moves in one dimension along the direction of the collimated laser beam. As the disk spins or the tape feeds, the line of bit-cells must be followed by the spot with sufficient precision to avoid missing any bit cells. The fine tracking is achieved by servo mechanisms moving the objective lens relative to the head assembly. An auto-focus servo system is also necessary to maintain the diffraction limited spot size because the medium motion inevitably causes some change in the lens/medium separation with time. Proper focus adjustment is possible because the medium is flat and smooth. Such a surface reflects incident light in well-defined directions like a mirror. Light reflected from the medium is collected by focusing optics and sent back along the collimated beam path for detection.

Scanning by several spots simultaneously is used to achieve high data rates through parallelism in one known system called the CREO® optical tape system.

The reading of optically stored data is a prime application example of this type of optical scanning. Commercial read/write heads for optical data storage systems scan with a diffraction-limited light spot, typically produced by focusing a collimated laser beam with a fast objective lens system as shown in FIG. **1**. The spot is scanned by moving an assembly of optical components (turning mirror, objective lens, position actuators) over the optical storage medium, either along a radius of a disc spinning under the spot or across the width of a tape moving through the head. The assembly moves in one dimension along the direction of the collimated laser beam. Light reflected from the storage medium is collected by the focusing optics and sent back along the collimated beam path. It is diverted out of the source path by a beam splitter **31** for routing to a detector **32**. However, because of the collimated beam optical design of this system, light entering the return path from areas outside the scanning spot can propagate some distance back toward the detector before the angular displacement is transformed into sufficient spatial displacement to be caught by an aperture stop. This extraneous light is more of a problem in a multiple spot system in which several areas of the scanned surface are illuminated at once, and crosstalk between adjacent and nearby spots is likely. The use of discrete optical components in such devices to eliminate this effect, poses great difficulty and cost for mass-manufacture because of the requirement of precise optical alignment of components.

One scanning device that avoids reliance on discrete optical elements to achieve scanning is described in U.S. Pat. No. 4,234, 788. In this scanner, an optical fiber is supported rigidly at one end in a cantilevered fashion. The supported end of the fiber is optically coupled to a light emitting diode or photo diode for transmitting or receiving light signals, respectively. The fiber is free to bend when a force is exerted on it. The fiber can thus be made to scan when light from the light-emitting diode emanates from the tip of the fiber as the fiber is forced back and forth repeatedly. To make the fiber wiggle back and forth, an alternating electric field, generally perpendicular to the axis of the fiber, is generated. The fiber is coated with a metallic film. A charge is stored on the film, especially near the tip, by forming a capacitance with a metallized plate oriented perpendicularly to the fiber axis (optically at least partly transparent). The stored charge makes the fiber responsive to the electric field.

A drawback of this device is the limit on the speeds with which the fiber can be made to oscillate. The device requires a series of elements to move the fiber: an external field-generating structure, a DC voltage source to place charge on the fiber coating, and an AC source to generate the external field. Another drawback of this prior art mechanism is the inherent problem of stress fractures in the fiber optics. Bending the fiber repeatedly places serious demands on the materials. Problems can wise due to changes in optical properties, changes in the mechanical properties causing unpredictable variation in the alignment of the plane followed by the bending fiber, the amplitude of vibration, the natural frequency of vibrations, and structural failure. Still another limitation is imposed by the need to place a conductor between the fiber tip and the optical medium to form the capacitance. This places another optical element between the fiber tip and the scanned surface and makes it impossible to sweep the tip very dose to the scanned surface as may be desired for certain optical configurations.

Another prior art scanning device is described in U.S. Pat. No. 5,422, 469. This patent specification describes a number of different devices to oscillate the end of an optical light guide or optical fiber. One embodiment employs a piezo-electric bimorph connected to the free end of a device to which the free end of an optical fiber and a focusing lens are attached. Reflected light is directed back through the fiber to a beam splitter which directs the reflected light out of the bidirectional (outgoing/return) path at some point along the fiber remote from the source of light. The above embodiment uses a simpler prime mover, a piezo-electric bimorph However, the need for a focusing lens attached to the end of the fiber, by increasing the mass, imposes difficult practical requirements for high speed oscillation of the fiber. In addition, to achieve very small projected spot size requires a high numerical aperture at the output end of the focusing optics. It is difficult to achieve this with the conventional optics contemplated by the '469 disclosure. Furthermore, the reciprocation of the fiber as described in the '469 patent requires a multiple-element device. Friction between the motor and the fiber can cause changes in the optical properties of the fiber, and mechanical changes in the motor, the fiber, or the interface, that result in changes (which may be unpredictable) in the amplitude of oscillation or the resonant frequency of the motor-fiber combination (which might generate, or be susceptible to, undesired harmonics). Also, the process of assembly of such a combination of a motor and a fiber presents problems. Ideally, for high frequency operation, the device would be very small.

Common to all storage/retrieval devices is the need for greater and greater data rates. Increases in speed have been achieved by increasing the speed of scanning. However, there are practical limits, particularly with regard to the writing operation, relating to physical properties inherent in the optical media.

Also common to the applications of optical scanning technology is the need for great precision in the focus of the scanning light source and the return signal.

## SUMMARY OF THE INVENTION

A multiple channel scanning device has a scanning head with multiple columns of apertures that emit light which is imaged by a lens onto the surface of a recorded medium. Light returned from the medium is imaged back onto the apertures and conducted to detectors. In a preferred embodiment, the scanning head is rapidly oscillated (may be on the order of 100 kHz rate), in a direction parallel to the columns. The medium is moved in a direction perpendicular to the columns so that the same recorded regions pass beneath successive columns of apertures. The data from the detectors is image-processed to improve the quality of data-reading using the successive readings from the same data regions. This allows errors to be corrected and throughput to be improved. In an alternative embodiment, scan spots are swept over nearly the same, or the same, regions to achieve oversampling.

According to an embodiment, the invention provides a scanning device for scanning a target surface with data written on it. The data is arranged in adjacent data cells on the target surface. Each of the cells has one of a set of possible configurations representing data. For example, a cell could be highly reflective to represent a "1" and less reflective to represent a "0." The scanning device has a read/write head, with at least one laser source, that transmits light to an array of output apertures from which light is emitted. The light returned from the surface is received through an array of input apertures. The read/write head and the target surface are mutually supported to move relative to each other to scan the target surface. The array of output apertures is arranged such that some scan substantially the same cells of the target surface. The read/write head includes detectors that detect the returned light and send resulting signals to an image processor. The image processor generates an estimate of a configuration of each cell from the redundant or quasi-redundant data and generates a signal stream representing the estimate. In a variation, the output apertures are coaxial with the input apertures. In another variation, the read/write head has an optoelectronic chip with internal light guides formed in it, each of the light guides being connected to one of the output apertures. In still another variation, the optoelectronic chip has at least one optical switch to modulate an output of either a reading laser source or a writing laser source to allow the scanning device to write data as well as read it. The light sources of the invention, for writing purposes, are, preferably, modulated by optical switches that selectively direct the output between a write output aperture and another direction leading ultimately to dissipation of energy of the writing laser source. This way, the writing laser source can operate continuously during writing. Multiple reading laser sources may be connected to an array of light guides interconnected to split light from the multiple reading laser sources into multiple paths, each connected to a one of the output apertures. The array of light guides may be interconnected with respective optical switches controlled by a controller programmed to cause the laser output to be shared among multiple output apertures by alternately shunting the laser output to a first fraction of the output apertures and shunting the laser output to second fraction of the output apertures. The fractions could constitute just a single aperture.

According to another embodiment, the invention provides a scanning device for scanning a target surface with data written on it. The data is arranged in columns of adjacent data cells on the target surface. Each of the columns of data cells has one of a set of possible configurations representing data as discussed above. The device has a read/write head with an array of input apertures arranged in successive columns such that each of the columns receives light from the same one of the columns of data cells. There is at least one detector connected to detect light received by the array of input apertures. The detector generates a signal indicating an estimate of one of the possible configurations by combining information derived from light received by all of the successive columns. In a variation, the detector combines the information by detecting light from each of the columns and synthesizing an improved estimate of the one of the possible configurations from the combination of signals generated.

According to still another embodiment, the invention provides a scanning device for scanning a target surface that has data written thereon, the data is arranged in columns of adjacent data cells on the target surface. Each of the columns of data cells has one of a set of possible configurations representing data. The device has a scanning head with an array of input apertures arranged in successive columns so each of the columns receives light returned from the columns of data cells passing under it. Also at least one detector is connected to detect light received by the array of input apertures. The detector generates a signal indicating an estimate of one of the possible configurations by combining information derived from light received by all of the successive columns. In a variation, the scanning head has at least one laser connected to conduct light so that it is emitted from the array of input apertures. In this way, the array of input apertures functions as an array of output apertures from which light is emitted. In another variation, an imaging optical element positioned between the scanning head and the target surface images light emitted from the output apertures onto the target surface. The light from the same one of the columns of data cells is light emitted from the array of output apertures, returned from the target surface, and imaged by the imaging optical element back onto the input apertures. In another variation, there is an array of output apertures, each being respective of one of the array of input apertures. Also, the scanning head includes a light guide leading from each of the input apertures to the respective detector.

According to still another embodiment, the invention provides a method of reading data from a recorded surface that has successive columns of data cells. The successive columns have at least one row of the data cells. The method has the following steps: Moving the recorded surface such that light from a first output aperture is focused onto a first of the successive columns. Receiving light returned from the recorded surface responsively to the first step of moving. Detecting light returned from the recorded surface and storing a first result thereof Moving the recorded surface such that light from a second output aperture is focused onto the first of the successive columns. Receiving light returned from the recorded surface responsively to the second step of moving. Detecting light returned to the first input aperture and storing a second result thereof Calculating data represented by the first of the respective columns responsively to a computed combination of the first and second results. In a variation of the method, in the first step of receiving, light is received at a first input aperture corresponding to the first output aperture. In addition, in the second step of receiving, light is received at a second input aperture corresponding to the second output aperture.

According to still another embodiment, the invention provides a method of reading data from a recorded surface with successive columns of data cells. The successive columns comprise at least one row of the data cells. The method has the following steps: Moving the recorded surface such that light from a first output aperture is focused onto a first of the successive columns. Receiving light returned from the recorded surface responsively to the first step of moving. Detecting light returned from the recorded surface and storing a first result thereof Moving the recorded surface such that light from a second output aperture is focused onto the first of the successive columns. Receiving light returned from the recorded surface responsively to the second step of moving. Detecting light returned to the first input aperture and storing a second result thereof Calculating data represented by the first of the respective columns responsively to a computed combination of the first and second results. In a variation of the method, in the first step of receiving, light is received at a first input aperture corresponding to the first output aperture. In addition, in the second step of receiving, light is received at a second input aperture corresponding to the second output aperture.

According to another embodiment, the invention provides a scanning device for scanning a medium with data written on it. The data is arranged in columns of adjacent data cells on the target surface. Each of the columns of data cells has one of a set of possible configurations representing data The scanning device has a scanning head with an array of input apertures arranged in successive columns such that each of the columns receives light from the same one of the columns of data cells. In addition, at least one detector is connected to detect light received by the array of input apertures. The detector generates a signal indicating an estimate of a one of the possible configurations by combining information derived from light received by all of the successive columns. There is a frame connected to the scanning head. The medium is attachable to the frame such that the medium is movable relative to the read/write head. As a result, the media moves in a first direction relative to the read/write head. An oscillating motor connected between the frame and the read/write head oscillates the scanning head relative to the medium. As a result a spacing of the input apertures may exceed a spacing of the adjacent cells while still permitting light returned from substantially all of the adjacent cells to be detected by the detector. In a variation, the medium is moved continuously in the first direction at a constant speed. In another variation, the direction of an oscillation of the read/write head has a component substantially perpendicular to the first direction. In still another variation, the scanning head includes at least one laser connected to conduct light so that it is emitted from array of input apertures. As a result, the array of input apertures functions as an array of output apertures from which light is emitted. In still another variation there is an imaging optical element (e.g., a lens system) positioned between the scanning head and the target surface to image light emitted from the output apertures onto the target. The light from the same one of the columns of data cells is emitted and returned from the array of output apertures. This light is imaged by the same imaging optical element back onto the input apertures. In another variation, there is an array of detectors, each being respective of one of the input apertures. The scanning head includes a light guide leading from each of the input apertures to the respective detector.

The invention provides an essential component in an optoelectronic chip designed to direct the flow of light and modulate the light output in a multi-channel optical scanning head. The invention leads to a reliable, robust, manufacturable, low-cost component for optical scanning devices used for optical data storage, bar code readers, image scanning for digitization or xerography, laser beam printers, inspection systems, densitometers, and 3-dimensional scanning (surface definition, surface characterization, robotic vision). Speed and accuracy are enhanced through the use of image processing techniques applied to redundant and partly redundant data.

## BRIEF DESCRIPTION OF THE DRAWING

In the drawing,

FIG. **1** is a ray trace diagram showing a scanning device according to the prior art.

FIG. **2** is an illustration of an optoelectronic chip with integral waveguides, beam switches, a laser source, and beam dumps to allow the generation of a modulated signal using one laser source through multiple channels simultaneously.

FIGS. **3**, **4**, and **5** illustrate the light flow taken by an optoelectronic switch in three respective modes.

FIG. **6** shows an embodiment similar to that of FIG. **2** except that a backup laser is included with a crossover to the backup laser to supply the multiple channel light guide network.

FIG. **7** is an illustration of a group of lasers formed in an optoelectronic chip interconnected by combiners to combine the energy of the lasers into one source.

FIG. **8** is a ray trace diagram showing a multiple channel scanning head according an embodiment of the invention, where the imaging optics are fixed and the scanning head is oscillated by a MEMS motor to scan a region of a target surface.

FIG. **9** is a ray trace diagram showing a multiple channel scanning head according an embodiment of the invention, where the imaging optics and scanning head are fixedly interconnected and oscillated as a unit by a MEMS motor to scan a region of a target surface.

FIG. **10** is a ray trace diagram showing a multiple channel scanning head according an embodiment of the invention, where the imaging optics are oscillated as a unit by a MEMS motor to scan a region of a target surface.

FIG. **11** illustrates a scanning head with fiber-optic light guides and multiple detectors for purposes of describing the scanning of a region simultaneously by multiple channels.

FIG. **12** illustrates a scanning head similar to the embodiment of FIG. **11** except that the light source employed combines the power of multiple individual light sources to produce light of sufficient intensity to write on the media. Alternatively, the additional light sources may serve as backup sources in case of failure of one source.

FIG. **13** illustrates an embodiment of a multiple channel scanning head where multiple columns of input apertures scan an identical region and image processing techniques are applied to the redundant data to enhance accuracy and increase throughput.

FIG. **14** is a simplified isometric rendering illustrating the embodiment of FIG. **13** with only one column of ray traces showing.

FIG. **15** illustrates the use of an image processing computer to process the data from multiple channels of redundant data for the embodiments of FIGS. **13** and **14**.

FIGS. **16–19** illustrate different ways of oversampling the scanned surface with variations of an embodiment of the invention.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

Referring to FIG. **2**, an optical scanning optoelectronic chip (OE) **616** has single laser source **606** that supplies light to multiple output apertures **601**. Light emitted by laser **606** is guided by light guides **617** to various rail taps **605***a*–**605***c*. Light from laser **606** is output, ultimately, through four output apertures **601** and applied to a scanned surface **10** at regions A, B, C, and D respectively. An optical switch **609** allows light from the laser to be directed to a beam dump **602** for dissipation and absorption of light energy. Switching the optical switch to a bypass position, in effect, modulates the output of light from the output apertures **601**. Note that although in the embodiment shown, light is directed at the scanned region without any focusing optics, focusing optics may be used between the chip **616** and the target **10**. Also note that although the chip **616** has an on-board laser, the laser could be a separate device and light applied to the light guide network through an input aperture.

The purpose of the optoelectronic chip in this system is to control the distribution of light from the laser sources to the optics that produce the scan and to direct the light signals returning from the scanned surface into the set of photo detectors. The integrated design allows the reduction of size, moving mass, component count, and manufacturing cost, compared to scanning systems with multiple discrete optics components. The optoelectronic chip design allows very accurate positioning of the light apertures by lithography without requiring monolithic, multiple output laser arrays. Parallel, integrated read/write channels with multiplexing have low cost per channel in a compact, robust configuration. Electro-optic switching is required to achieve the required data rates. The most cost effective technology available today is a polymer waveguide optoelectronic chip made using Photonic Large Scale Integration (PLSI).

The basic element of the PLSI chip is a one channel to two channel splitter, which can direct light from one input into one of two outputs, or split the intensity between the two outputs. This has been achieved easily by implementing waveguide structures containing non-linear optical polymeric material that has an index of refraction controlled by planar metal electrodes. This basic design allows for the fabrication of electro-optic switches and optical rail taps (directional couplers). Many such devices have been fabricated using simple, multi layer metal and polymer films photo lithographically defined with batch methods commonly employed for silicon chip fabrication.

The nominal multiplexed design of FIG. **2** uses four levels of switching between a single laser and four output channels directed respectively at target spots A–D. Assuming 80% transmission through each switch level, this results in as much as a 4 dB loss due to four switches through the output routing. Non-linear optical polymer waveguides can be fabricated that have no more than 0.1–0.2 dB losses at the operating wavelength. Using this estimate, the total losses in a single output channel with four levels of switching should be no more than 5 dB. In a design using a column of 64 spots for scanning a 4-mm width of surface in parallel (each spot scans±32 $\mu$m), 16 lasers are required. Each laser feeds a set of 4 output channels for write scanning at power levels high enough to affect the surface, but is switched among the channels at a 50% duty cycle. Read scanning generally requires much lower power levels. In this mode each laser can feed 16 channels, each at a 100% duty cycle. This extra capacity (compared to the write mode) is applied to achieve redundancy in reading by driving four parallel columns of 64 spots each; the columns scan the same surface area in sequence.

The light guides **617** (or optical wave guides) are formed directly in the chip **616** using fabrication techniques similar to those employed in the manufacture of integrated circuits. Optoelectronic chips are formed in a layer-by-layer process beginning with a suitable substrate such as silicon or glass wafer. A thin metal film is applied to the substrate and patterned to define electrodes and conductors. Next, a layer of material is added to form the optical waveguides and the material is patterned using photolithography. Switches may be formed by doping the material to create non-linear optical effects in the switching regions. In a purely additive process, additional material layers can be applied sequentially, on each of which additional optical paths, electrodes, and conductors can be formed.

In the embodiment of FIG. **2**, the chip **616** is configured to distribute the power input from one laser to four different output channels that will be used for scanning. The optical railtaps **605***a* through **605***c* are capable of selectively distributing the light power flow (minus internal losses of a few dB) among the various paths defined by light guides **617**. Each optical rail tap **605***a*–**605***c*, has at least three operating modes. Referring to FIG. **3**, in the first, rail tap **605** permits all the light energy entering it at **651** to pass straight through to **653** (of course, there are losses). Referring to FIG. **4**, in the second mode, all of the energy entering at **651** is bypassed to the branch at **652**. Referring to FIG. **5**, in the third mode, half the energy is bypassed to branch **652** and half permitted to pass straight through to branch **653**. When all three of the rail taps **605***a*–**605***c* are set to 50% bypass, the third mode, light passes through the output channels such that the energy arriving at the four output apertures is substantially equal. Referring now also to FIG. **2**, if the three rail taps are operated sequentially as indicated in the following table, all of the laser output can be directed to the respective output apertures in succession.

| Target | Rail tap positions | | | |
|---|---|---|---|---|
| Region | 605a | 605b | 605c | 605d |
| A | mode 2 | mode 2 | no effect | Mode 1 |
| B | mode 2 | mode 1 | no effect | Mode 1 |
| C | mode 1 | no effect | mode 1 | Mode 1 |
| D | mode 1 | no effect | mode 2 | Mode 1 |

As the terms are used in the following discussion, “write” refers to making a durable change in a medium. The term “read” refers to the process of collecting information from a medium without permanently altering the medium. Assume that the maxim laser output is just enough (after system losses) to supply one channel with power for a writing scanning beam. A read/write head with the chip in FIG. **2** would use the switching functions of the optical railtaps to direct all of the laser power to each of the four output channels in succession for writing with precise synchronization to address each channel at the time when its output was positioned to write. Modulation of the writing power channel is done using the first rail tap **605***d*. The chip will use that switch to divert the laser output to the beam dump when the output channel is writing a space and supply the fill power when writing a mark. In this way, the laser can remain on at constant power with less stress and longer lifetime.

In many cases (e.g., reading and writing on phase-change optical storage media), much less light energy is used to read a pattern already written than to write the pattern. In that case, the chip **616** can divide the laser input power equally among the four output channels during the reading function, and four reading channels can be scanned simultaneously. For reading, each channel output is on all the time, and the scanned pattern on the surface modulates the return signal.

Referring to FIG. **6**, a chip **617** with an optical railtap **605***e* to allow crossover between the laser input channel, in case of a laser failure, allows a neighboring or backup laser **608** to be switched in to feed the outputs originally assigned to the source that failed **606**. This crossover feature could also be used as shown in FIG. **7** to gang the output of several lasers to meet a scanning intensity requirement that exceeded the output of a single laser. The outputs of multiple lasers **306** can be combined for an application that requires an output intensity greater than a single laser can produce alone. Referring to FIG. **7**, in an optoelectronic chip **316**, multiple optical rail taps **320** are used to combine the outputs of more than one laser **306** that could be, for example, phase-locked. In this embodiment, four lasers combine to generate one combined output **325**. This embodiment is particularly useful for use with laser devices such as vertical cavity sure emitting lasers (VCSELs) when used to write on materials requiring several milliwatts of power.

Using the invention, laser light can be allocated among several output channels with very fast switching rates for optimum use of power for both reading and writing applications. Cost savings can also be achieved. Single laser outputs requiring more power than can be achieved with a single laser can be supported by using the output-combining feature described. In addition, laser output can be modulated without directly varying laser output power, thus allowing the laser to operate in a continuous wave (CW), long-lifetime, stable mode.

Referring to FIG. **8**, the small size of the embodiments discussed above lends itself to scanning using MEMS technology motors. In an embodiment of the invention, a multiple output scanning head, OE chip **581** according to any of the previous embodiments discussed, has multiple outputs, as described. Although the drawings only indicate schematic ray traces for three beams, it is understood that the drawing is compatible with any number of outputs. OE chip **581** is oscillated by a motor **584** based on microelectromechanical systems GEMS) technology. A scanning motion of multiple spots **60** can be obtained with this arrangement. The multiple focused spots **60** will scan over the surface **10** when the source array **580** is oscillated relative to the optical axis **90** of the lens system. In the embodiment of FIG. **8**, the lens system **46** is held fixed and the optoelectronic chip **581** is oscillated. In a nominal lens system with 1:1 magnification, the spots move along the surface **10** the same distance as OE chip **581**.

Referring to FIG. **9**, in an alternative embodiment, similar to that of FIG. **8**, the focusing optics **46**, as well as the light guide array **580**, is oscillated. The focusing optics **46** and the source array **580** are supported on a single stage **521** which is oscillated by a motor (not shown). Referring to FIG. **10**, in still another embodiment, lens system **546** is supported on stage **525** that is oscillated relative to both the scanned surface **10** and the source array **580**. Preferably, the lens system is oscillated to cause a rotary motion since a purely lateral oscillation would not produce the same degree of oscillation in the focused spots **60**.

Using the invention, laser light can be allocated among several output channels with very fast switching rates for optimum use of power for both reading and writing applications. Cost savings can also be achieved. Single laser outputs requiring more power than can be achieved with single laser can be supported by using the output-combining feature described. In addition, laser output can be modulated without directly varying laser output power, thus allowing the laser to operate in a continuous wave (CW), long-lifetime, stable mode.

Referring to FIG. **11**, a laser array **806** supplies scanning light to an array of light guides **817** formed in an optoelectronic chip package **816**. Optical fibers **39***a*–**39***d* protrude from the optoelectronic chip package **816** emitting light transmitted from light guides **817** at a high numerical aperture ratio from tips **83**. The emitted light is imaged to a spot **60** on a target surface **10** by a lens (which could be lens system). Electro-optical switches **9***a*–**9***c* are controlled to switch the laser source **806** sequentially among the four optical fibers **39***a*–**39***d* to produce a series of scanning spots **60** in succession on target surface **10**. Note that imaging using any of the above embodiments can be done using a focusing lens system as shown in the embodiment of FIG. **11** or by positioning the output channels very close to the target surface as shown in FIG. **2**. Note also that while in the above embodiments, the output channels are oscillated by moving the entire optical circuit, it is possible to achieve the required oscillatory motion by vibrating the fibers by bending them using bimorph elements as described in the copending applications incorporated herein by reference. That is, the fibers can be moved by bimorph elements each driven by the same excitation voltage source. Or the fibers could be mounted to a stage, as discussed, and the stage oscillated. In the case of a moving stage, the fiber tip array should protrude only one or two fiber diameters from the chip and the entire chip moved with a fast "shaker" (e.g. MEMS electrostatic actuator, piezoelectric drive, etc.). In a nominal lens system design with 1:1 magnification, the spot moves along the scanned surface the same distance that the fiber tip moves perpendicular to the optical axis. If appropriate, magnification ratios other than 1:1 can be used to have the scanning spot move further than or less than the fiber tip moves. If the fiber tip moves in such a way that its tip does not move in a plane, the focusing lens system can, in some cases, be designed to compensate for this non-planar motion and maintain planar motion of the scanning spot if so desired. In addition, various ways of accomplishing this are discussed above.

Fabrication of edge-emitting laser diode arrays is a mature, advancing technology that provides compact, robust, and inexpensive multiple laser light sources with relatively small power requirements. For example, for an optical data storage scanner used with phase change media, a single package laser array with 8–16 lasers will fit this application by meeting the following laser requirements: (a) operation at good optical-out/electrical-in efficiency to provide CW power onto the optical media for writing (7–15 mW for 150 ns) and reading (10 $\mu$W–5 mW) after subtracting fiber optic transport and coupling losses and (b) operation at wavelengths appropriate for digital optical data storage (<1 $\mu$m).

Edge-emitting, single mode laser diode arrays with the required power at 830 nm wavelength are available off-the-shelf. Achieving smaller diffraction limited spot sizes for high density optical storage requires laser arrays with the shorter wavelengths now available in low-power discrete diode lasers (e.g. 670 nm at 15 mW). Vertical cavity surface emitting lasers (VCSELs) represent another configuration of solid state laser that have output beam characteristics more suited to optical scanners and are more amenable to incorporation in a single chip multiple device design.

Referring to FIG. **12**, VCSELs are presently limed to lower output power than edge-emitting lasers. For use in this invention, the outputs of several VCSELs **846** may be ganged, for example with phase locking, to provide power for writing when higher channel power levels are required. The laser array may be integrated with the optoelectronic chip to achieve low-loss coupling of the laser output into the chip waveguides **817**. Interfacing the chip "switchyard" with the laser source, be it single laser or a ganged device as shown in FIG. **12**, can be accomplished by attaching optical fibers between each laser and the switchyard input ("pigtailing"), using a hybrid arrangement with the laser array butt-coupled to the optoelectronic chip, or totally integrating the lasers in the optoelectronic chip.

The chip could also be designed with optical railtaps to allow crossover between the laser input channels, so that, in case of a laser failure, a neighhoring or backup laser could be switched in to feed the outputs originally assigned to the source that failed. That is, for example, in the embodiment of FIG. **12**, if one of the lasers **846** fails, another one can be switched in to provide a backup source. As described above, the same crossover feature is used to gang the output of several lasers to meet a scanning intensity requirement that exceeds the output of a single laser.

The return light from the surface is imaged back onto the tip of the emitting fiber and passes back into the chip where it is shunted by a respective directional coupling **8***a*–**8***d* to a corresponding photo detector **7***a*–**7***d*. Silicon-based devices provide response over the wavelength range from the near IR to visible blue light, and PIN-type (p+|intrinsic|n+) silicon photo diodes are simple, fast, long-lived, inexpensive devices routinely used in optical fiber data links and other applications at rates of 1 GHz and higher. These devices are integrated monolithically within a silicon substrate in the chip.

The novel scanning and light allocation design of the embodiments discussed above, and which are discussed further below, require switching speeds on the order of 20 nanoseconds when employed in optical data storage. Although electro-optic switching is required, this is not a stressing demand on the technology since sub-nanosecond switching times have been demonstrated. Similar technology has been employed for multi-output data transmission.

As discussed in the related applications incorporated herein by reference and elsewhere in this application, the laser light emitted from the tip of the properly designed fiber or waveguide diverges with a high numerical aperture (A) ratio. A simple, fast lens system with matching NA is used to focus the light emitted from the fiber tip or waveguide to a spot on the surface to be scanned. For high resolution scanning applications, the fibers are single mode. For optical data storage and other minimum scan spot size applications, the lens system is designed to produce the smallest practical diffraction limited spot on the scanned surface. The light reflected from the surface is collected and re-imaged by the same lens system back into the same fiber or waveguide tip. The fiber or waveguide carries the return light back into the optoelectronic chip for detection. The one-to-one mapping properties of the imaging system constrain the optics to focus back into each fiber tip all light that originates from the spot on the surface illuminated by that fiber tip and reject any light coming back from the target surface from another location. This acts as an aperture stop and has the effect of limiting cross-talk among parallel data channels fed by multiple scanning light spots. In this design, the lens system could be made from a single holographic element.

In the above embodiments, because each spot performs multiple, overlapping scans to sweep the area that it is reading, there is no need for micro-tracking systems to maintain micron-scale positioning of the spots on the surface. Precision autofocus control of the head as a unit will be necessary, as in conventional optical heads. The focus quality signal will be based on maximizing the signal level returned from a given surface area. When the light collected back into the fiber tip is maximized, the system is in focus.

Referring to FIG. **13**, to illustrate design issues for this invention, parameters are presented for an application example of the integrated head: read/write scanning of a digital optical data tape moving under it. The read/write head of this embodiment includes an 8 by 4 array of output apertures, either the ends of light waveguides or the tips of optical fibers according to any of the above embodiments. Each output aperture is spaced apart by 64 microns The data cells written and read are spaced on 1 micron centers so that an array of 32 bits cells **901**, is covered by a ±32 micron sweep of each output aperture as the read/write head is oscillated.

Phase-change optical media has shown the capacity to store readable bits in cells spaced center-to-center at the smallest practical diffraction limited spot diameter, which is of the order the laser wavelength. However, under optimal conditions, several techniques have been developed to achieve higher bit densities. The above design assumes 1×1 $\mu m^2$ data cell dimensions. Since each output aperture oscillates ±32 $\mu$m the corresponding spot on a tape medium sweeps over a 64 $\mu$m long strip perpendicular to the tape edge. As the nominal design has a 4×8 array of output apertures in a rectangle centered on the optical axis of a 1-mm aperture lens system, at any instant of time, the system projects a 4×8 array of light spots **913** on the target surface. The 8 output apertures in each column of the array are spaced on 64 $\mu$m centers so that they cover a band 512 $\mu$m across the tape. Referring to FIG. **14**, a single module **848** consisting of read/write head **846** (a 4×8 array of output apertures) with a single imaging lens **843** may be duplicated eight-fold to produce a read/write head **856** spanning a full 4-mm width. The modules in the embodiment shown are arranged vertically and attached to a frame **850** for support. Such a read/write head **856** produces a 4 by 64 array of light spots. Although in the figure only eight central ray traces are shown at **846** projected by each module **848**, it is to be understood that the embodiment includes four columns of eight ray bundles. The direction of motion of the medium relative to the read/write head **856** is indicated by the arrow **877**. An arrow **878** indicates the direction of oscillation of the read/write head **856**, but not the magnitude which is about the size of the spacing between adjacent output apertures as indicated by the spacing of the origins of the ray central traces shown at **846**.

The four columns of output apertures along the translation direction of the medium relative to the read/write head allow the same area of the medium to be scanned independently four separate times for redundancy as the medium moves under the read/write head. In the write mode, the four scans may be used to: 1) read the tape surface for previously written data or fiducial marks to determine position; 2) write; 3) read to confirm what was written; 4) read again. Note that, preferably, the lens systems are offset from each other to cover the entire medium-displacement-path width, and thus a continuous band across the medium will not be read simultaneously.

To read or write 67 Mbits (8 MBytes) in 1 second for the above design on 4-mm tape, each fiber in a column must scan 1 Mb/s. With 64 bits per 64 $\mu$m scan length, the fiber must complete at least 16,384 data scans per second. Because oscillation frequencies well above 100 kHz are easily achieved for MEMS systems, a fiber scan rate several times higher than this minimum can be used in the read mode. The net effect is that the set of 8 light spots from each column of fibers sweeps a 512 $\mu$m wide band of the tape moving under it with enough oversampling that reflectivity data from each data bit is received multiple times. In the write mode, each fiber will oscillate at 16 kHz and write to 64 data cells in a column on the tape during one half of a cycle only. Half the fibers (32) may write during the downstroke, then the lasers will be switched to the other half that will write during the upstroke. This allows a 50% duty cycle for a laser to write through each output aperture; if each laser can supply enough power to two output apertures writing simultaneously, then 16 lasers can handle all 64 fiber channels in one column spanning the 4-mm tape width

The vertical displacement (direction perpendicular to arrow **877**, the direction of movement of the read/write head **856** relative to the scanned surface **10**) of successive columns of output apertures in the embodiment of FIG. **14**, for example, may be non-zero, but less than the data-cell pitch, so that each column of outputs scans a slightly different part of the surface. This vertical displacement may also be zero. In either case, preferably, the data streams from the detectors reading the return signals from each fiber are digitized and processed. Thus, all the streams from all four detectors are processed together so that data from successive sweeps of the same area (or almost the same area, when the vertical displacement of columns is non-zero) are presented to an image processing computer. Using known image-processing techniques (e.g., weighted averaging or most representative trace for each cell), this information can be used to provide a very fast, low error rate reading of the scanned surface pattern. The lateral spacing of the fibers in each array of fiber scanners (which determines the delay between the successive scans of the same surface area) is determined by a tradeoff between physical design constraints and data buffering/processing considerations. For the tape scanning application described next the optoelectronic switching functions and the MEMS system requires at least 50 MHz clock rates in an on-board controller.

Note that while in the embodiments described, the size of the array of output apertures is 4 ×8, it is also possible to form arrays with other dimensions to obtain the same benefits. Also, the data cell size may be other than as described in the above embodiments. In any of the above embodiments, it is possible to project light, and receive light back from the scanned surface, by direct proximity of the output apertures as in FIG. **2** or by using imaging optics as in FIG. **14**. Note also that the lasers could be switched on and off to modulate for writing rather than as in the preferred system described where optical switches are used for modulation. Note also that the image processing techniques discussed can take the form of different kinds of data encoding, so that data does not have to be written as separate data-cells. Other kinds of surface modulation techniques may be employed in connection with the invention and for each of these, redundant scanning will achieve similar benefits in terms of high reading rates, along with the benefits discussed above with respect to writing as well. In addition, referring to FIG. **19**, it is also possible to arrange the output apertures and their spacing such that redundancy is provided by sweeping the scan spots over overlapping regions **66** by virtue of the range of motion of the oscillations. That is, instead of sweeping apertures spaced on a 64 micron pitch and sweeping ±32 microns, the sweep could be greater than the spot pitch so that the same areas are scanned more than once. Thus, spot **47***a* and **47***c* sweep the same region **66**. Image processing could be applied to such data, buffered appropriately, as well. For a series of identically positioned scans performed serially across the same information area, the image processing step could be as simple as a democratic vote that takes the most agreed-on value among the 4 voting channels. For staggered apertures, the image processing step in the simplest case would be a best-fit to a series of stored expected images associated with each possible value (which could include known erroneous values).

Referring to FIG. **15**, an image processor **852** receives multiple channel signals, each from a respective one of the detectors connected to the four apertures receiving signals from the same or nearly same region of the scanned surface. Image processor **852** receives the signal from read/write head **846**. Only four channels are shown, but in the embodiment of FIG. **14**, for example, 64 sets of 4 channels would be transmitted to be image-processed. The result of image processing is a prediction of the correct "value" of the cell read multiple times which may output as a serial data stream on line **854**. The term "value" is used loosely here in that the data is stored as some sort of symbol which may correspond to multiple independent numeric values depending on the encoding scheme used. For example, the data could be recorded with multiple bits per mark (gray scale).

The above embodiment, where separate output apertures sweep the same regions of the scanned surface, is not the only way to oversample the target surface. Referring to FIGS. **16**, **17**, and **18**, various alternative ways to achieve oversampling are shown. In FIG. **16**, the output apertures **47** are staggered so that each sweeps over a different area The rate of oscillation relative to the rate of translation of the surface, indicated by the zig-zag line **49**, is such that the same data cells **48** are scanned multiple times. In the embodiment described above and shown in FIG. **17**, the multiple fiber (or, more generally, light-waveguide) configuration simply multiplies the data rate by scanning/reading with several light-spots over the same area. In the embodiment of FIG. **16**, each spot scans a different area (and this would require the spots be staggered in the direction of the oscillation so that different spots do not sweep the same regions), but each spot scans the same area more than once. In the latter case, the operation of each spot while scanning and collecting data is essentially independent of the others. The physical configurations of these two alternatives is the same as depicted in the other figures.

In another embodiment such as described by FIG. **16**, a cantilever-mounted fiber-optic bimorph, such as described in the applications incorporated by reference below, (for example, in the application entitled "Scanning Device Using Fiber Optic Bimorph.") are used to generate the light spot. In this case, a single light spot is generated by each bimorph. As shown in FIG. **16**, in this embodiment, oversampling is accomplished by having a spot perform its scan oscillation with a frequency such that its center scans through a data cell several times before crossing the columnar boundary to the next data cell or region of the target surface.

For example, in an optical tape system, the data cells move past the scanning locus of the spot oscillation as the tape moves under the read/write head. The optical properties (e.g., reflectivity) of the data cell area are oversampled because more than one trace of the sampling spot passes through the data cell area, with the locus of each trace displaced from the previous one by some fraction of the data cell width. The best measure of the data cell can be formed by either processing the multiple traces together (e.g., weighted averaging) or by selecting a best or most representative data trace for each data cell.

Note that, the image-processing techniques can be applied in an embodiment of the invention in which the parallel columns of input apertures are offset relative to each other. That is, the data readings are semi-redundant in the sense that non-identical portions of the same data cells are read and image-processed. That is, slightly different portions of a data cell are read by each column of input apertures. The image-processing algorithms may have to take account of the offset (that is, have it predefined) and therefore be different from (or more generalized versions of - zero-offset is just a special case of variable offset) the algorithms applicable to a zero-offset situation. Although it is also possible to register the values of the offset by image processing. Obviously the scans will contain information about the repeating pattern which should make it possible to avoid specifying the offset a priori in the algorithm Also, the offset could be determined through calibration using a medium with known fiducials imprinted on it.

It is also possible to scan in a hybrid fashion such as shown in FIG. **18**. In this case, the surface displacement rate and the oscillation speed are such that the spots sweep the same region multiple times, but, in addition, at least one successive scan spot **47***b* follows the first **47***a* and sweeps over the same region of the target surface. So redundant or partly redundant data are obtained in two ways at the same time.

The optical design discussed above avoids the use of costly, large aperture discrete optics through the use of integrated fabrication techniques that reduce alignment problems and allow low-cost manufacturing in quantity. In addition, the optoelectronic chip controls the light distribution and permits the use of many more scanning channels than lasers with low cost per added channel and very high parallel data transfer rates The optoelectronic chip also allows lithographically-determined, precise spacing of output apertures for separate laser sources. Also, the chip permits efficient use of laser power including ganging of low power sources such as VCSEL sources; and continuous wave laser operation during write mode. Moreover, the design achieves scanning action through optical fiber motion produced by either microelectromechanical systems (MEMS) technology or a known micro scale vibratory motion technique such as a piezoelectric transducer. In addition, the invention includes the use of parallel, redundant laser scanning, a low-cross-talk design, and an "image analysis" approach to signal processing.

The best MEMS scanning method depends on the practical engineering tradeoffs attending the specific application. For example, the mass of the moving element, the amplitude of the oscillation, and the frequency. One optimization goal might be to opt for high frequency and therefore favor minimum mass of the moving element. This would suggest an individual fiber is best. Engineering, however, places other constraints on the application, for example, the actual position of the surface emitting the light relative to the focal point of the optics. See for example, Brei et. al, incorporated herein by reference below.

Regarding the manufacturing of MEMS devices, for example, the light emitting aperture, shape and surface treatment, manufacturing issues are not a problem. For example methods have been developed to apply metals to glass fibers to enable capacitive coupling for driving the fiber motion. Individual methods of fabrication and then manufacture may be addressed depending on the availability of resources, e.g. metallization of a polymer "fiber" or waveguide, or application of piezoelectric material to a polymer. Regarding the optical properties of the fiber output, particularly with regard to numerical aperture (NA), some trial-and-error experimentation may be required to achieve an optimum configuration. If constructed layer by layer, the fiber tip construction is totally conventional. The optical quality and properties of the exit aperture as mentioned above are critical, and therefore exact recipes may require some trial-and-error experimentation. For example, a graded index clad may be necessary, or new process methods due to required design considerations. In an embodiment employing an optical fiber, the exit aperture may be defined by cleaving. In an embodiment employing a multilayer (e.g., polymer) structure, processing at the end of the fiber is important. Conventional methods at present include ion beam "polishing" of the tip or exit aperture.

The cantilever "style" vibrating fiber structure requires a waveguiding "core," as with any optical fiber. Also a cladding is required to confine the optical energy. The fiber, or, more generally, light guide, can have a round, square, or rectangular cross section depending on design considerations for the purpose of light "piping." A square or rectangular cross section is easiest to deal with from a manufacturing and fabrication point of view, as well as from the point of view of driving oscillations. Planar "capacitive" plates are easily implemented in a layered, bimorph configuration that optimizes energy transfer for driving oscillation while minimizing the required power. However, this puts severe constraints on optical design due to the need for polarization conservation elsewhere in the system, as well as mode conservation and balance. A layer by layer fabrication process is the best approach; in that case, the "fixed end" of the fiber is on top of the underlying structural and functional layers. The quality checks necessary are both optical and mechanical. Longevity will be related to mechanical work with frequency, total number of oscillations, material, composite structures, adhesion, etc. also being contributing factors.

Note, regarding a fundamental mechanism of failure in stressed single crystal materials, such as Si, defects in single crystals diffuse thermal and aggregate in the material. This is well known (see for example Silicon Processing for the VLSI Era, S. Wolf and R. N. Tauber, Lattice Press and other books addressing the processes in Si fabrication, particularly crystal growth). Note that various embodiments could make use of the same lasers for both reading and writing, as discussed above. In such a case, a head could have separate exit apertures for reading and for writing, or have one set of apertures serving both functions.

The respective entireties of the following United States patent applications, filed concurrently herewith, are hereby incorporated by reference in the present application:

Scanning Device Using Fiber Optic Bimorph (Adam Thomas Drobot, Robert Courtney White)

Multiple Parallel Source Scanning Device (Adam Thomas Drobot, Robert Courtney White, Newell Convers Wyeth)

Multiple Channel Data Writing Device (Adam Thomas Drobot, Robert Courtney White, Newell Convers Wyeth, Albert Myron Green)

Multiple Channel Scanning Device Using Optoelectronic Switching (Adam Thomas Drobot, Robert Courtney White, Newell Convers Wyeth)

Method and Apparatus for Controlling the Focus of a Read/Write Head for an Optical Scanner (Edward Alan Phillips, Newell Convers Wyeth)

Multiple Channel Scanning Device Using Oversampling and Image Processing to Increase Throughput (Adam Thomas Drobot, Robert Courtney White, Newell Convers Wyeth, Albert Myron Green, Edward Alan Phillips)

The respective entireties of the following references are hereby incorporated by reference in the present application:

M. Ataka, A Omodaka, N. Takeshima, and H. Fujita, "Fabrication and Operation of Polyimide Bimorph Actuators for a Ciliary Motion System", JMEMS, Volume 2, No. 4, page 146.

D. E. Brei and J. Blechschmidt, "Design and Static Modeling of a Semicircular Polymeric Piezoelectric Microactuator", JMEMS, Volume 1, No. 3, page 106.

J. W. Judy, R. S. Muller, and H. H. Zappe, "Magnetic Microactuation of Polysilicon Flexure Structures", JMEMS, Volume 4, No. 4, page 162.

T. S. Low and W. Guo, "Modeling of a Three-Layer Piezoelectric Bimorph Beam with Hysteresis", JMEMS.

Q. Meng, M. Mehregany, and R. L. Mullen, "Theoretical Modeling of Microfabricated Beams with Elastically Restrained Supports", JMEMS, Volume 2, No. 3, page 128 et. seq.

K. Minami, S. Kawamura, and M. Esashi, "Fabrication of Distributed Electrostatic Micro Actuator (DEMA)", JMEMS, Volume 2, No. 3, page 121 et. seq.

J. G. Smits, and A. Ballato, "Dynamic Admittance Matrix of Piezoelectric Cantilever Bimorphs", JMEMS, Volume 3, No. 3, page 105 et. seq.

Yuji Uenishi, Hedeno Tanaka, and Hiroo Ukita, NTT Interdisciplinary Research Laboratories (Tokyo, Japan), "AlGaAs/GaAs micromachining for monolithic integration of optical and mechanical components", Optical power driven cantilever resonator. Proceedings SPIE et. seq.

What is claimed is:

1. A scanning device for scanning a target surface having data written thereon, said data being arranged in adjacent data cells on said target surface, each of said cells having one of a set of possible configurations representing data, the device comprising:

a read/write head with at least one reading laser source connected to emit light from an array of output apertures and receive light through an array of input apertures;

an image processor;

said read/write head and said target surface being supported to move relative to each other to scan said target surface;

said array of output apertures being arranged such that multiple ones of said output apertures scan substantially a same cell of said surface;

said read/write head including detectors to produce detection signals, each corresponding to a respective one of said array of input apertures and connected to said image processor; and

said image processor receives said detection signals and is configured to process said detection signals to generate an estimate of a configuration of said same cell and to generate a signal stream representing said estimate.

2. A device as in claim **1**, wherein said output apertures are coaxial with said input apertures.

3. A device as in claim **1**, wherein said read/write head includes a optoelectronic chip having light guides formed therein, each of said light guides being connected to a one of said output apertures.

4. A device as in claim **1**, wherein said optoelectronic chip includes at least one optical switch to modulate an output of one of said reading laser source and a writing laser source.

5. A device as in claim **4**, wherein said at least one optical switch modulates said laser source by selectively directing said output between a write output aperture and another direction leading ultimately to dissipation of energy of said writing laser source, whereby said writing laser source is enabled to operate in a continuous manner while writing.

6. A device as in claim **1**, wherein said read/write head further comprises multiple reading laser sources, each connected to an array of light guides interconnected to split a laser output of said each of said multiple reading laser sources into multiple paths, each connected to a one of said output apertures.

7. A device as in claim **6**, wherein said array of light guides are interconnected with respective optical switches controlled by a controller programmed to cause said laser output to be shared among multiple ones of said output apertures by shunting said laser output to a first fraction of said multiple ones of said output apertures at a first time and shunting said laser output to a second fraction of said multiple ones of said output apertures at a second time.

8. A device as in claim **7**, wherein said first fraction of said multiple ones of said output apertures is equal to a single one of said output apertures.

9. A device as in claim **1**, wherein:

said read/write head further comprises multiple reading laser sources, each connected to an array of light guides interconnected to split a laser output of said each of said multiple reading laser sources into multiple paths defined by said light guides, each path being connected to a one of said output apertures; and

said array of light guides are interconnected with respective optical switches controlled by a controller programmed to cause said laser output to be shared among multiple ones of said output apertures by shunting a percentage of said laser output to a first fraction of said multiple ones at a first time and shunting a second fraction of said laser output to second fraction of said multiple ones at a second time.

10. A scanning device for scanning a target surface having data written thereon, said data being arranged in columns of adjacent data cells on said target surface, each of said columns of data cells having one of a set of possible configurations representing data, the device comprising:

a read/write head with an array of input apertures arranged in successive columns such that each of said columns receives reflected light from a same one of said columns of data cells;

at least one detector connected to detect light received by said array of input apertures;

said array of input apertures sampling more than once at least a portion of said data cells; and

said detector generating a signal indicating an estimate of a one of said possible configurations by combining information derived from light received by all of said input apertures.

11. A device as in claim **10**, wherein said detector combines said information by detecting light from each of said columns and synthesizing an improved estimate of said one of said possible configurations from a combination of signals generated thereby.

12. A scanning device for scanning a target surface having data written thereon, said data being arranged in columns of adjacent data cells on said target surface, each of said columns of data cells having one of a set of possible configurations representing data, the device comprising:

a scanning head with an array of input apertures arranged in successive columns such that each of said columns receives reflected light from a same one of said columns of data cells;

at least one detector connected to detect light received by said array of input apertures;

said array of input apertures sampling more than once at least a portion of said data cells; and

said detector generating a signal indicating an estimate of one of said possible configurations by combining information derived from light received by all of said input apertures.

13. A device as in claim **12**, wherein said scanning head includes at least one laser connected to conduct light to said array of input apertures, whereby said array of input apertures functions as an array of output apertures from which light is emitted.

14. A device as in claim **13**, further comprising an imaging optical element positioned between said scanning head and said target surface to image light emitted from said output apertures onto said target surface, said light from said same one of said columns of data cells being light emitted from said array of output apertures, returned from said target surface, and imaged by said imaging optical element back onto said input apertures.

15. A device as in claim **14**, wherein at least one detector is an array of detectors, each being respective of one of said array of input apertures and said scanning head includes a light guide leading from each of said input apertures of said array of input apertures to said respective detector.

16. A method of reading data from a recorded surface having successive columns of data cells, said successive columns comprising at least one row of said data cells, comprising the steps of:

moving said recorded surface such that light from a first output aperture is focused onto a first of said successive columns;

receiving light returned from said recorded surface responsively to said first step of moving said recorded surface;

detecting light returned to said first output aperture and storing a first result thereof;

moving said recorded surface such that light from a second output aperture is focused onto said first of said successive columns;

receiving light returned from said recorded surface responsively to said second step of moving;

detecting light returned to said second output aperture and storing a second result thereof; and

calculating data represented by said first of said respective columns responsively to a computed combination of said fist and second results.

**17**. A method as in claim **16**, wherein:

said first step of receiving includes receiving light at a first input aperture corresponding to said first output aperture; and

said second step of receiving includes receiving light at a second input aperture corresponding to said second output aperture.

**18**. A scanning device for scanning a target surface with data written thereon, said data being arranged in data cells each having one of a set of possible configurations representing data, comprising:

a scanning head with an array of input apertures arranged such that each of said input apertures receives light reflected from said target surface from a same data cell;

at least one detector configured to detect light received by said array of input apertures; said detector generating a signal indicating an estimate of one of said possible configurations by combining information derived from light received by all of said input apertures;

a frame connected to said scanning head; and

an oscillating motor connected between said frame and said scanning head to oscillate said scanning head relative to said target surface.

**19**. A device as in claim **18**, wherein said medium is moved continuously in said first direction at a constant speed.

**20**. A device as in claim **18**, wherein a direction of an oscillation of said read/write head has a component substantially perpendicular to said first direction.

**21**. A device as in claim **20**, wherein said scanning head includes at least one laser connected to conduct light to said array of input apertures, whereby said array of input apertures functions as an array of output apertures from which light is emitted.

**22**. A device as in claim **21**, further comprising an imaging optical element positioned between said scanning head and said target surface to image light emitted from said output apertures onto said target surface, said light from said same one of said columns of data cells being light emitted from said array of output apertures, returned from said target surface, and imaged by said imaging optical element back onto said input apertures.

**23**. A device as in claim **22**, wherein at least one detector is an array of detectors, each being respective of one of said array of input apertures and said scanning head includes a light guide leading from each of said input apertures of said array of input apertures to said respective detector.

**24**. A scanning device for scanning a target surface having data cells written thereon, the device comprising:

a light source;

a first output aperture coupled to said light source and configured to emit light onto a data cell and receive light reflected from said data cell;

a second output aperture coupled to said light source and configured to emit light onto said data cell and receive light reflected from said data cell;

at least one detector coupled to said first and second output apertures that detects said reflected light and generates a first detection signal corresponding to light received at said first output aperture and a second detection signal that corresponds to light received at said second output aperture;

an image processor that receives said first and second detection signals and is configured to process said first and second detection signals to generate an estimate value of said data cell.

**25**. A scanning device for scanning a target surface with data cells comprising:

a scanning head with an array of input apertures that receive light reflected from said target surface from a same one of said data cells;

at least one detector configured to detect light received by said array of input apertures; said detector generating a signal indicating an estimate of one of a set of possible configurations of said same one of said data cells by combining information derived from light received by all of said input apertures; and

an oscillating motor connected to said scanning head to oscillate said scanning head relative to said target surface.

**26**. A scanning device for scanning a target surface with data cells written thereon, comprising:

a scanning head with an array of input apertures arranged in successive columns such that each of said input apertures receives light reflected from said target surface from a same one of said data cells;

at least one detector that detects light received by said array of input apertures; said detector generating a signal representing an estimate of one of a set of possible data value configurations by combining information derived from light received by all of said input apertures; and

an oscillating motor connected to said scanning head to oscillate said scanning head.

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US006545422B1

(12) **United States Patent**
**George et al.**

(10) **Patent No.:** **US 6,545,422 B1**
(45) **Date of Patent:** **Apr. 8, 2003**

(54) **SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/697,346**

(22) Filed: **Oct. 27, 2000**

(51) **Int. Cl.**[7] .................................................. **G09G 3/10**

(52) **U.S. Cl.** ...................... **315/169.3**; 313/485; 445/24; 445/33

(58) **Field of Search** .............................. 315/169.3, 312, 315/324; 313/484, 485, 491, 502, 506; 445/24, 26, 27, 29, 33

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,559,190 A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | 7/1976 | Greeson, Jr. | 315/169.3 |
| 3,990,068 A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 A | 12/1981 | Torobin | 65/21.4 |
| 4,393,326 A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 A | 11/1985 | Dick | 340/775 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdp-display.com/eng/news/e_read.as?nSeqno=22.

(List continued on next page.)

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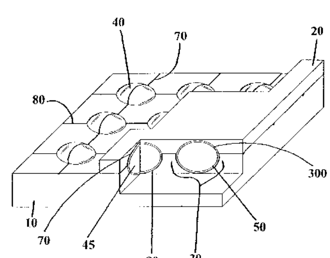
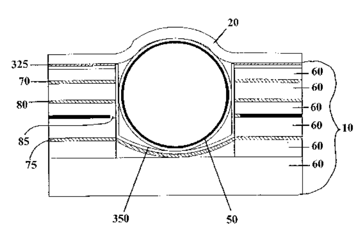
*Assistant Examiner*—Thuy Vinh Tran
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components at least partially disposed in a socket and sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes.

**23 Claims, 18 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 4,563,617 | A | * | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | | 3/1987 | Shelton | 315/111.71 |
| 4,697,123 | A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | | 3/1988 | Dick | |
| 4,833,463 | A | | 5/1989 | Dick et al. | |
| 4,843,281 | A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Deschamps et al. | |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | * | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |

OTHER PUBLICATIONS

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp-?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSe-qNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay-.com/eng/news/e_read.asp?nSeqNo=16&type=& word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.p-dpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type= &word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp-?nSeqNo=13&type=&word.

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco PlasmaWall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco PlasmaWall Pl–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco PlasmaWall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Rauf, S., Kushner, M.J., *Operation of a Coplanar–Electrode Plasma Display Panel Cell,* IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Shin, Y.K., Lee, J.K., Shon, C.H., *Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry,* IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 14–15.

Kurihara, M. Makabe, T., *Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency,* IEEE Transactions on Plasma Science, vol. 27, No. 5, Oct. 1999, pp. 1372–1378.

Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly,* Alien Technology Corp., Oct. 1999, pp. 1–7.

International Search Report dated Sep. 23, 2002.

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

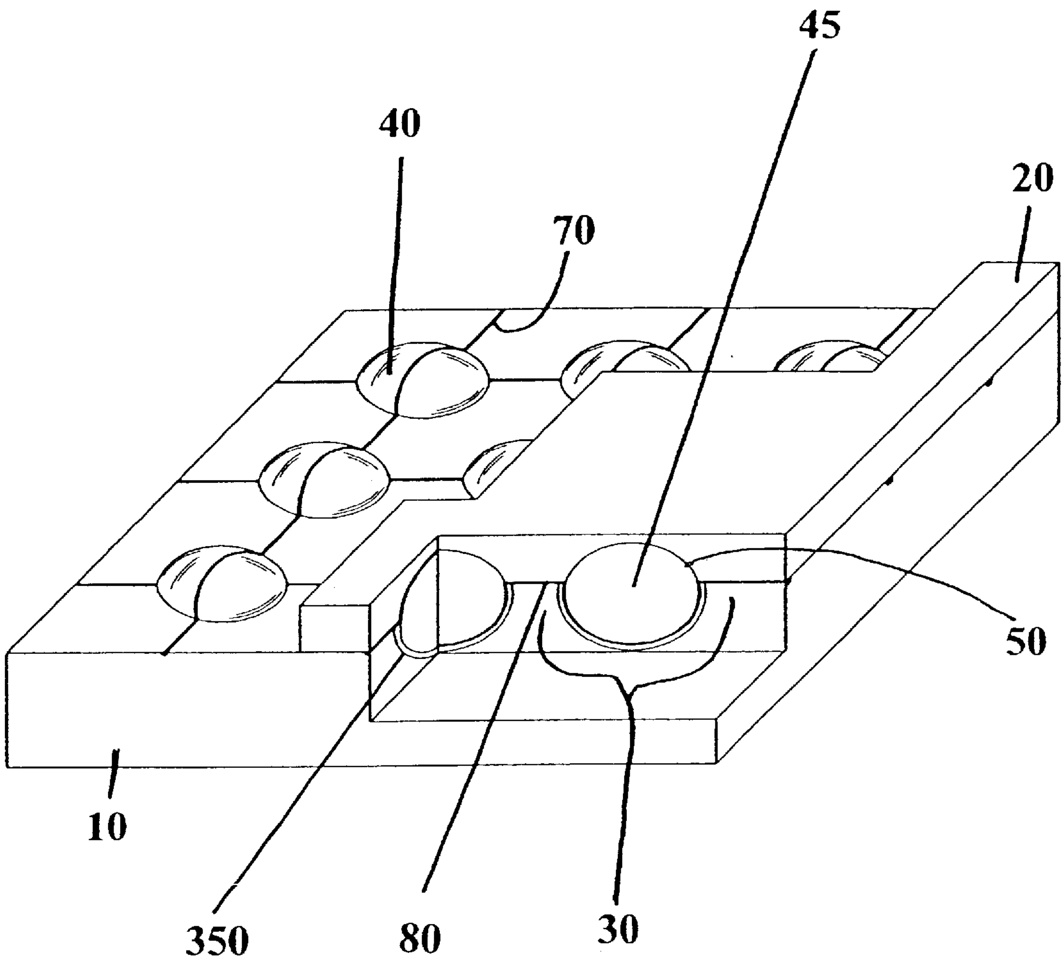
Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

* cited by examiner

Fig. 1



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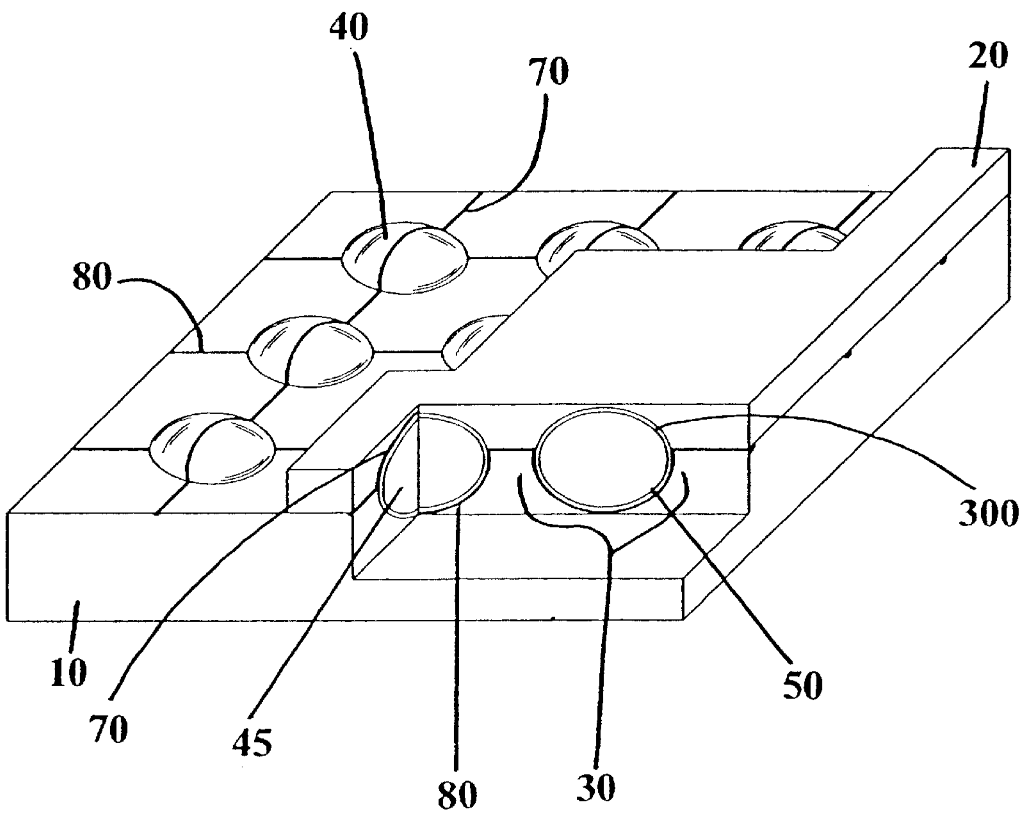


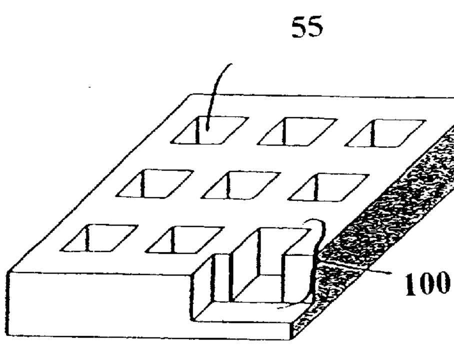
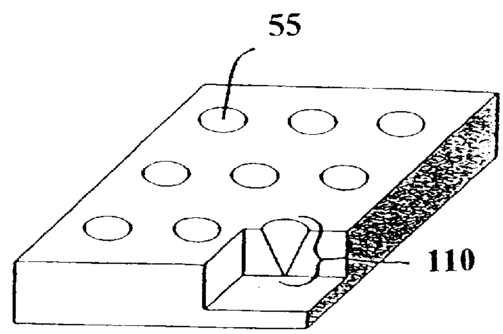



Fig. 3A

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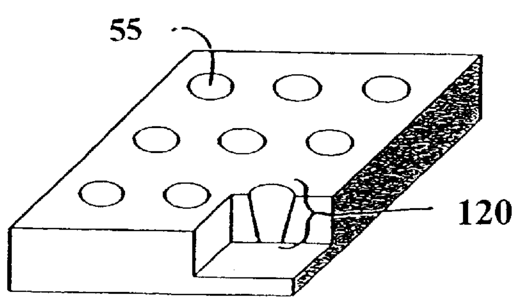


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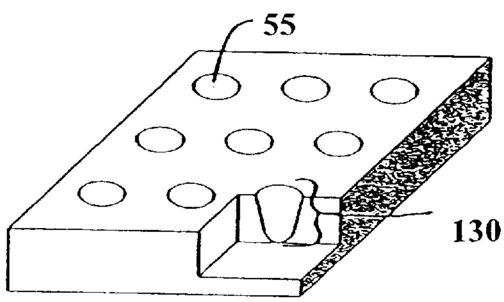


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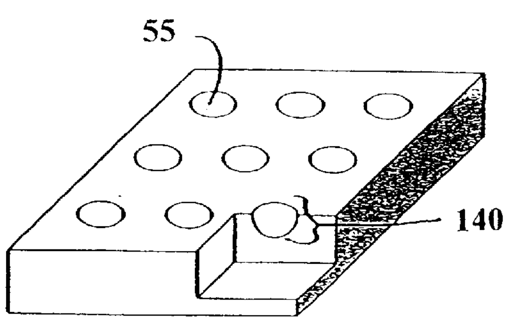


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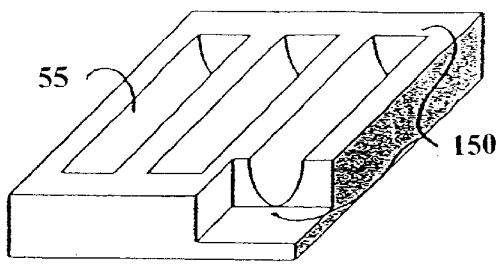


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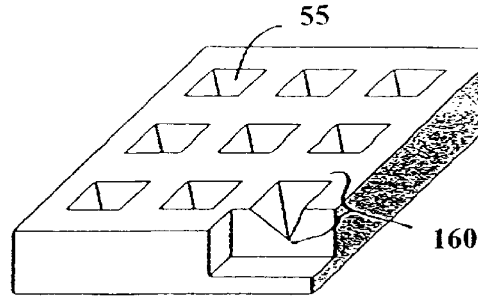


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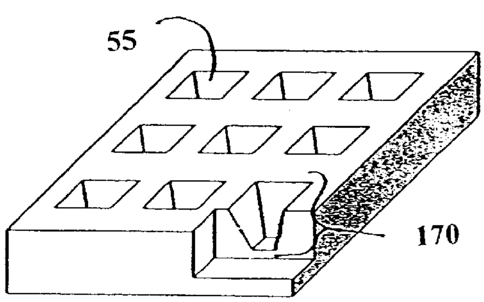


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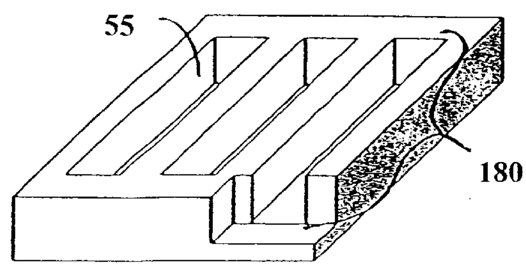


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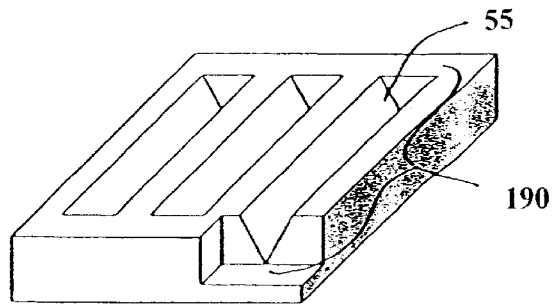
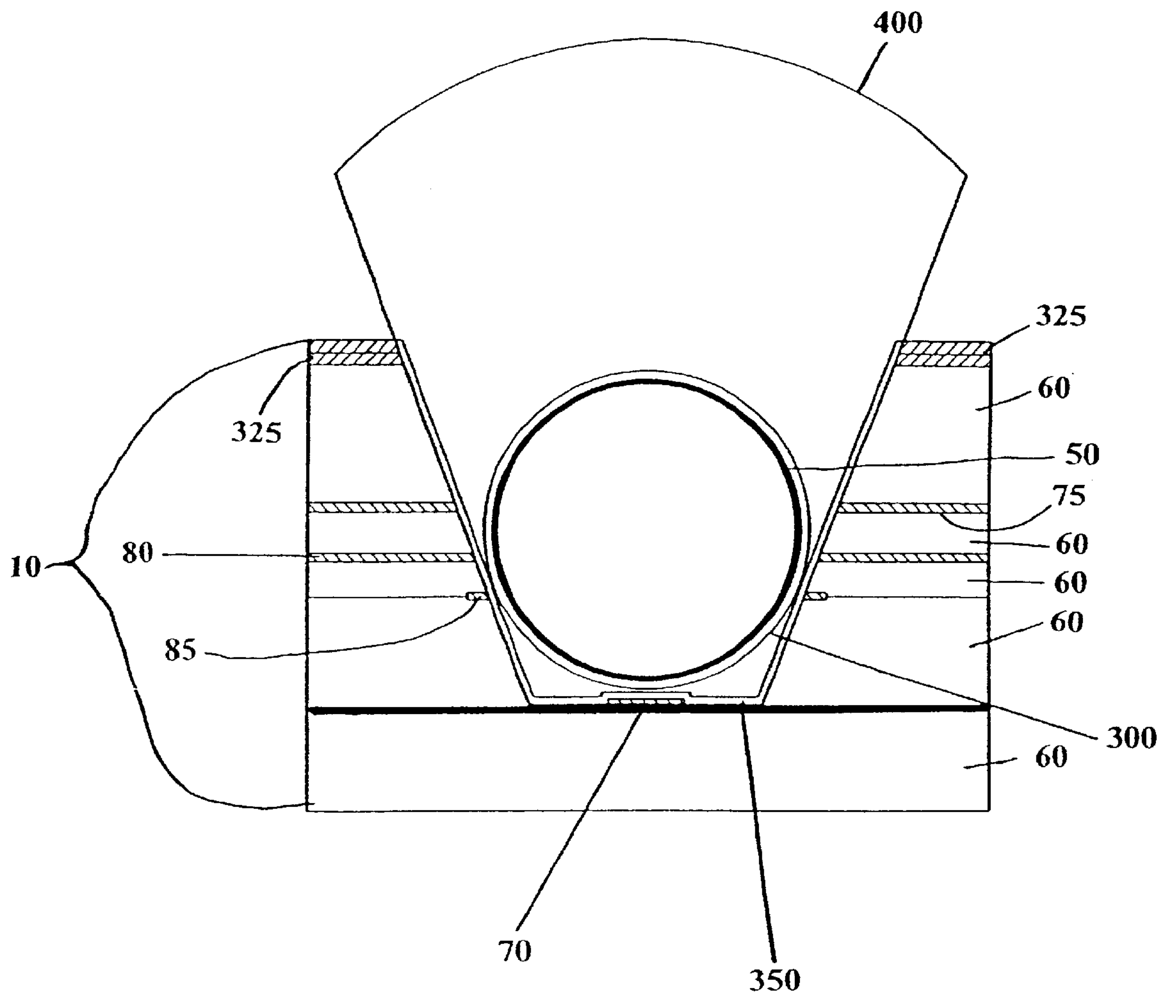



Fig. 3J

Fig. 4



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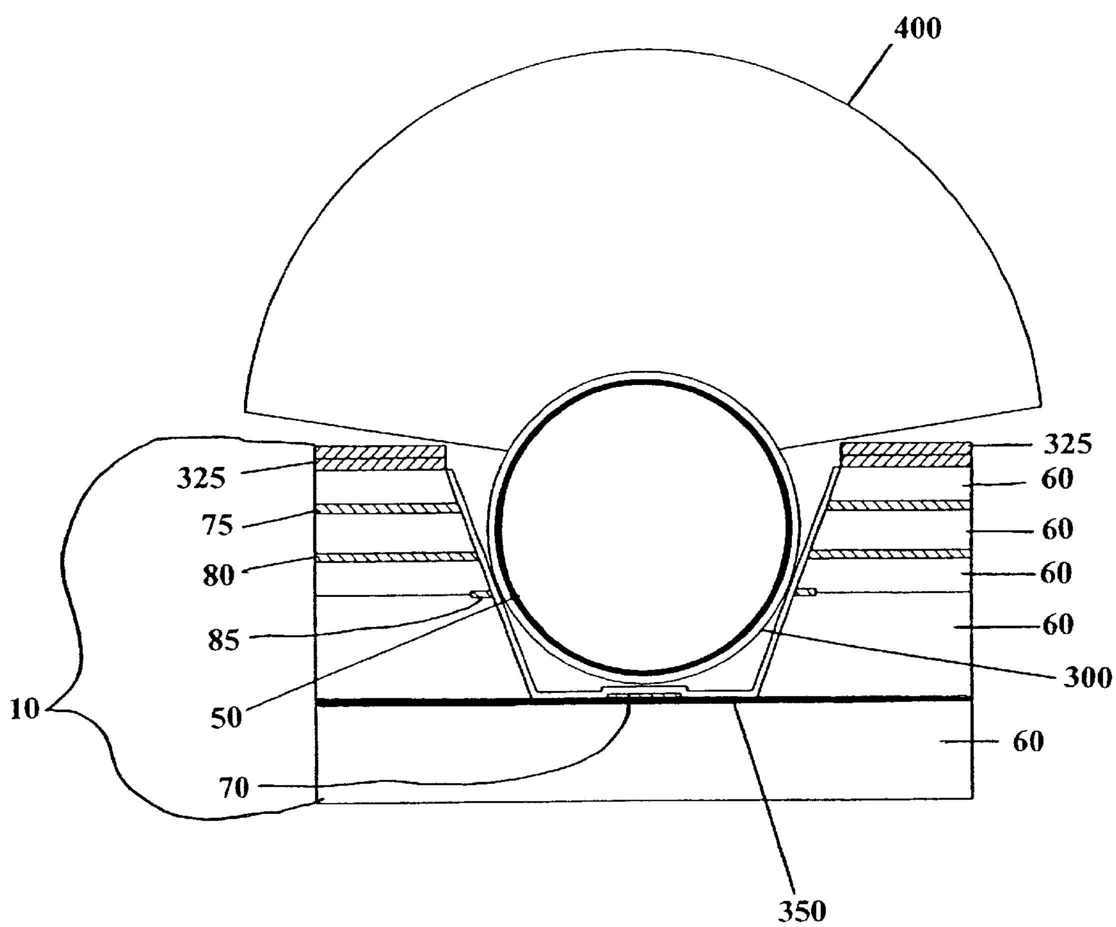

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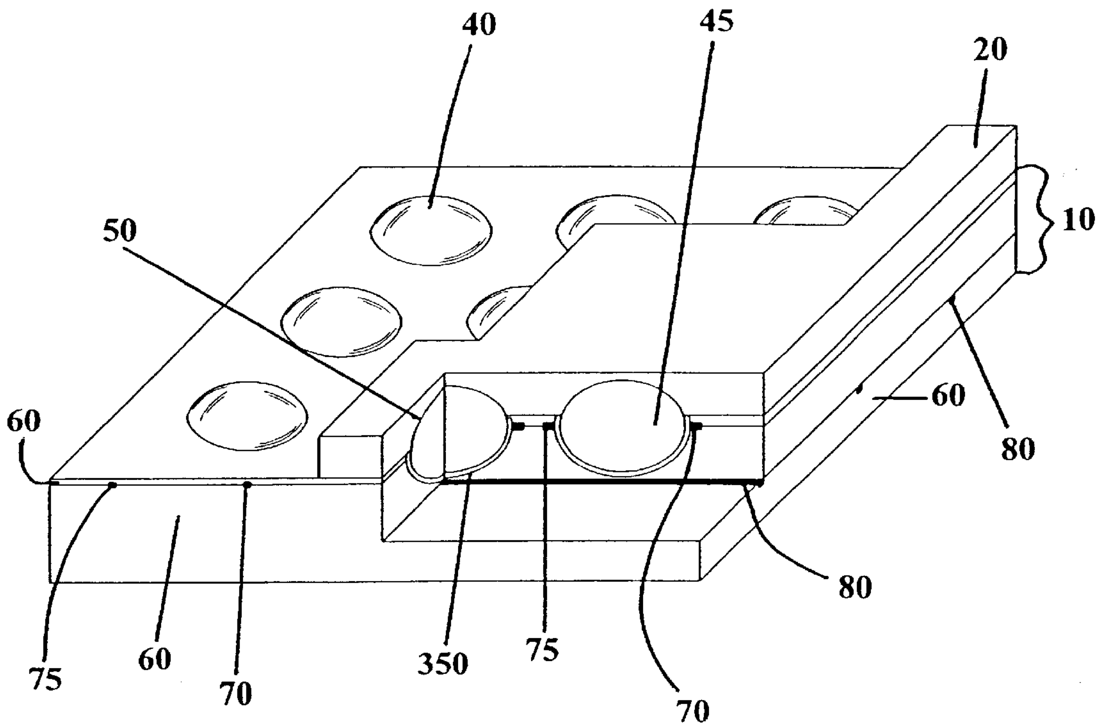

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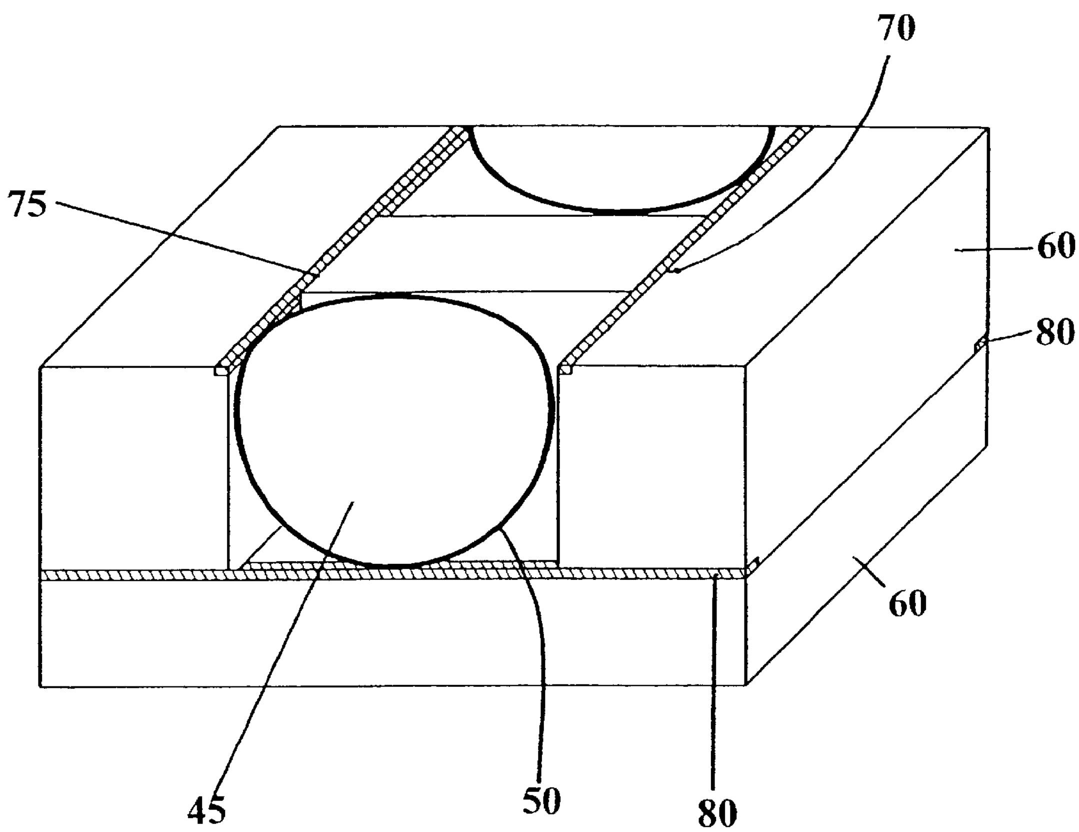

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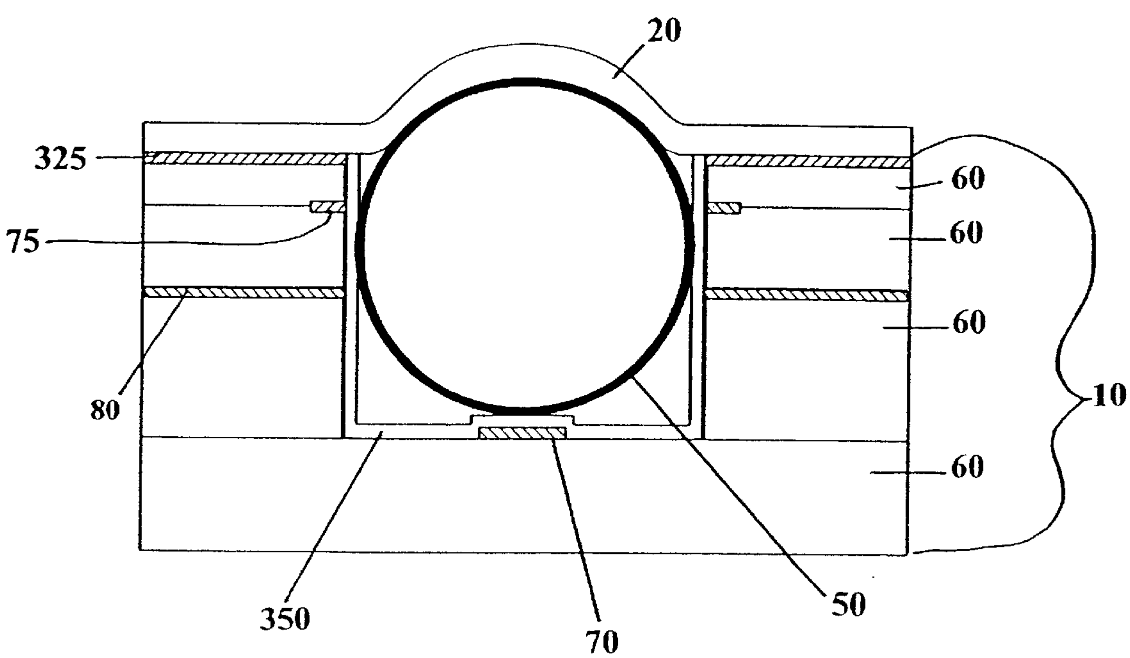

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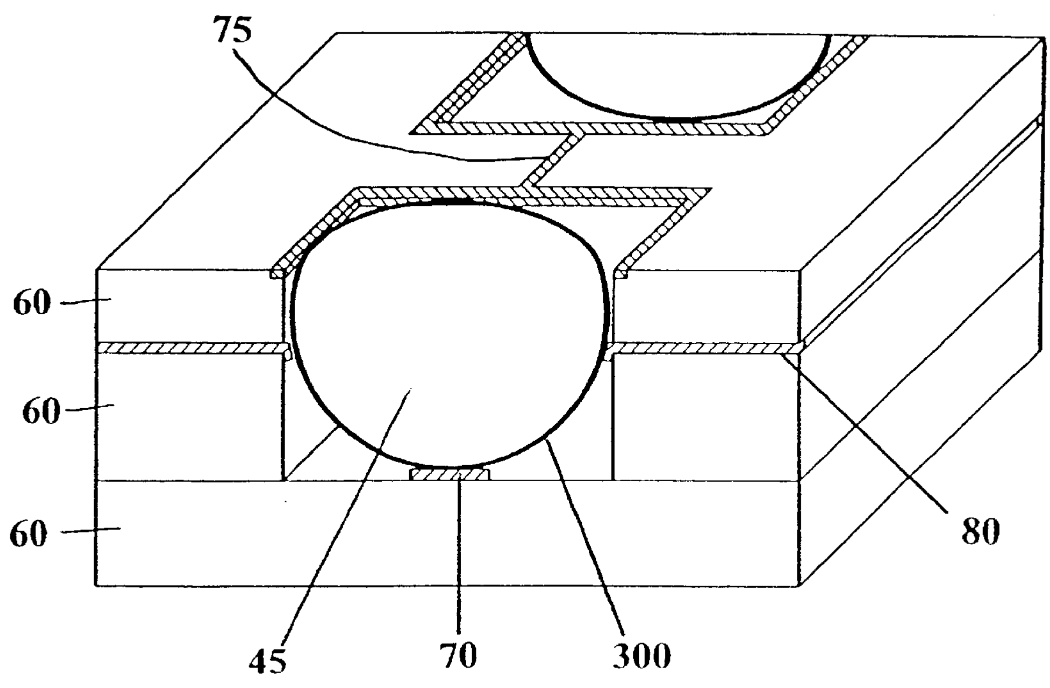

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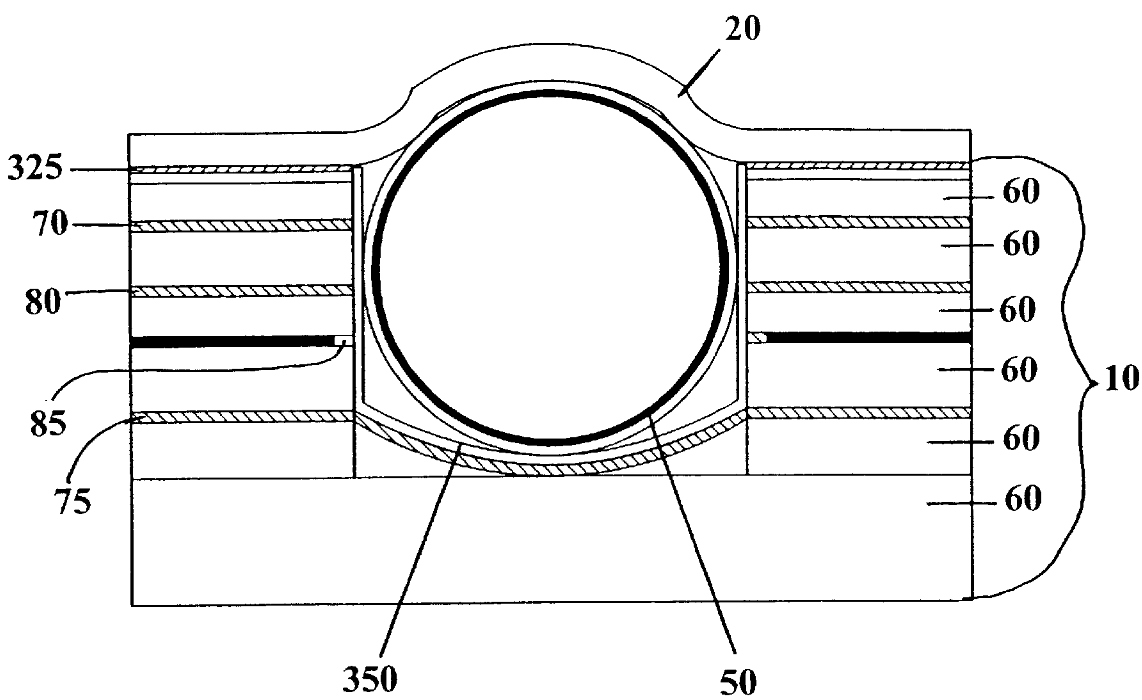

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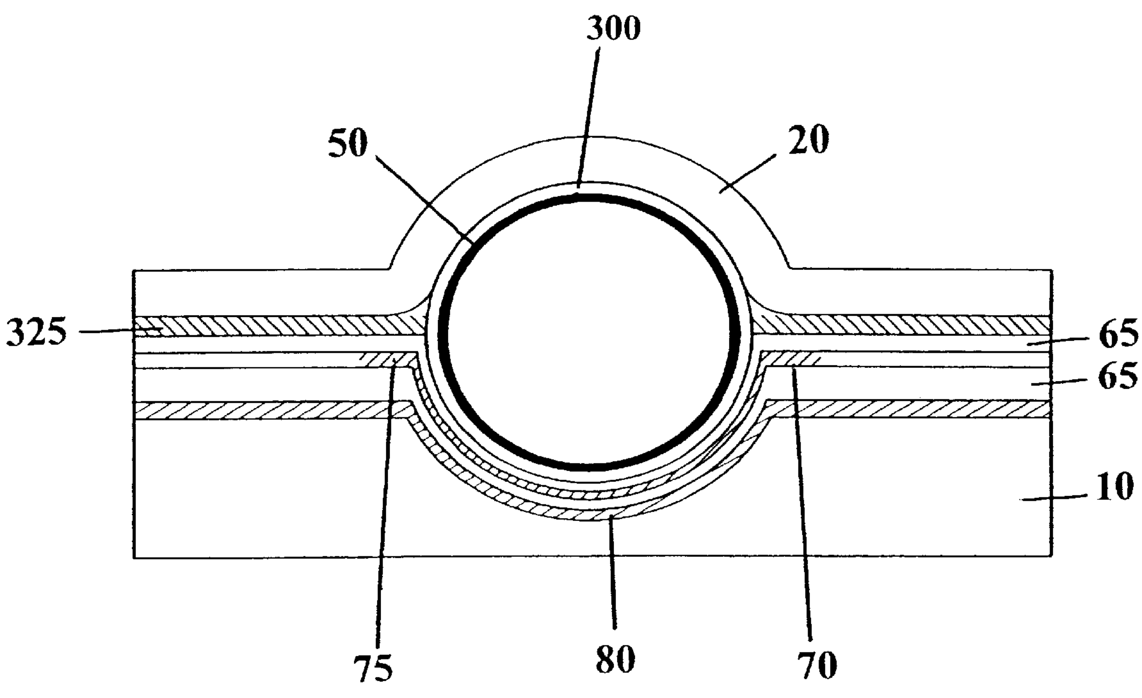

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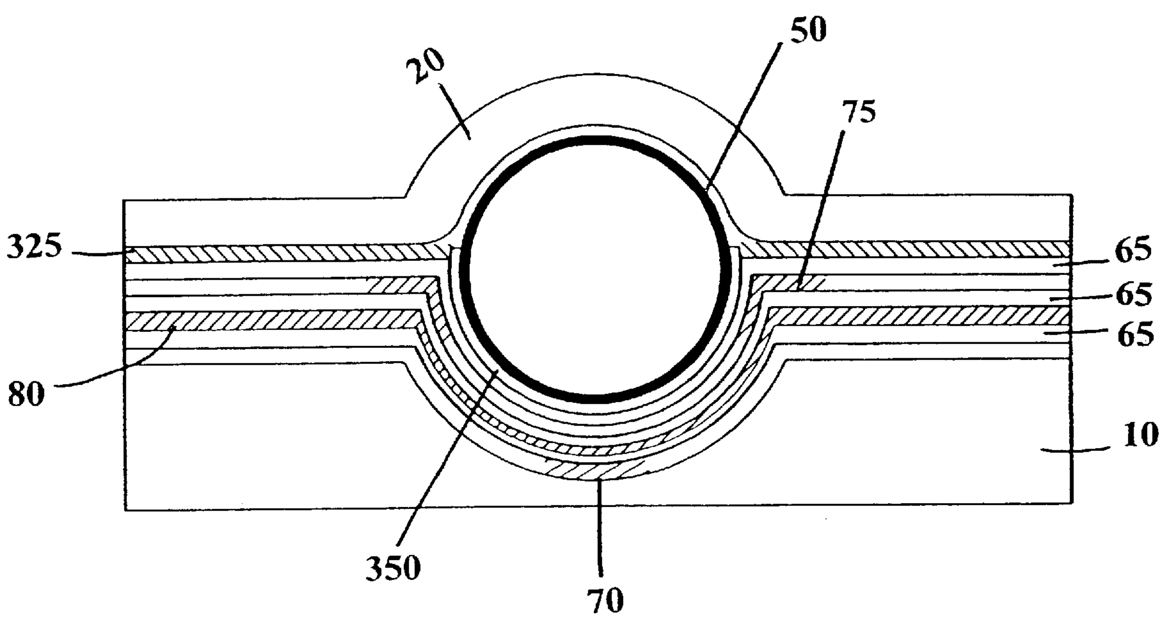

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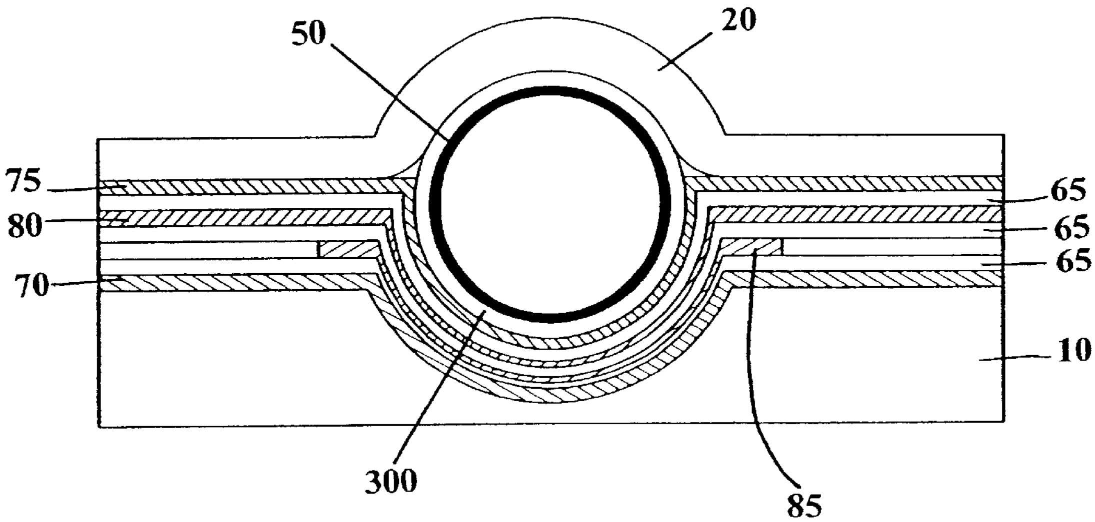

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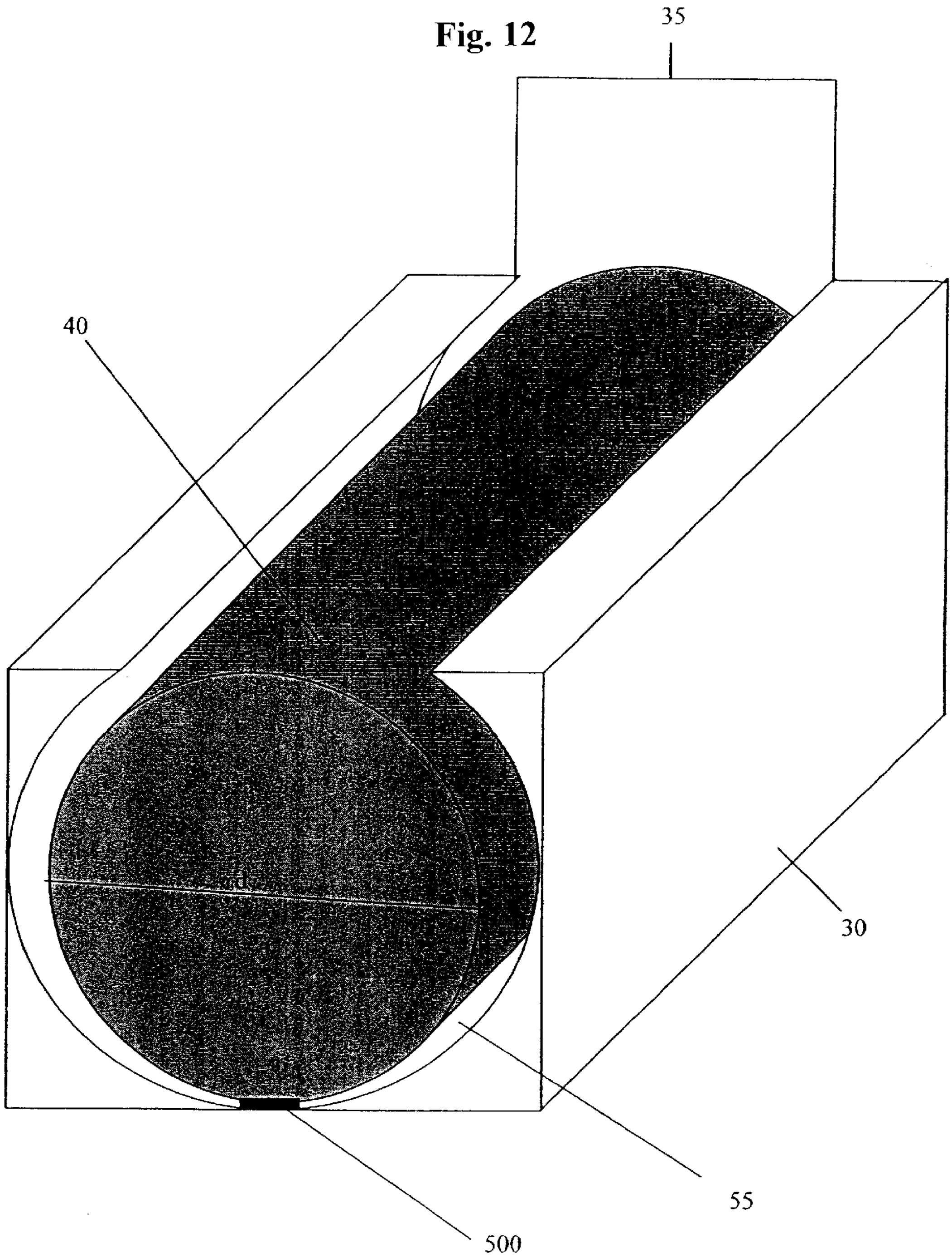

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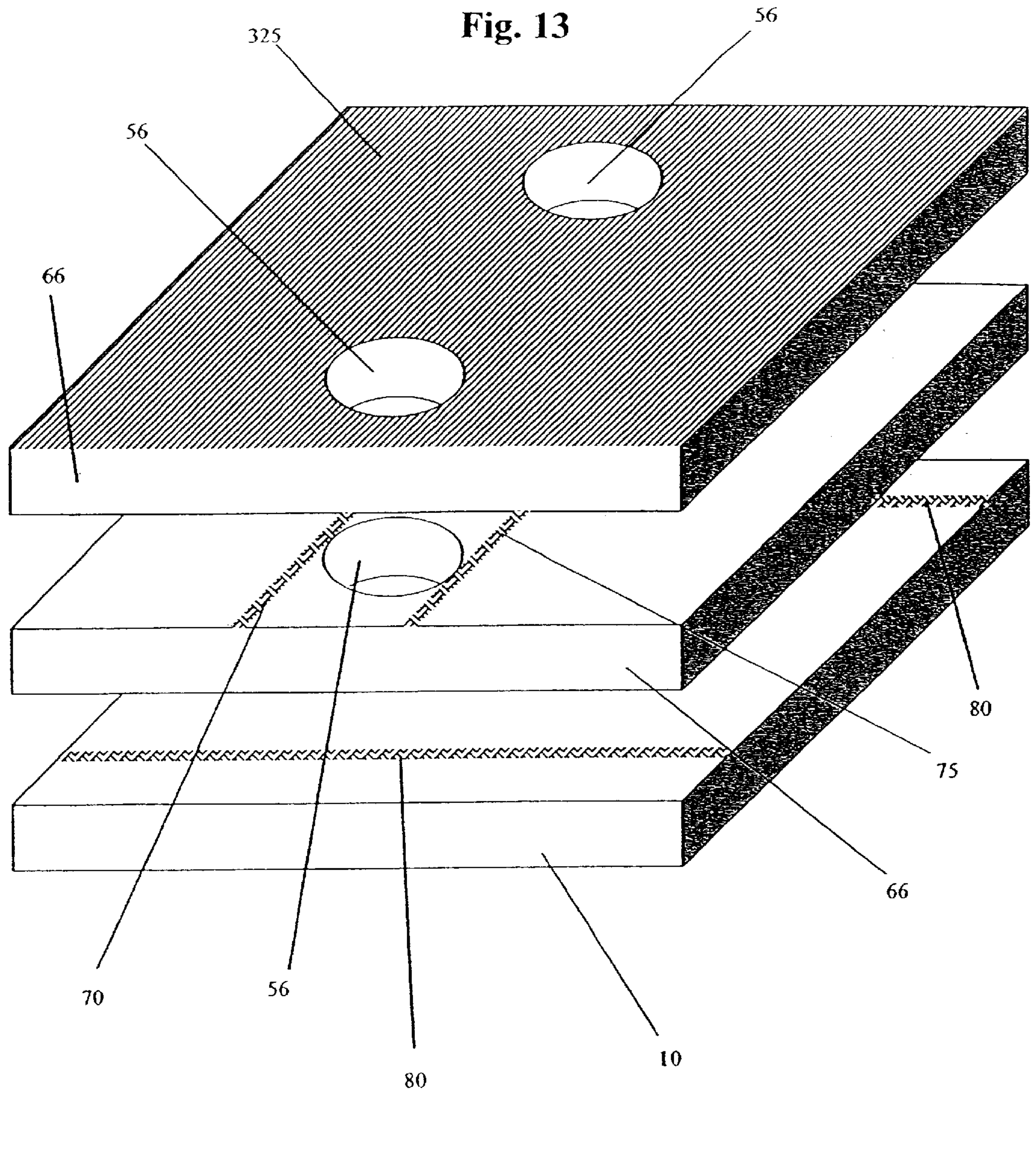

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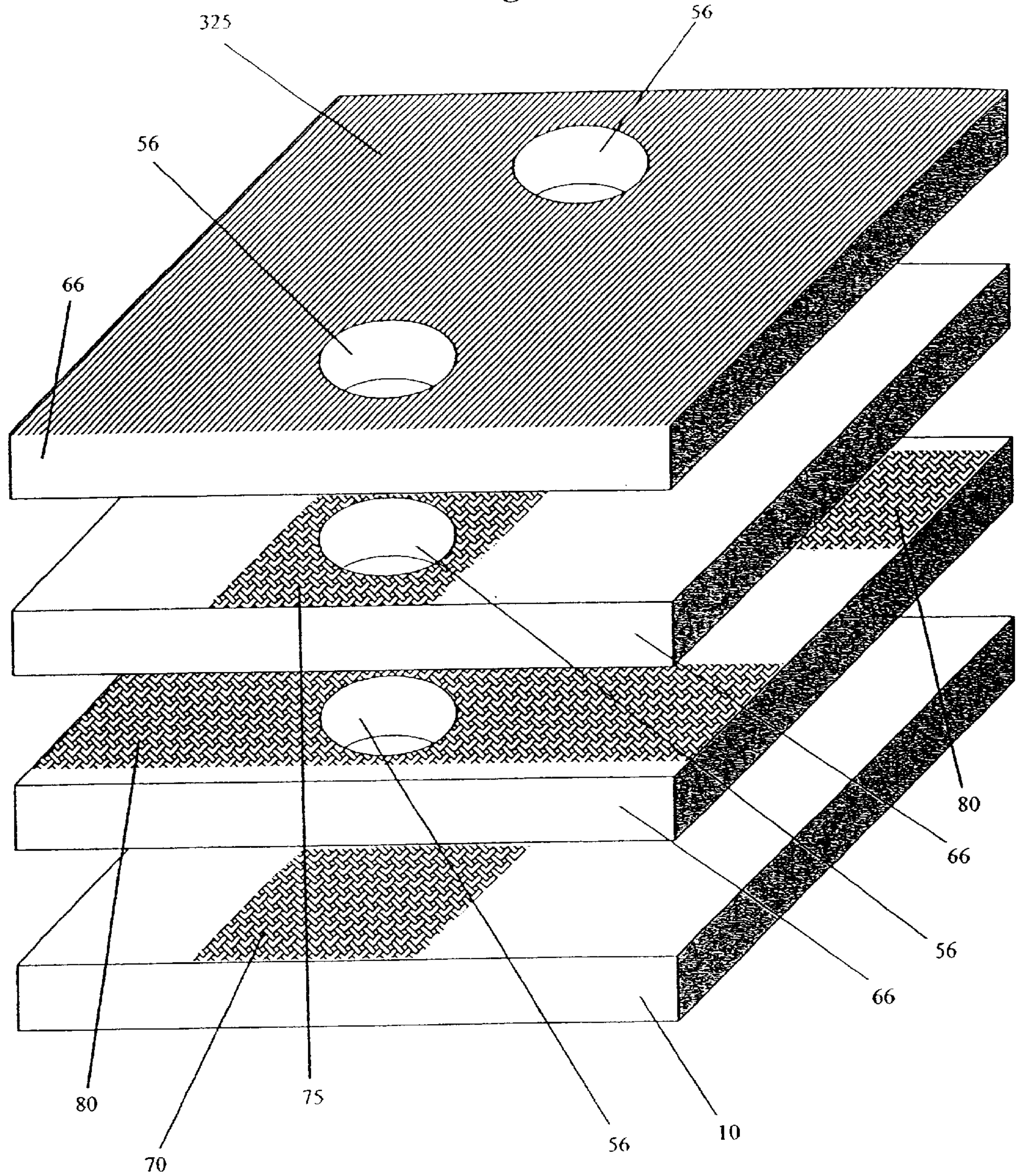
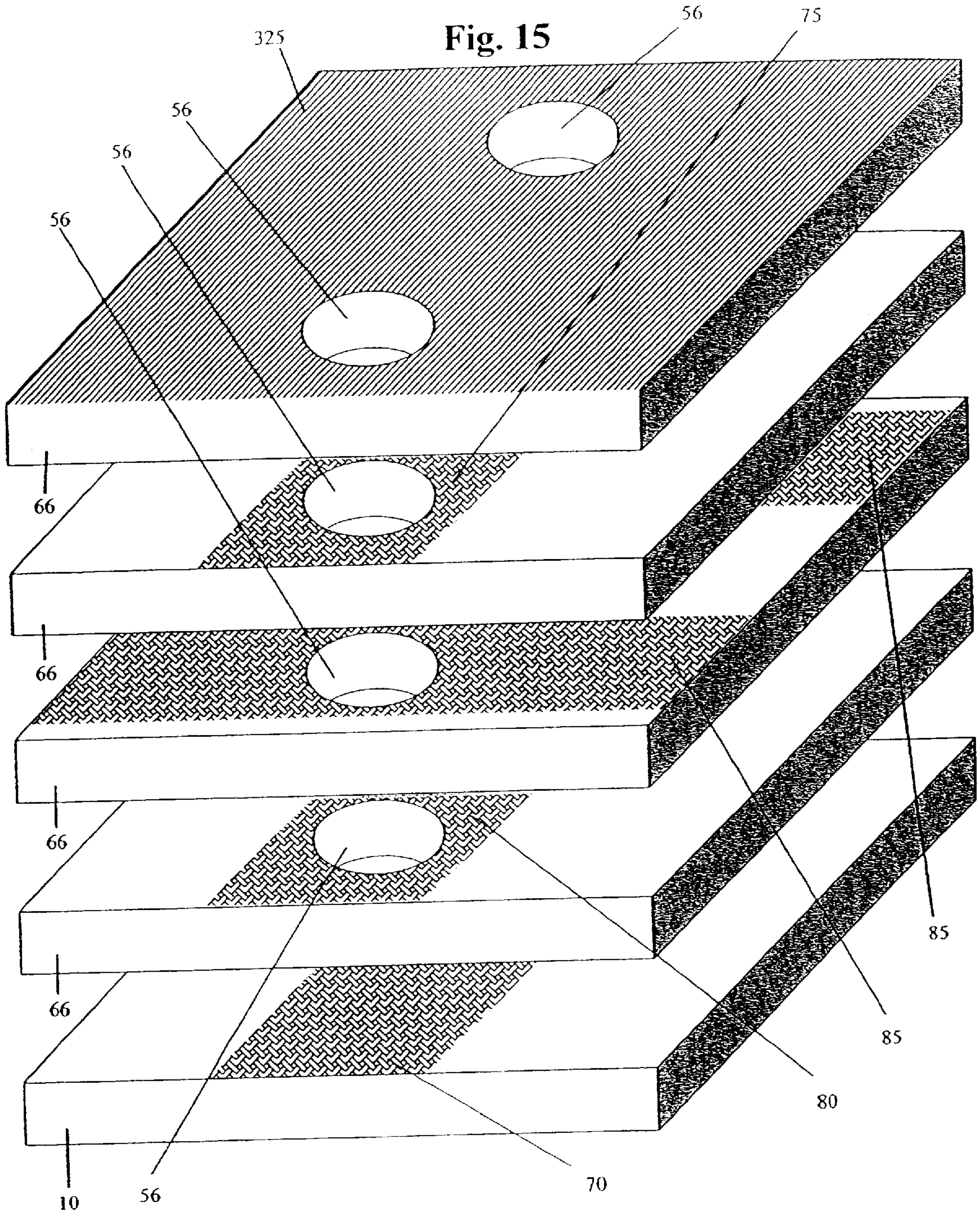


Fig. 15



# SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a socket, for use in a light-emitting panel, in which a micro-component is at least partially disposed.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits, light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain



operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates.

This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure .

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel.

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. Various embodiments of the present invention are drawn to different socket structures.

In one embodiment of the present invention, a cavity is patterned on a substrate such that it is formed in the substrate. In another embodiment, a plurality of material layers form a substrate and a portion of the material layers is selectively removed to form a cavity. In another embodiment, a cavity is patterned on a substrate so that the cavity is formed in the substrate and a plurality of material layers are disposed on the substrate such that the material layers conform to the shape of the cavity. In another embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity. Other embodiments are directed to methods for forming the sockets described above.

Each socket includes at least two electrodes that are arranged so voltage applied to the two electrodes causes one or more micro-components to emit radiation. In an embodiment of the present invention, the at least two electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to the first substrate and at least one electrode is adhered to the second substrate. In another embodiment, the at least two electrodes are arranged so that the radiation emitted from the micro-component when energized is emitted throughout the field of view of the light-emitting panel such that the radiation does not cross the two electrodes. In another embodiment, at least one electrode is disposed within the material layers.

A cavity can be any shape or size. In an embodiment, the shape of the cavity is selected from a group consisting of a cube, a cone, a conical frustum, a paraboloid, spherical, cylindrical, a pyramid, a pyramidal frustum, a parallelepiped, and a prism. In another embodiment, a socket and a micro-component are described with a male-female connector type configuration. In this embodiment, the micro-component and the cavity have complimentary shapes, wherein the opening of the cavity is smaller than the diameter of the micro-component so that when the micro-component is disposed in the cavity the micro-component is held in place by the cavity.

The size and shape of the socket influences the performance and characteristics of the display and may be chosen, for example, to optimize the panel's efficiency of operation. In addition, the size and shape of the socket may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. Further, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. In an embodiment, the inside of a socket is coated with a reflective material, which provides an increase in luminosity.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a socket capable of being used in the light-emitting panel and supporting at least one micro-component.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components **40** may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel, each cylindrical-shaped structure may hold micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

A cavity **55** formed within and/or on a substrate provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. In addition, in another embodiment of the present invention as shown in FIG. **12**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

The size and shape of the socket **30** influences the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and the electrodes disposed on or within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component that is deposited within a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

There are a variety of coatings **350** that may be at least partially added to a socket that also influence the performance and characteristics of the light-emitting panel. Types of coatings **350** include, but are not limited to, adhesives, bonding agents, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters. One skilled in the art will recognize that other coatings may also be used. The coatings **350** may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used. Alternatively, or in conjunction with the variety of socket coatings **350**, a micro-component **40** may also be coated with a variety of coatings **300**. These micro-component coatings **300** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may readily hold a micro-component or plurality of micro-components in a socket or may require additional activation energy to secure the micro-components or plurality of micro-components in a socket. In an embodiment of the present invention, where the micro-component is configured to emit UV light, the inside of each of the sockets **30** is at least partially coated with phosphor in order to convert the UV light to visible light. In a color light-emitting panel, in accordance with another embodiment, red, green, and blue phosphors are used to create alternating red, green, and blue, pixels/subpixels, respectively. By combining these colors at varying intensities all colors can be formed. In another embodiment, the phosphor coating may be combined with an adhesive so that the adhesive acts as a binder for the phosphor and also binds the micro-component **40** to the socket **30** when it is cured. In addition, the socket **30** may be coated with a reflective material, including, but not limited to, optical dielectric stacks, to provide an increase in luminosity, by directing radiation traveling in the direction of the substrate in which the sockets are formed out through the field of view **400** of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **65** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **65** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the cavities **55** are patterned on the first substrate **10** so that the cavities are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the cavities **55** are formed by selectively removing a portion of the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where the cavities **55** are patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **13**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **14**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **15**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A light-emitting panel comprising:

a first substrate comprising a plurality of material layers;

a second substrate opposed to the first substrate;

a plurality of sockets, each socket comprising a cavity, the cavity being formed by selectively removing a portion of the material layers, wherein the cavity is in a shape selected from the group consisting of a cube, a cone, a conical frustum, a paraboloid, spherical, cylindrical, a pyramid, a pyramidal frustum, a parallelepiped, and a prism;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least one electrode of the plurality of electrodes is disposed on or within the material layers.

**2**. The light-emitting display of claim **1**, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing the at least two electrodes.

**3**. The light-emitting panel of claim **1**, wherein the depth of the cavity is selected to achieve a specific field of view for the light-emitting display.

**4**. The light-emitting panel of claim **1**, wherein at least one socket is at least partially coated with phosphor.

**5**. The light-emitting panel of claim **1**, wherein at least one socket is at least partially coated with a reflective material.

**6**. The light-emitting panel of claim **1**, further comprising an adhesive or bonding agent disposed in the cavity.

**7**. The light-emitting panel of claim **1**, wherein the plurality of material layers comprise at least one enhancement material selected from the group consisting of anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, and protective coatings.

**8**. The light-emitting panel of claim **1**, wherein the plurality of material layers comprise at least one enhancement material selected from the group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**9**. A method for forming a socket for use in a light emitting display, comprising the steps of:

disposing a plurality of material layers, wherein the step of disposing the plurality of material layers comprises the step of disposing at least one electrode within the material layers; and

selectively removing a portion of the plurality of material layers and the at least one electrode to form a cavity, wherein the cavity is capable of at least partially supporting at least one micro-component.

**10**. The method of claim **9**, performed as part of a continuous inline process.

**11**. The method of claim **10**, performed as part of a continuous inline process.

**12**. A method for forming a socket for use in a light-emitting display, comprising the steps of:

providing a substrate;

patterning the substrate so as to form a cavity in the substrate;

disposing a plurality of material layers on the substrate such that the plurality of material layers conform to the shape of the cavity, wherein the step of disposing a plurality of material layers on the substrate comprises the step of disposing at least one electrode within the material layers.

**13**. A light-emitting panel comprising:

at least one micro-component;

a socket, wherein the socket comprises a cavity, wherein the at least one micro-component and the cavity have complimentary shapes, and wherein the opening of the cavity is smaller than the diameter of a micro-component so that when the at least one micro-component is disposed in the cavity the at least one micro-component is held in place by the cavity; and

at least two electrodes, wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**14**. A light-emitting panel comprising:

a first substrate;

a plurality of material layers disposed on the first substrate, wherein each material layer of the plurality of material layers comprises an aperture;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket comprises a cavity and wherein the cavity is formed by aligning the apertures of the plurality of material layers;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket;

a plurality of electrodes, wherein at least one electrode of the plurality of electrodes is disposed on or within the material layers.

**15**. The light-emitting display of claim **14**, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing the at least two electrodes.

**16**. The light-emitting panel of claim **14**, wherein the cavity is in a shape selected from the group consisting of a cube, a cone, a conical frustum, a paraboloid, spherical, cylindrical, a pyramid, a pyramidal frustum, a parallelepiped, and a prism.

**17**. The light-emitting panel of claim **14**, wherein the depth of the cavity is selected to achieve a specific field of view for the light-emitting display.

**18**. The light-emitting panel of claim **14**, wherein at least one socket is at least partially coated with phosphor.

**19**. The light-emitting panel of claim **14**, wherein at least one socket is at least partially coated with a reflective material.

**20**. The light-emitting panel of claim **14**, further comprising an adhesive or bonding agent disposed in the cavity.

**21**. The light-emitting panel of claim **14**, wherein the plurality of material layers comprise at least one enhancement material selected from the group consisting of anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, and protective coatings.

**22**. The light-emitting panel of claim **14**, wherein the plurality of material layers comprise at least one enhancement material selected from the group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**23**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, each socket of the plurality of sockets comprising a cavity patterned on the first substrate so as to be formed in the first substrate, wherein an adhesive or bonding agent is disposed in the cavity;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to the each of the first substrate and the second substrate and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

* * * * *

US006570335B1

(12) **United States Patent**
George et al.

(10) **Patent No.:** US 6,570,335 B1
(45) **Date of Patent:** May 27, 2003

(54) **METHOD AND SYSTEM FOR ENERGIZING A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/697,345**

(22) Filed: **Oct. 27, 2000**

(51) **Int. Cl.**$^{7}$ .................................................. **G09G 3/10**

(52) **U.S. Cl.** ............................... **315/169.3**; 315/169.4; 313/581

(58) **Field of Search** .......................... 315/169.3, 169.4; 313/484, 485, 486, 501, 506, 581, 582, 306, 307; 445/24

(56) **References Cited**

U.S. PATENT DOCUMENTS


| | | | |
|---|---|---|---|
| 3,559,190 A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | 7/1976 | Greeson, Jr. | 315/169.3 |
| 3,990,068 A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 A | 12/1981 | Torobin | 65/21.4 |
| 4,393,326 A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | 8/1985 | D'Onofrio, et al. | 445/24 |
| 4,554,537 A | 11/1985 | Dick | 340/775 |


(List continued on next page.)

FOREIGN PATENT DOCUMENTS


| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |


OTHER PUBLICATIONS

International Search Report dated Sep. 23, 2002.
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.
"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.
"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

(List continued on next page.)

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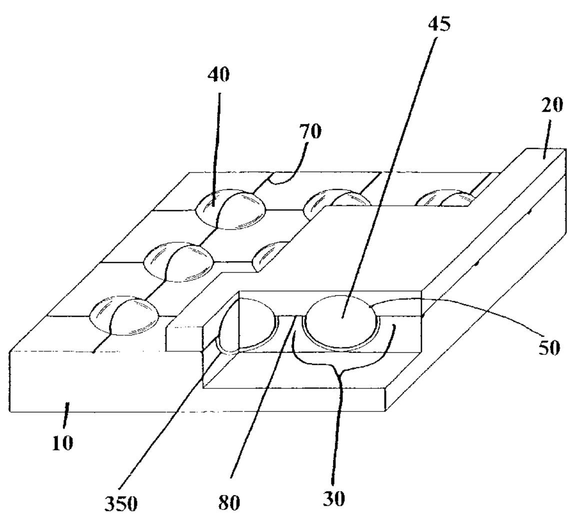
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of energizing a micro-component is also disclosed.

**38 Claims, 17 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 4,563,617 | A | * | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | | 3/1987 | Shelton | 315/111.71 |
| 4,697,123 | A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | | 3/1988 | Dick | |
| 4,833,463 | A | | 5/1989 | Dick et al. | |
| 4,843,281 | A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | | 7/1991 | Salavin et al. | 315/169.3 |
| 5,062,916 | A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Deschamps et al. | |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | | 10/1999 | Kaake, et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Franworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | * | 10/2000 | Lammers | 345/72 |
| 6,201,518 | B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nato et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |

OTHER PUBLICATIONS

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp-?nSeqNo=13&type=&word.

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco PlasmaWall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco PlasmaWall P1–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco PlasmaWall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Rauf, S., Kushner, M.J., *Operation of a Coplanar–Electrode Plasma Display Panel Cell*, IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Shin, Y.K., Lee, J.K., Shon, C.H., *Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry*, IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 14–15.

Kurihara, M. Makabe, T., *Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency*, IEEE Transactions on Plasma Science, vol. 27, No. 5, Oct. 1999, pp. 1372–1378.

Alien Technology Corporation's Technology Overview; copyright ® 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

International Search Report of Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journals/sj/363/Jacobson.html.

Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

Written Opinion for Application No. PCT/US01/42782, dated Dec. 13, 2002.

Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

* cited by examiner

Fig. 1

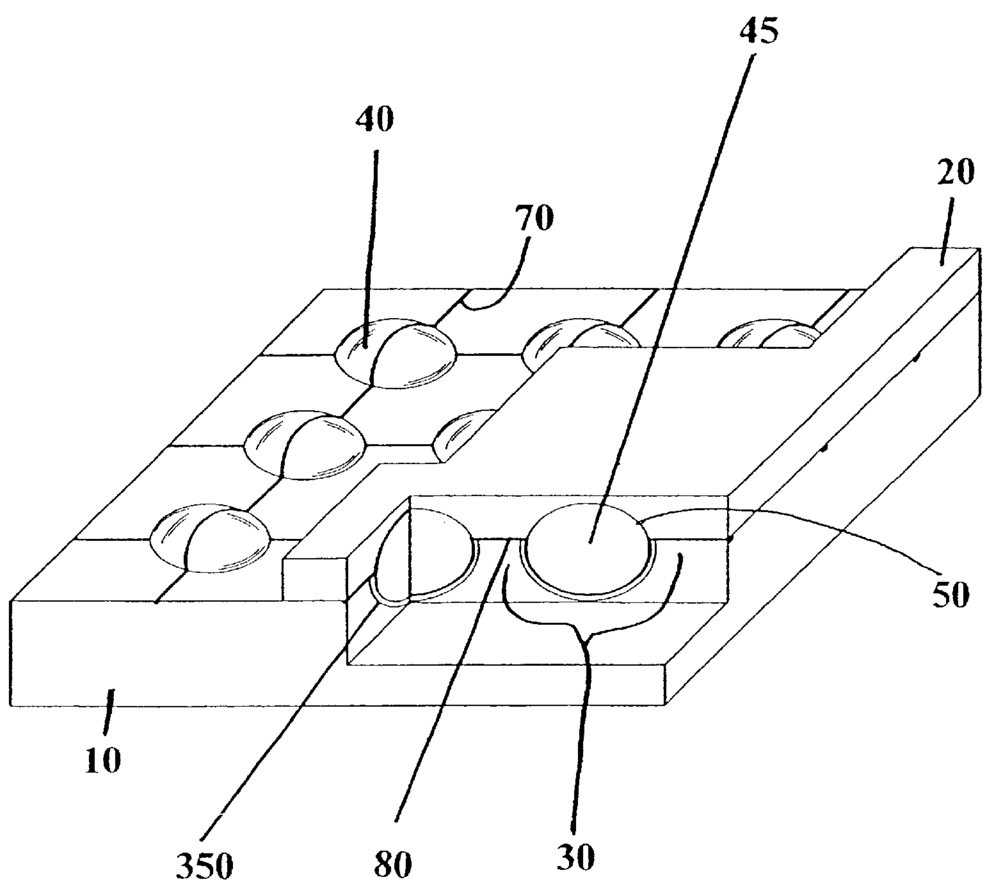
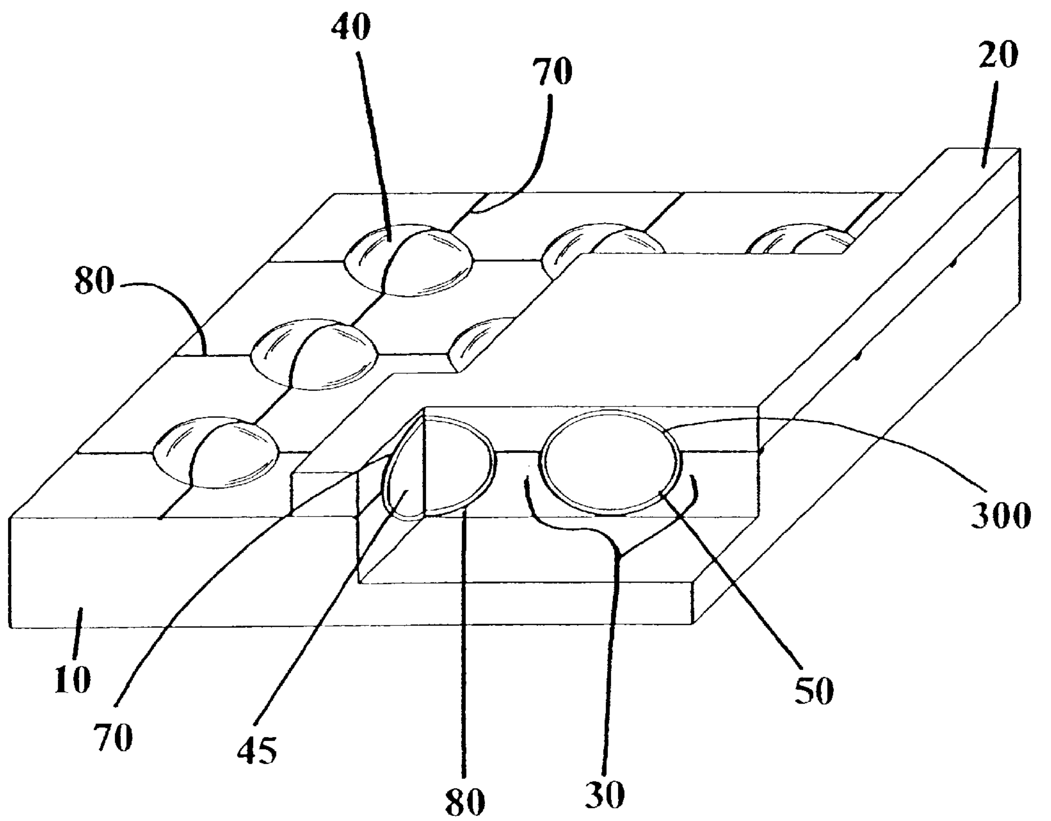


Fig. 2



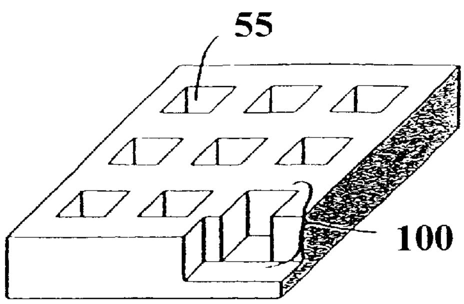



Fig. 3A

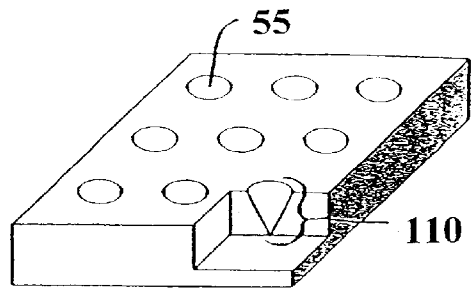



Fig. 3B

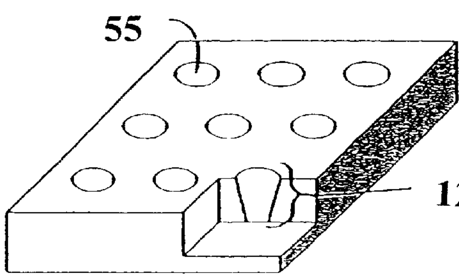



Fig. 3C

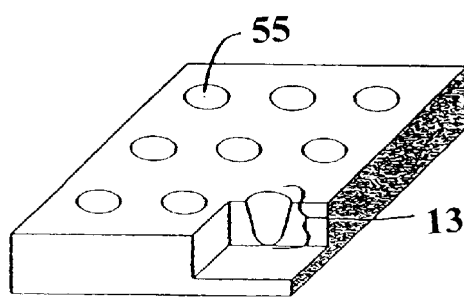



Fig. 3D

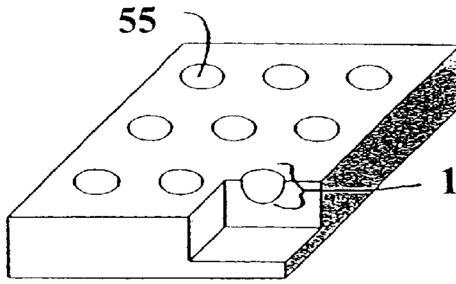



Fig. 3E

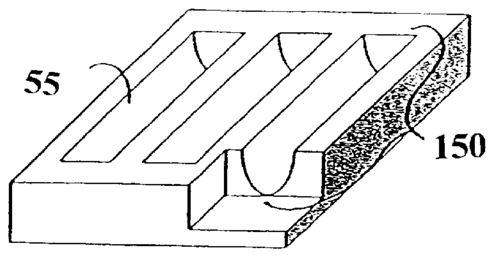



Fig. 3F

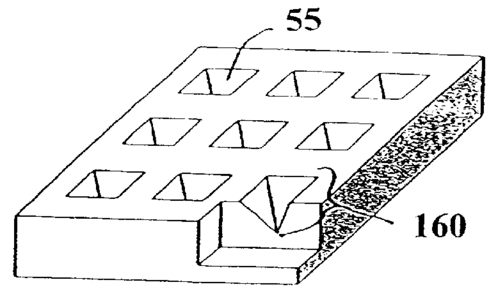



Fig. 3G

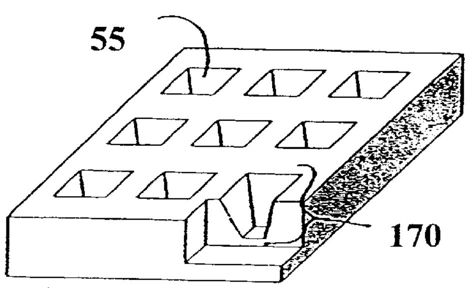



Fig. 3H

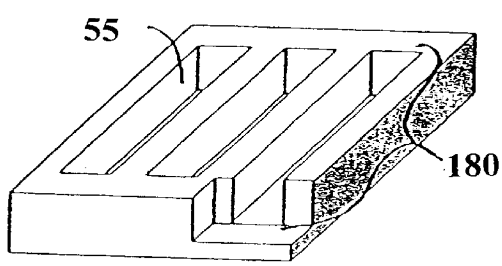



Fig. 3I

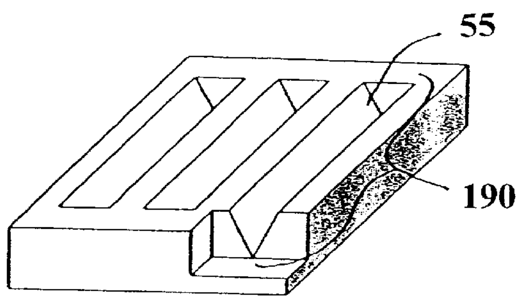



Fig. 3J

Fig. 4

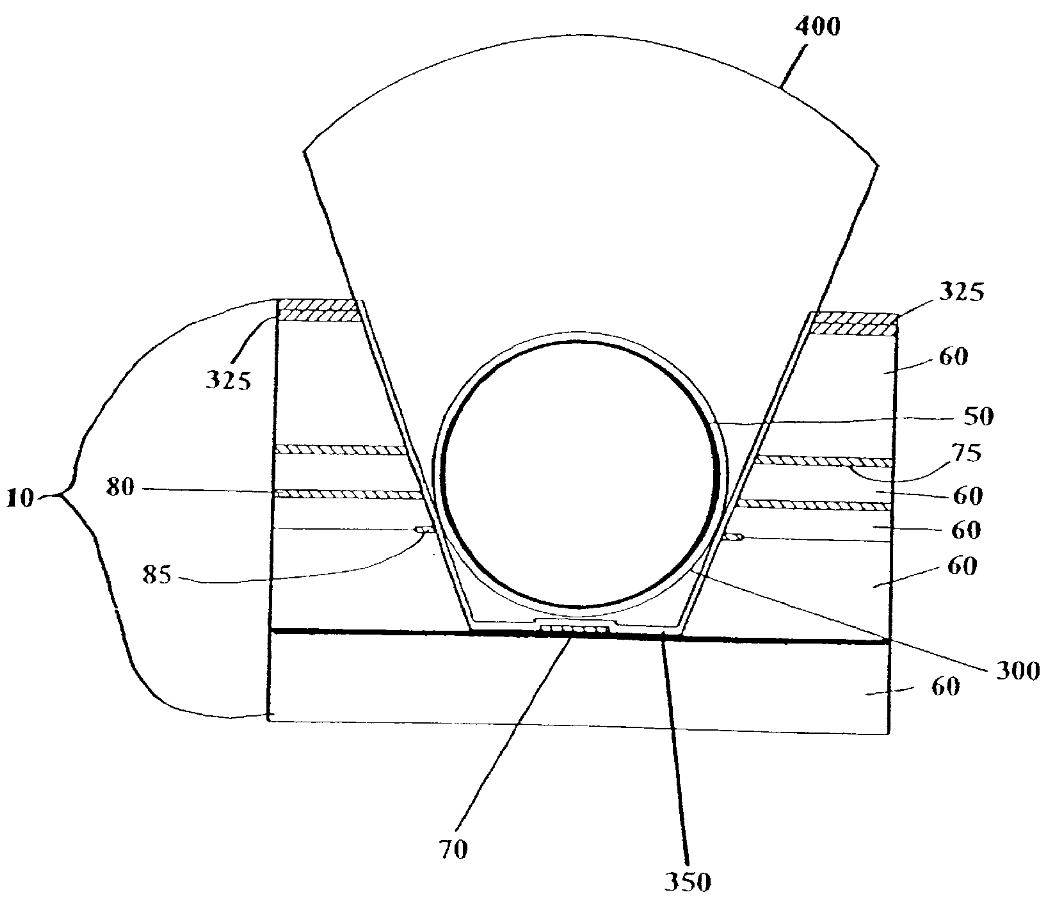


Fig. 5

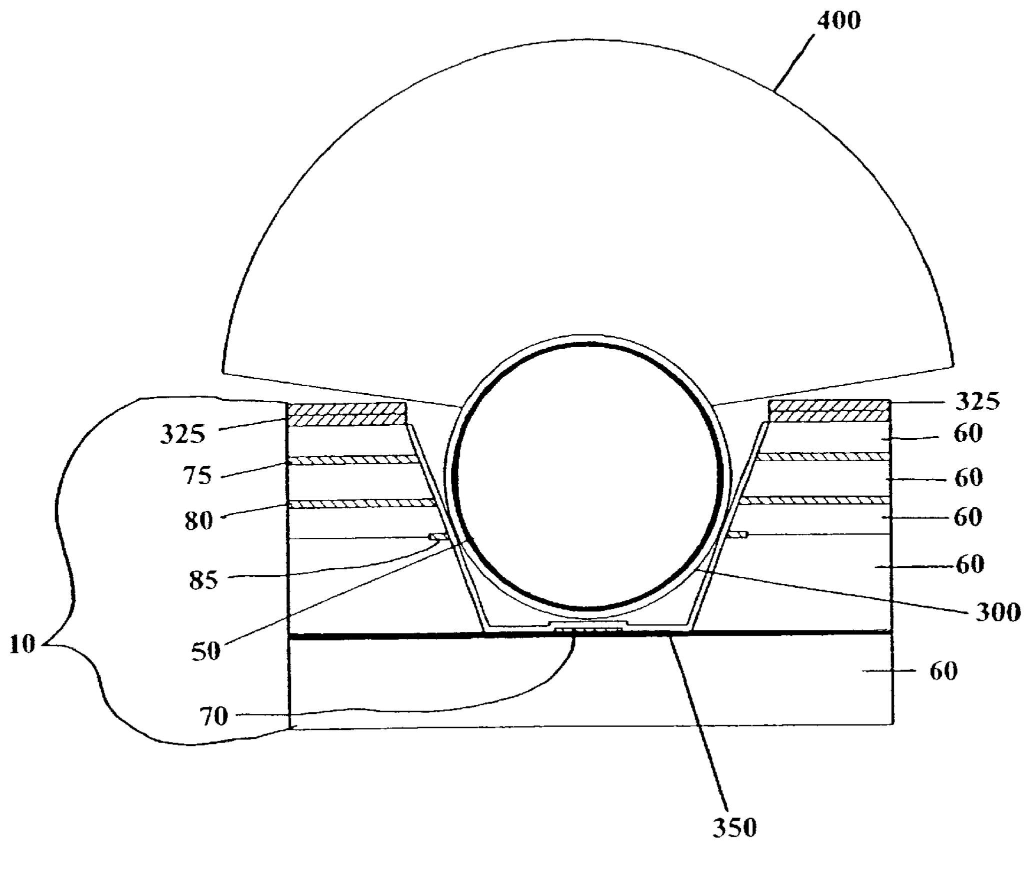


Fig. 6A

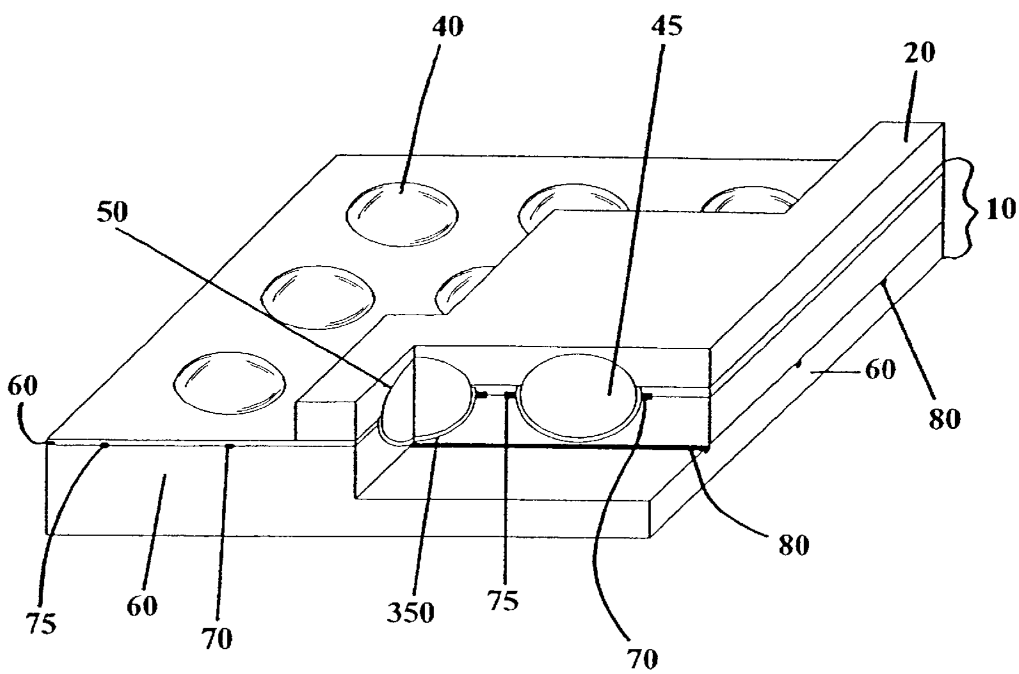


Fig. 6B

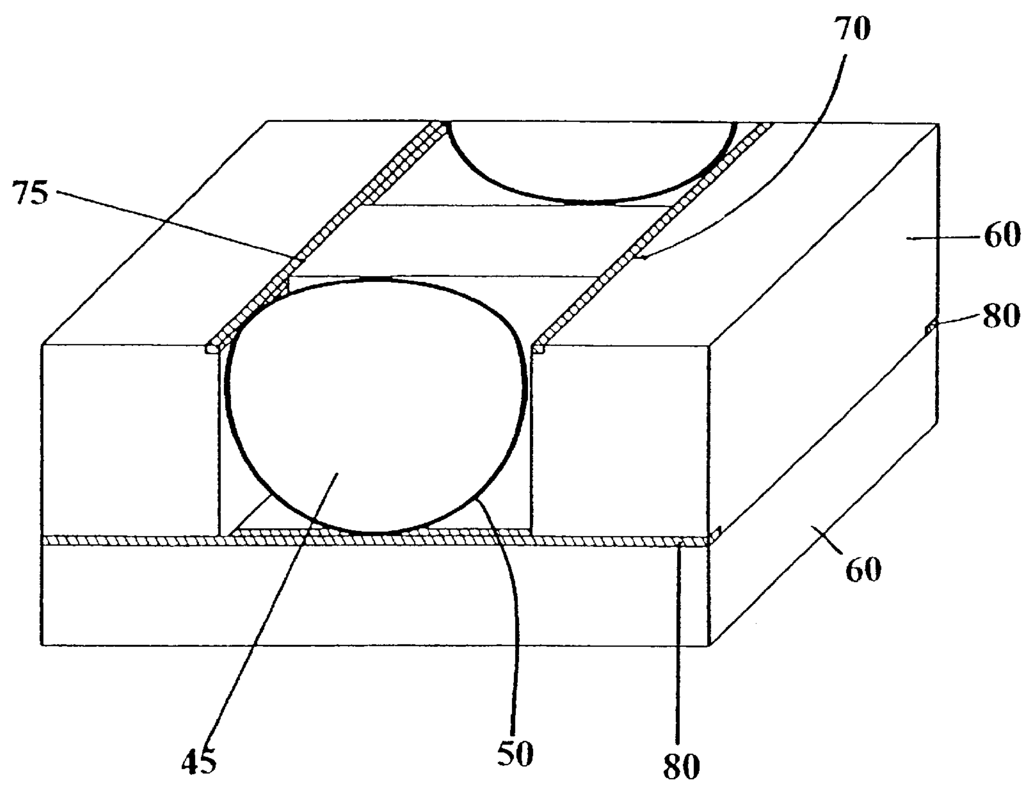


Fig. 7A

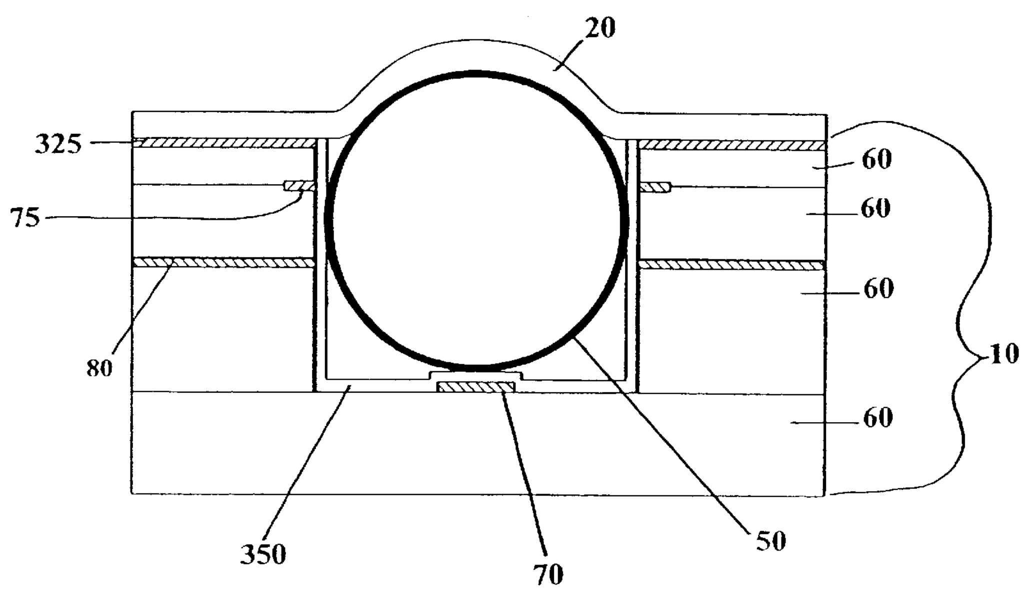


Fig. 7B

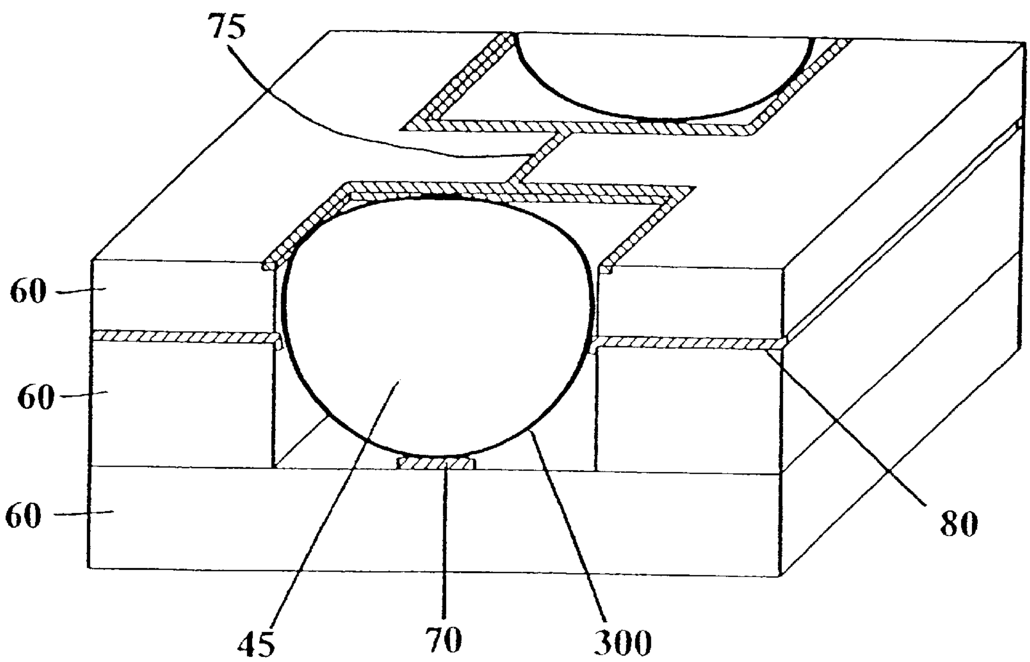


Fig. 8

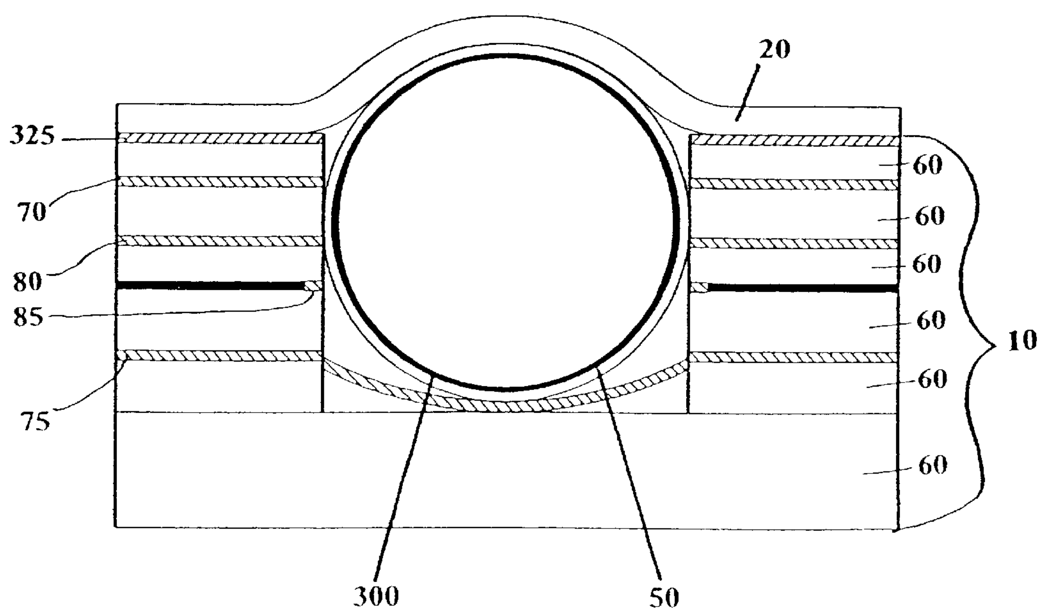


Fig. 9

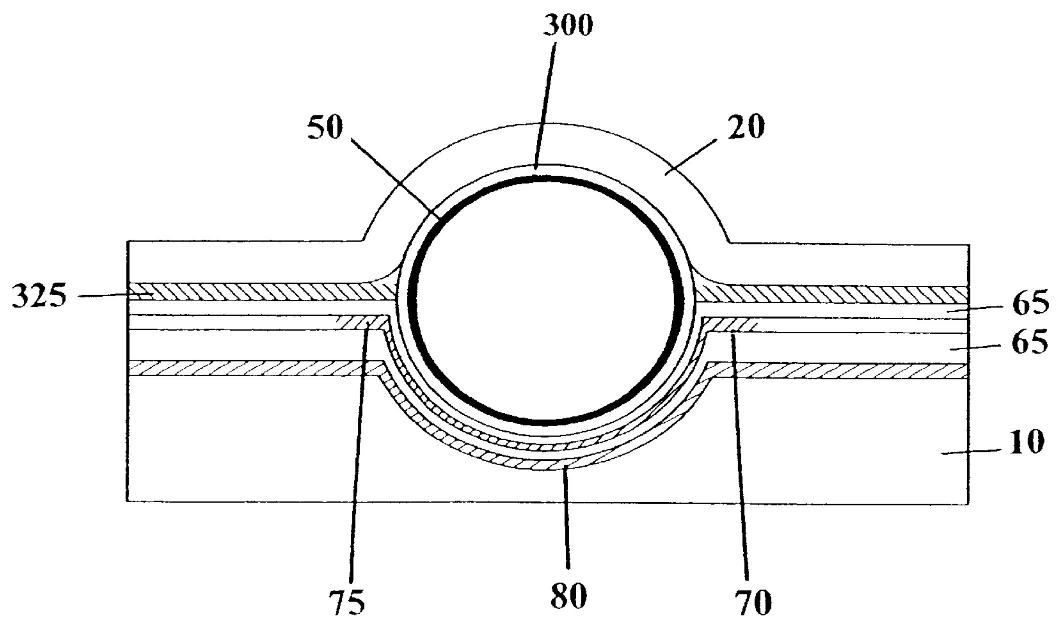


Fig. 10

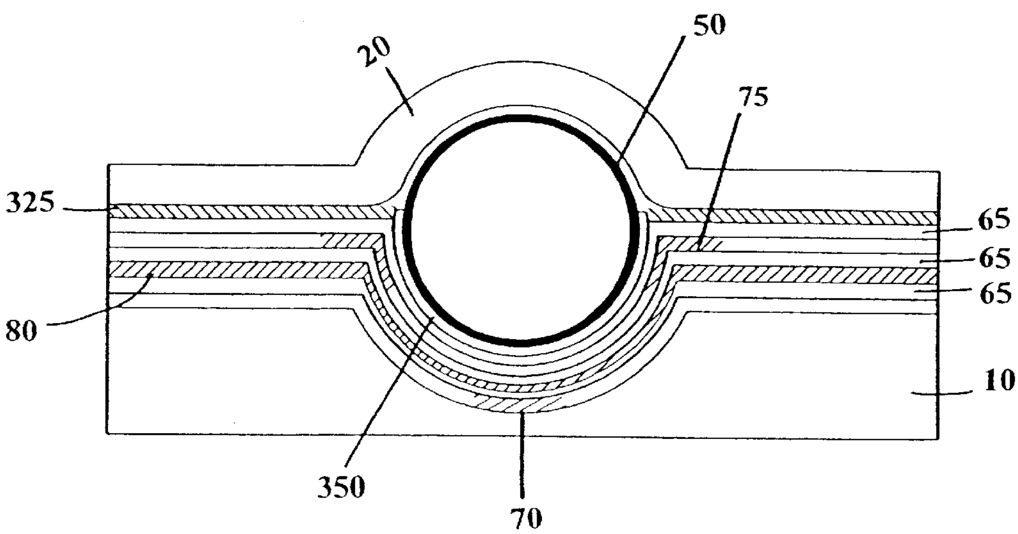
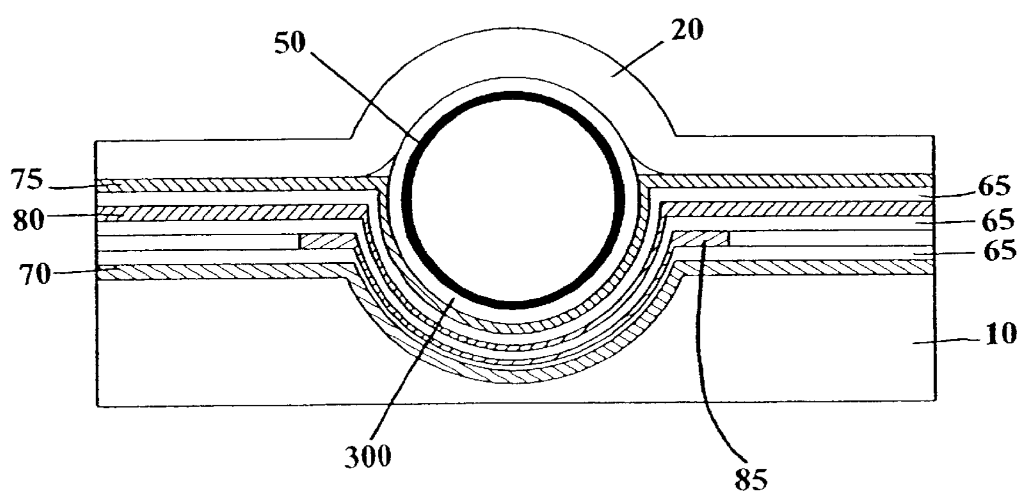


Fig. 11



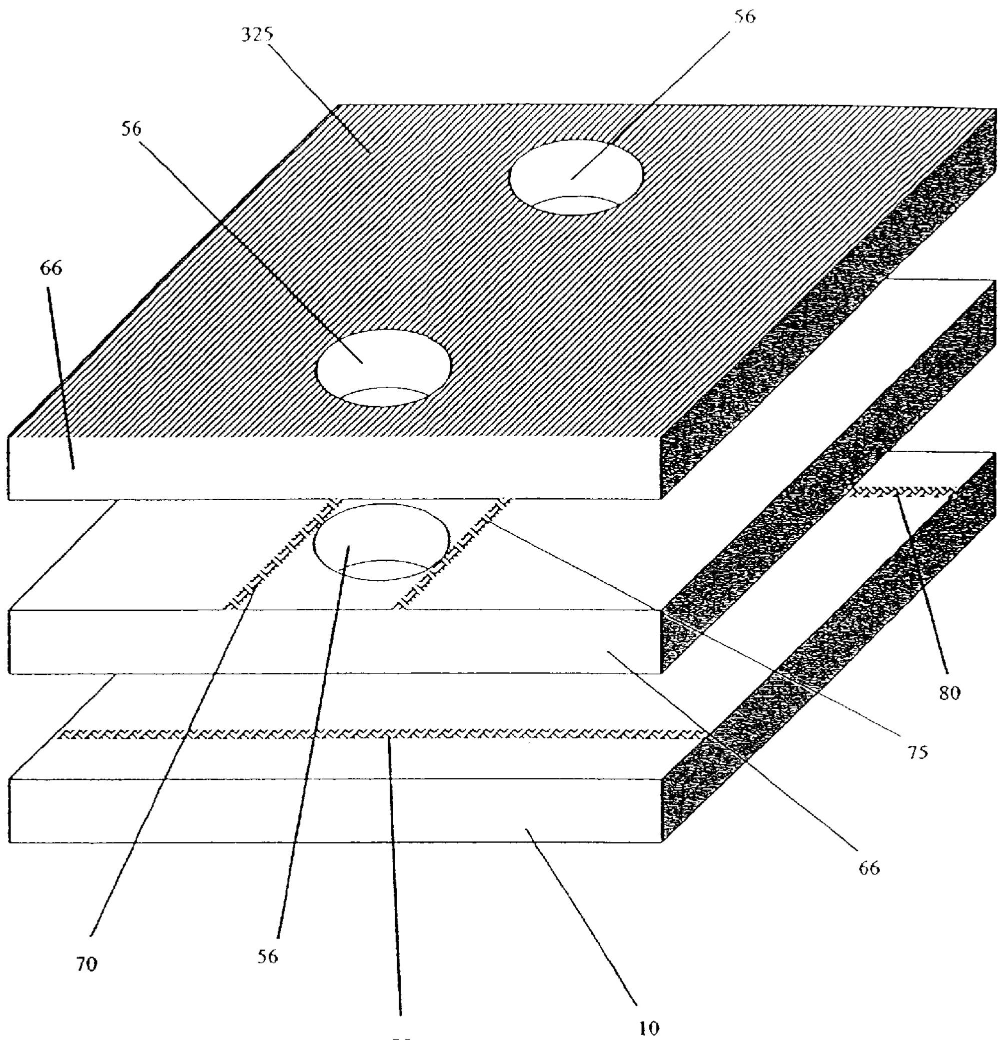



Fig. 12

Fig. 13

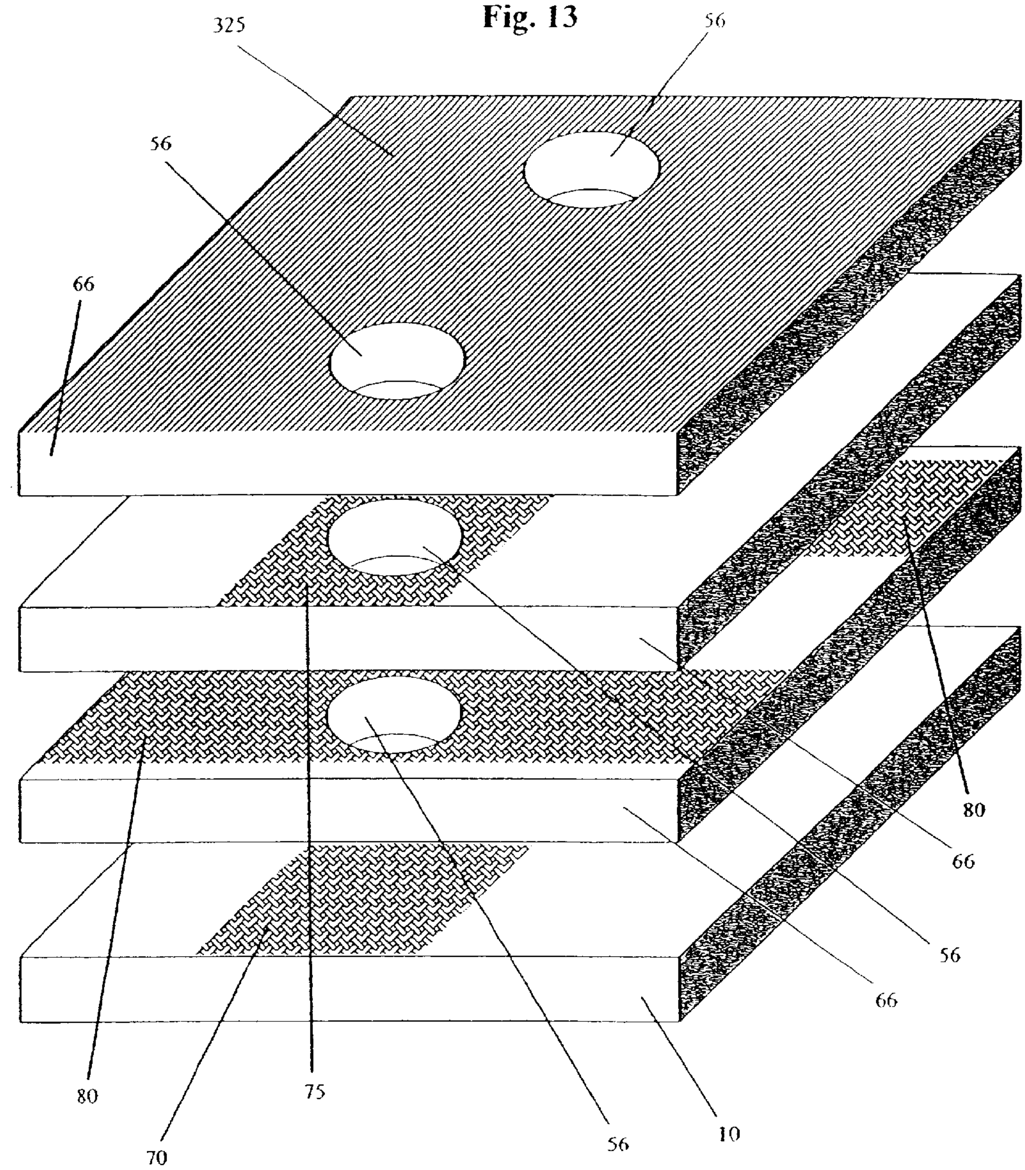
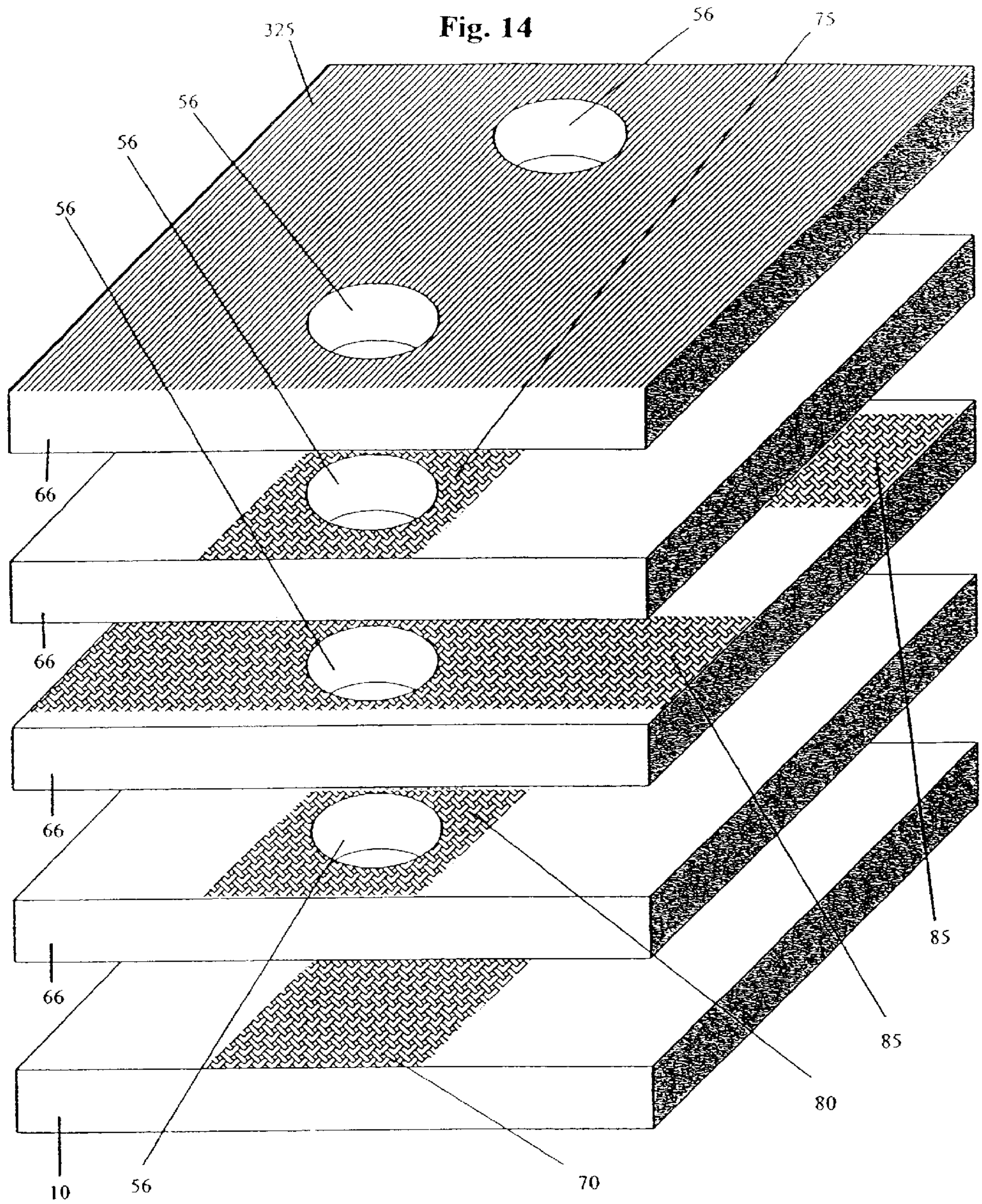


Fig. 14



# METHOD AND SYSTEM FOR ENERGIZING A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use with a Micro-Component in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a light-emitting panel and methods of fabricating the same. The present invention further relates to a method and system for energizing micro-components in a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain



operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates.

This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In an embodiment of the present invention, the plurality of sockets include a cavity that is patterned in the first substrate and at least two electrodes adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, the plurality of sockets include a cavity that is patterned in the first substrate and at least two electrodes that are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In another embodiment, a first substrate comprises a plurality of material layers and a socket is formed by selectively removing a portion of the plurality of material layers to form a cavity and disposing at least one electrode on or within the material layers.

In another embodiment, a socket includes a cavity patterned in a first substrate, a plurality of material layers disposed on the first substrate so that the plurality of material layers conform to the shape of the socket and at least one electrode disposed within the material layers.

In another embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity.

Other embodiments are directed to methods for energizing a micro-component in a light-emitting display using the socket configurations described above with voltage provided to at least two electrodes causing at least one micro-component at least partially disposed in the cavity of a socket to emit radiation.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be disposed on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

In an embodiment for a light-emitting panel, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a light-emitting panel, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either on or within the material layers, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a light-emitting panel, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, antiglare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. The electrodes may be disposed in the light-emitting panel using any technique known to one skilled in the art including, but not limited to, any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more microcomponents to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** each include a cavity patterned in the first substrate **10**, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In an embodiment for a method of energizing a micro-component, the electrodes may be disposed either before the cavity is formed or after the cavity is formed. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration and the address function will be performed between at least one of the sustain electrodes and the address electrode. It is believed that energizing a micro-component with this arrangement of electrodes will produce increased luminosity. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing function from the sustain electrodes. It is believed that this arrangement will provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. It is also believed that by separating the sustain and address electrodes so different voltage sources may be used to provide the address and sustain functions, a lower or different type of voltage source may be used to provide the address or sustain functions.

In an embodiment where a cavity **55** is patterned in the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In an embodiment for a method of energizing a micro-component, electrodes formed on the first substrate may be disposed either before the cavity was patterned or after the cavity was patterned. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration and the address function will be performed between at least one of the sustain electrodes and the address electrode. It is believed that energizing a micro-component with this arrangement of electrodes will produce increased luminosity. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing function from the sustain electrodes. It is believed that this arrangement will provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. It is also believed that by separating the sustain and address electrodes so different voltage sources may be used to provide the address and sustain functions a lower or different type of voltage source may be used to provide the address or sustain functions.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **12**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **13**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration and the address function will be performed between at least one of the sustain electrodes and the address electrode. It is believed that energizing a micro-component with this arrangement of electrodes will produce increased luminosity. As seen in FIG. **14**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing function from the sustain electrodes. It is believed that this arrangement will provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. It is also believed that by separating the sustain and address electrodes so different voltage sources may be used to provide the address and sustain functions a lower or different type of voltage source may be used to provide the address or sustain functions.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket of the plurality of sockets comprises a cavity and wherein the cavity is patterned in the first substrate;

a plurality of micro-components, wherein at least two micro-components of the plurality of micro-components are at least partially disposed in each socket; and

at least two electrodes, wherein the at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof, and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**2**. The light-emitting panel of claim **1**, wherein the at least two electrodes comprise one or more address electrodes and one or more sustain electrodes, and wherein at least one address electrode is traverse to at least one sustain electrode.

**3**. The light-emitting panel of claim **1**, wherein the at least two electrodes comprise one or more address electrodes and one or more sustain electrodes, and wherein at least one address electrode or at least one sustain electrode is at least partially disposed in the cavity.

**4**. The light-emitting panel of claim **1**, wherein each socket comprises at least one enhancement material, wherein the at least one enhancement material is disposed in or proximate to each socket, and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.



**5**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket of the plurality of sockets comprises a cavity and wherein the cavity is patterned in the first substrate, and further wherein each socket comprises at least one enhancement material, wherein the at least one enhancement material is disposed in or proximate to each socket, and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing the at least two electrodes.

**6**. The light-emitting panel of claim **5**, wherein the at least two electrodes comprise one or more address electrodes and one or more sustain electrodes, and wherein at least one address electrode is traverse to at least one sustain electrode.

**7**. The light-emitting panel of claim **5**, wherein the at least two electrodes comprise one or more address electrodes and one or more sustain electrodes, and wherein at least one address electrode or at least one sustain electrode is at least partially disposed in the cavity.

**8**. A light-emitting panel comprising:

a first substrate comprising a plurality of material layers;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket comprises a cavity and wherein the cavity is formed by selectively removing a portion of the material layers;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least one electrode of the plurality of electrodes is disposed on or within the material layers.

**9**. The light-emitting panel of claim **8**, wherein each socket further comprises a first address electrode, a first sustain electrode and a second sustain electrode, such that the first sustain electrode and the second sustain electrode are disposed in a co-planar configuration.

**10**. The light-emitting panel of claim **8**, wherein each socket further comprises a first address electrode, a first sustain electrode and a second sustain electrode, such that the first address electrode is disposed in a mid-plane configuration.

**11**. The light-emitting panel of claim **8**, wherein each socket further comprises a first address electrode, a second address electrode, a first sustain electrode, and a second sustain electrode, such that the first address electrode and the second address electrode are disposed between the first sustain electrode and the second sustain electrode.

**12**. The light-emitting panel of claim **8**, wherein each socket comprises at least one enhancement material, wherein the at least one enhancement material is disposed in or proximate to each socket, and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control-electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**13**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket of the plurality of sockets comprises

a cavity, wherein the cavity is patterned in the first substrate, and

a plurality of material layers, wherein the plurality of material layers are disposed on the first substrate such that the plurality of material layers conform to the shape of the cavity of each socket;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least one electrode of the plurality of electrodes is disposed within the material layers.

**14**. The light-emitting panel of claim **13**, wherein each socket further comprises a first address electrode, a first sustain electrode and a second sustain electrode, such that the first sustain electrode and the second sustain electrode are disposed in a co-planar configuration.

**15**. The light-emitting panel of claim **13**, wherein each socket further comprises a first address electrode, a first sustain electrode and a second sustain electrode, such that the first address electrode is disposed in a mid-plane configuration.

**16**. The light-emitting panel of claim **13**, wherein each socket further comprises a first address electrode, a second address electrode, a first sustain electrode, and a second sustain electrode, such that the first address electrode and the second address electrode are disposed between the first sustain electrode and the second sustain electrode.

**17**. The light-emitting panel of claim **13**, wherein each socket comprises at least one enhancement material, wherein the at least one enhancement material is disposed in or proximate to each socket, and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**18**. A method for energizing a micro-component in a light-emitting panel comprising steps of:

forming a first substrate by disposing a plurality of material layers, wherein the step of disposing the plurality of material layers comprises the step of disposing at least one electrode on or within the material layers;

selectively removing a portion of the material layers to form a cavity;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**19**. The method of claim **18**, further comprising the step of disposing at least one enhancement material on or within the plurality of material layers and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**20**. A method for energizing a micro-component in a light-emitting panel, comprising he steps of:

providing a first substrate;

patterning a cavity in the first substrate;

disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to the shape of the cavity, wherein the step of disposing the plurality of material layers comprises the step of disposing at least one electrode on or within the material layers;

at least partially disposing at least at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**21**. The method of claim **20**, further comprising the step of disposing at least one enhancement material on or within the plurality of material layers and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**22**. A light-emitting panel comprising:

a first substrate;

a plurality of material layers disposed on the first substrate, wherein each material layer of

the plurality of material layers comprises an aperture;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket comprises a cavity and wherein the cavity is formed by aligning the apertures of the plurality of material layers;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least one electrode of the plurality of electrodes is disposed on or within the material layers.

**23**. The light-emitting panel of claim **22**, wherein each socket further comprises a first address electrode, a first sustain electrode and a second sustain electrode, such that the first sustain electrode and the second sustain electrode are disposed in a co-planar configuration.

**24**. The light-emitting panel of claim **22**, wherein each socket further comprises a first address electrode, a first sustain electrode and a second sustain electrode, such that the first address electrode is disposed in a mid-plane configuration.

**25**. The light-emitting panel of claim **22**, wherein each socket further comprises a first address electrode, a second address electrode, a first sustain electrode, and a second sustain electrode, such that the first address electrode and the second address electrode are disposed between the first sustain electrode and the second sustain electrode.

**26**. The light-emitting panel of claim **22**, wherein each socket comprises at least one enhancement material, wherein the at least one enhancement material is disposed in or proximate to each socket, and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**27**. A method for energizing a micro-component in a light-emitting panel comprising the step of:

providing a first substrate;

disposing a plurality of material layers on the first substrate, wherein each material layer of the plurality of material layers comprises an aperture, and wherein the step of disposing the plurality of material layers comprises the steps of

aligning the apertures of each material layer so that when the plurality of material layers are disposed on the first substrate the apertures from a cavity, and

disposing at least one electrode on or within the material layers;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**28**. The method of claim **27**, further comprising the step of disposing at least one enhancement material on or within the plurality of material layers and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**29**. A method for energizing a micro-component in a light-emitting panel, comprising the steps of:

forming a first substrate by disposing a plurality of material layers, wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first address electrode between a first material layer and a second material layer, and

(b) disposing a first sustain electrode and a second sustain electrode between the second material layer and a third material layer;

selectively removing a portion of the material layers to form a cavity;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**30**. A method for energizing a micro-component in a light-emitting panel, comprising the steps of:

forming a first substrate by disposing a plurality of material layers, wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first sustain electrode between a first material layer and a second material layer;

(b) disposing a first address electrode between the second material layer and a third material layer; and

(c) disposing a second sustain electrode between the third material layer and a fourth material layer;

selectively removing a portion of the material layers to form a cavity;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**31**. A method for energizing a micro-component in a light-emitting panel, comprising the steps of:

forming a first substrate by disposing a plurality of material layers, wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first sustain electrode between a first material layer and a second material layer,

(b) disposing a first address electrode between the second material layer and a third material layer,

(c) disposing a second address electrode between the third material layer and a fourth material layer, and

(d) disposing a second sustain electrode between the fourth material layer and a fifth material layer;

selectively removing a portion of the material layers to form a cavity;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**32**. A method for energizing a micro-component in a light-emitting panel comprising the steps of:

providing a first substrate;

patterning a cavity in the first substrate;

disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to the shape of the cavity, wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first address electrode between the first substrate and a first material layer, and

(b) disposing a first sustain electrode and a second sustain electrode between the first material layer and a second material layer;

at least partially disposing at least at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

**33**. A method for energizing a micro-component in a light-emitting panel comprising the steps of:

providing a first substrate;

patterning a cavity in the first substrate;

disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to the shape of the cavity, wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first sustain electrode between the first substrate and a first material layer,

(b) disposing a first address electrode between the first material layer and a second material layer, and

(c) disposing a second sustain electrode between the second material layer and a third material layer;

at least partially disposing at least at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

34. A method for energizing a micro-component in a light-emitting panel comprising the steps of:

providing a first substrate;

patterning a cavity in the first substrate;

disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to the shape of the cavity, wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first sustain electrode between the first substrate and a first material layer,

(b) disposing a first address electrode between the first material layer and a second material layer,

(c) disposing a second address electrode between the second material layer and a third material layer, and

(d) disposing a second sustain electrode between the third material layer and a fourth material layer;

at least partially disposing at least at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

35. A method for energizing a micro-component in a light-emitting panel comprising the steps of:

providing a first substrate;

disposing a plurality of material layers on the first substrate, wherein each material layer of the plurality of material layers comprises an aperture, and wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first address electrode between a first material layer and a second material layer, and

(b) disposing a first sustain electrode and a second sustain electrode between the second material layer and a third material layer;

aligning the apertures of each material layer so that when the plurality of material layers are disposed on the first substrate the apertures for a cavity, and

disposing at least one electrode on or within the material layers;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

36. A method for energizing a micro-component in a light-emitting panel comprising the steps of:

providing a first substrate;

disposing a plurality of material layers on the first substrate, wherein each material layer of the plurality of material layers comprises an aperture, and wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first sustain electrode between a first material layer and a second material layer;

(b) disposing a first address electrode between the second material layer and a third material layer; and

(c) disposing a second sustain electrode between the third material layer and a fourth material layer;

aligning the apertures of each material layer so that when the plurality of material layers are disposed on the first substrate the apertures for a cavity, and disposing at least one electrode on or within the material layers;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

37. A method for energizing a micro-component in a light-emitting panel comprising the steps of:

providing a first substrate;

disposing a plurality of material layers on the first substrate, wherein each material layer of the plurality of material layers comprises an aperture, and wherein the step of disposing the plurality of material layers comprises the steps of

(a) disposing a first sustain electrode between a first material layer and a second material layer,

(b) disposing a first address electrode between the second material layer and a third material layer,

(c) disposing a second address electrode between the third material layer and a fourth material layer, and

(d) disposing a second sustain electrode between the fourth material layer and a fifth material layer;

aligning the apertures of each material layer so that when the plurality of material layers are disposed on the first substrate the apertures for a cavity, and

disposing at least one electrode on or within the material layers;

at least partially disposing at least one micro-components in the cavity, such that the at least one micro-component is in electrical contact with the at least one electrode; and

providing a voltage to at least two electrodes causing the at least one micro-component to emit radiation.

38. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket of the plurality of sockets comprises a cavity and wherein the cavity is patterned in the first substrate;

a plurality of micro-components, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

at least two electrodes, wherein the at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof, so as to be electrically but not physically contacted to one or more of the plurality of micro-components, and further wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

* * * * *

US006612889B1

(12) **United States Patent**
**Green et al.**

(10) **Patent No.: US 6,612,889 B1**
(45) **Date of Patent: Sep. 2, 2003**

(54) **METHOD FOR MAKING A LIGHT-EMITTING PANEL**

(75) Inventors: **Albert Myron Green**, Springfield, VA (US); **Adam Thomas Drobot**, Vienna, VA (US); **Edward Victor George**, Lake Arrowhead, CA (US); **Roger Laverne Johnson**, Encinitas, CA (US); **Newell Convers Wyeth**, Oakton, VA (US)

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 230 days.

(21) Appl. No.: **09/697,344**

(22) Filed: **Oct. 27, 2000**

(51) **Int. Cl.**[7] .................................................. **H01J 9/24**

(52) **U.S. Cl.** ........................................................ **445/24**

(58) **Field of Search** ........................................... 445/24

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,559,190 A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | 7/1976 | Greeson, Jr. | |
| 3,990,068 A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | 7/1977 | Roeber | 315/169 TV |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alien-technology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdp-display.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

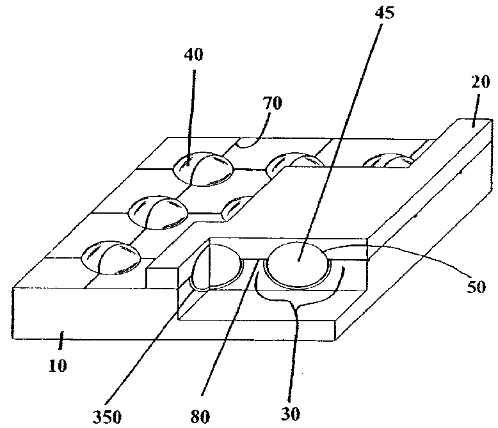
(List continued on next page.)

*Primary Examiner*—Kenneth J. Ramsey
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous inline process.

**20 Claims, 22 Drawing Sheets**



## U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,303,433 A | | 12/1981 | Torobin | 65/21.4 |
| 4,393,326 A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 A | | 11/1985 | Dick | 340/775 |
| 4,563,617 A | | 1/1986 | Davidson | 315/312 |
| 4,591,847 A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 A | | 3/1987 | Shelton | 315/111.71 |
| 4,697,123 A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 A | | 3/1988 | Dick | |
| 4,833,463 A | | 5/1989 | Dick et al. | |
| 4,843,281 A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 A | | 12/1989 | Parker | 313/634 |
| 4,912,364 A | | 3/1990 | Holló et al. | 313/623 |
| 4,935,093 A | * | 6/1990 | Reeb | 216/6 |
| 5,019,807 A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 A | | 7/1991 | Salavin et al. | |
| 5,062,916 A | * | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 A | | 12/1991 | Deschamps et al. | |
| 5,126,632 A | | 6/1992 | Parker | 313/634 |
| 5,150,007 A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 A | | 8/1998 | Sun et al. | 204/279 R |
| 5,793,158 A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,837,221 A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 A | | 7/1999 | Jones | 257/40 |
| 5,945,174 A | | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 A | | 10/1999 | Kisner | 313/484 |
| 5,984,747 A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 A | | 3/2000 | Song | 349/43 |
| 6,039,619 A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,630 A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 A | | 6/2000 | Okajima | 313/581 |
| 6,080,606 A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,097,147 A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 B1 | | 9/2001 | Park et al. | 313/586 |
| 6,288,488 B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 B1 | | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 B1 | | 11/2001 | Amundson et al. | 438/99 |

## OTHER PUBLICATIONS

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e$_{13}$ read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.asp?nSeqNo=13&type=&word.

"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco Plasma Wall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco Plasma Wall P1–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco Plasma Wall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http:www.runco.com/Products/Plasma/PL61.htm.

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

Preliminary Examination Report for U.S. Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

International Search Report for Application No. PCT/IUS01/51439, dated Sep. 23, 2002 (mailing date).

Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ ttoday / summer 95 / microeng.htm.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

* cited by examiner

Fig. 1

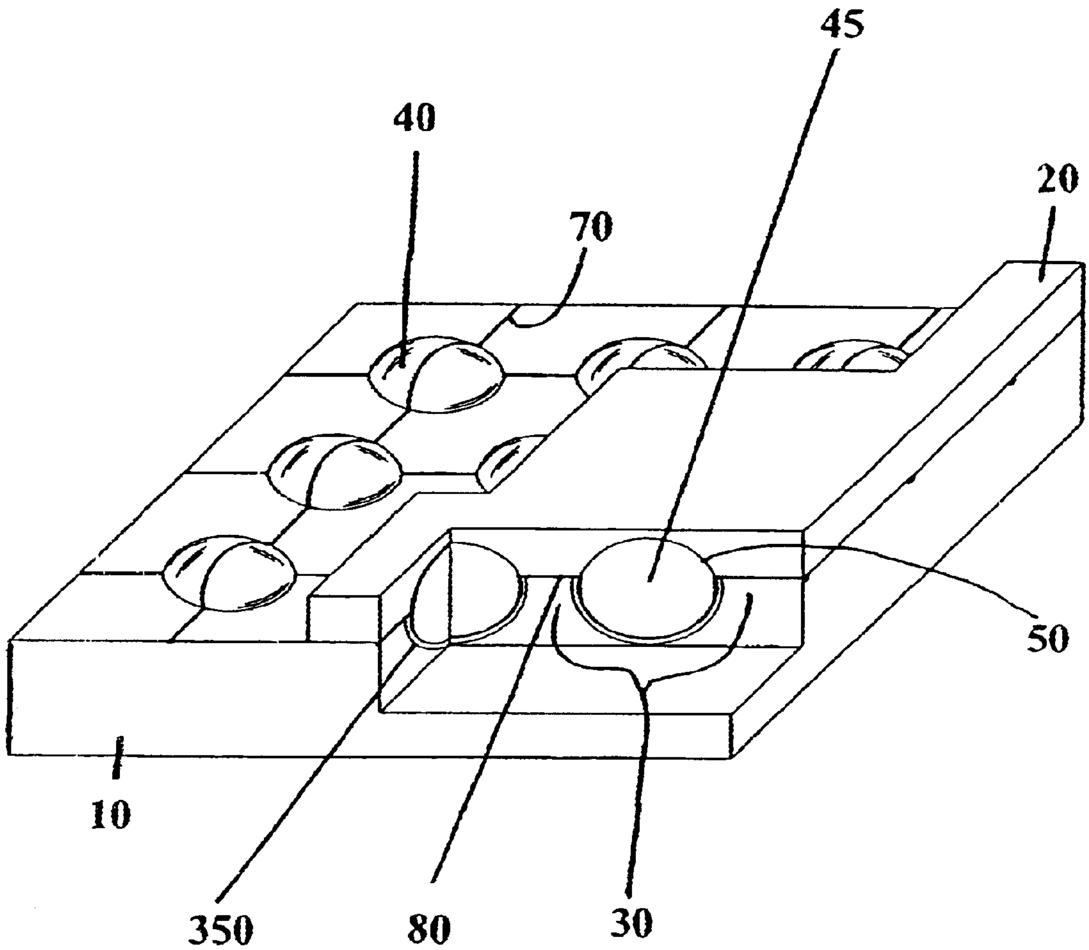
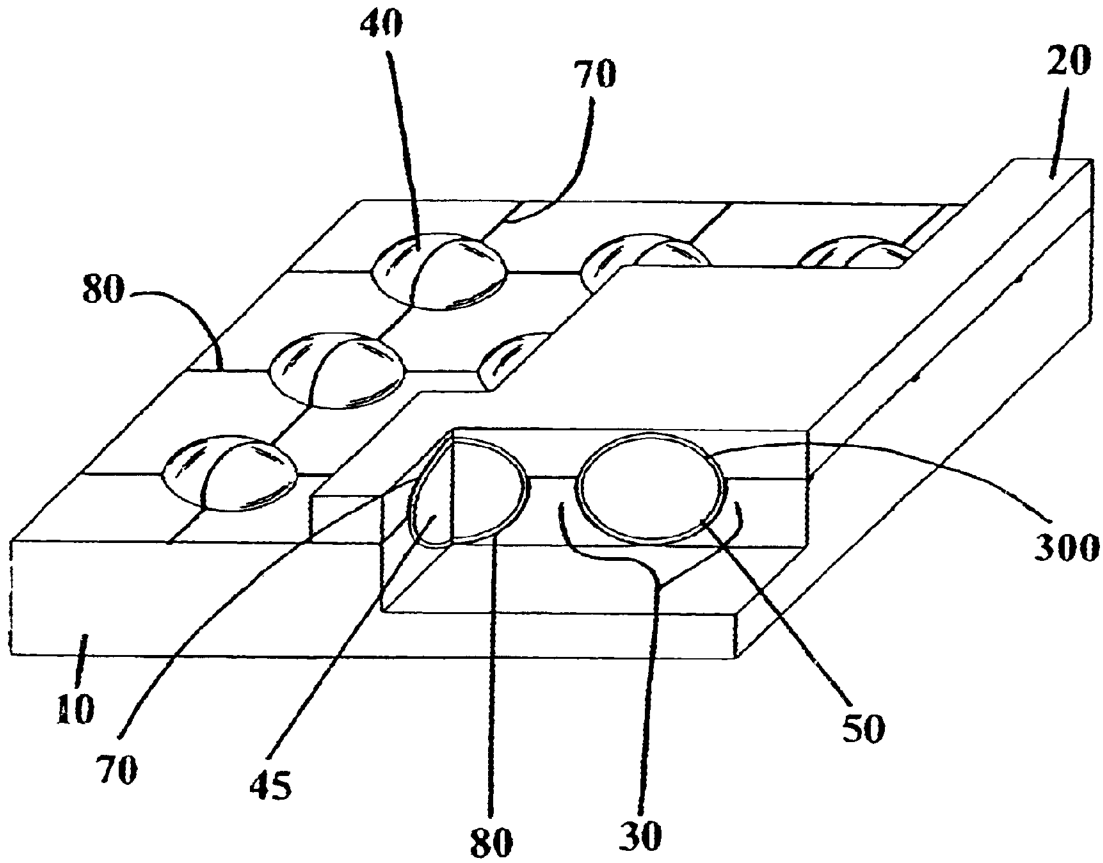


Fig. 2



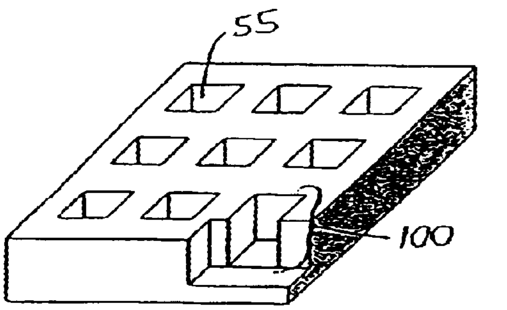



Fig. 3 A

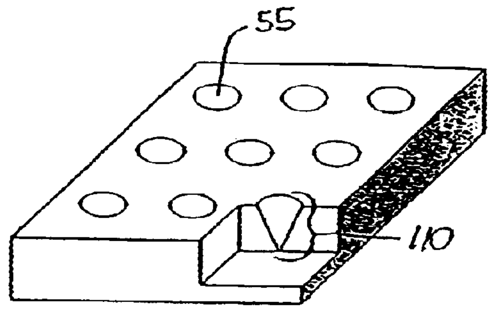



Fig. 3 B

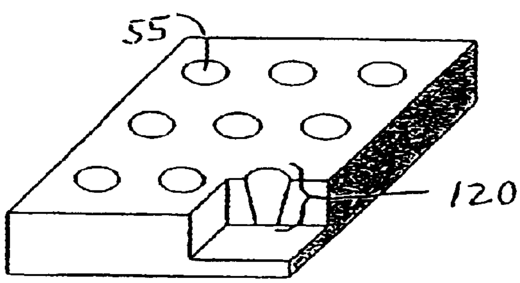



Fig. 3C

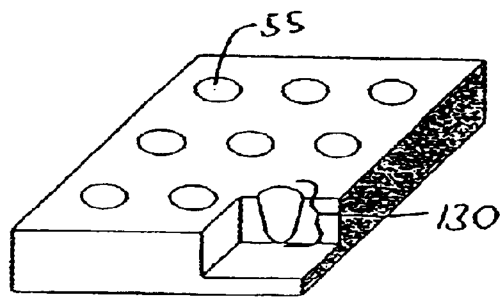



Fig 3D

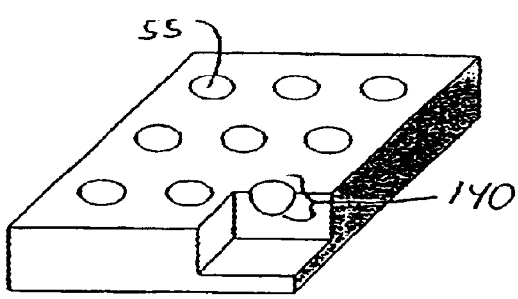



Fig 3E

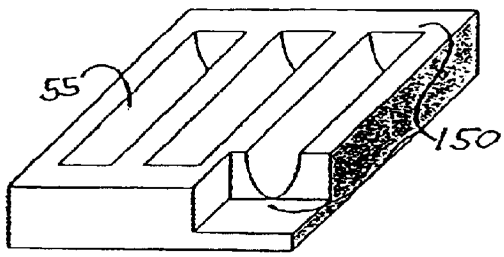
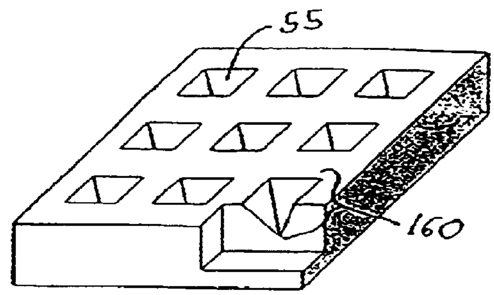


Fig. 3F



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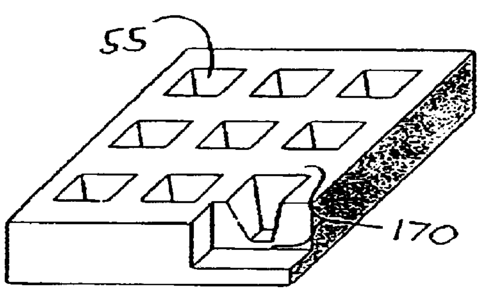

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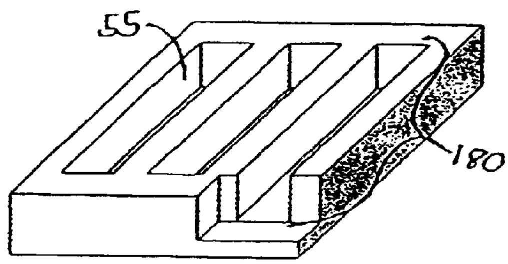


Fig. 3I

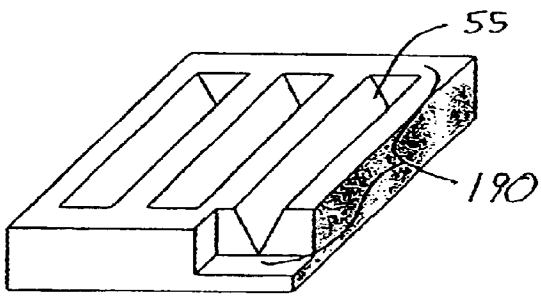


Fig. 3J

Fig. 4

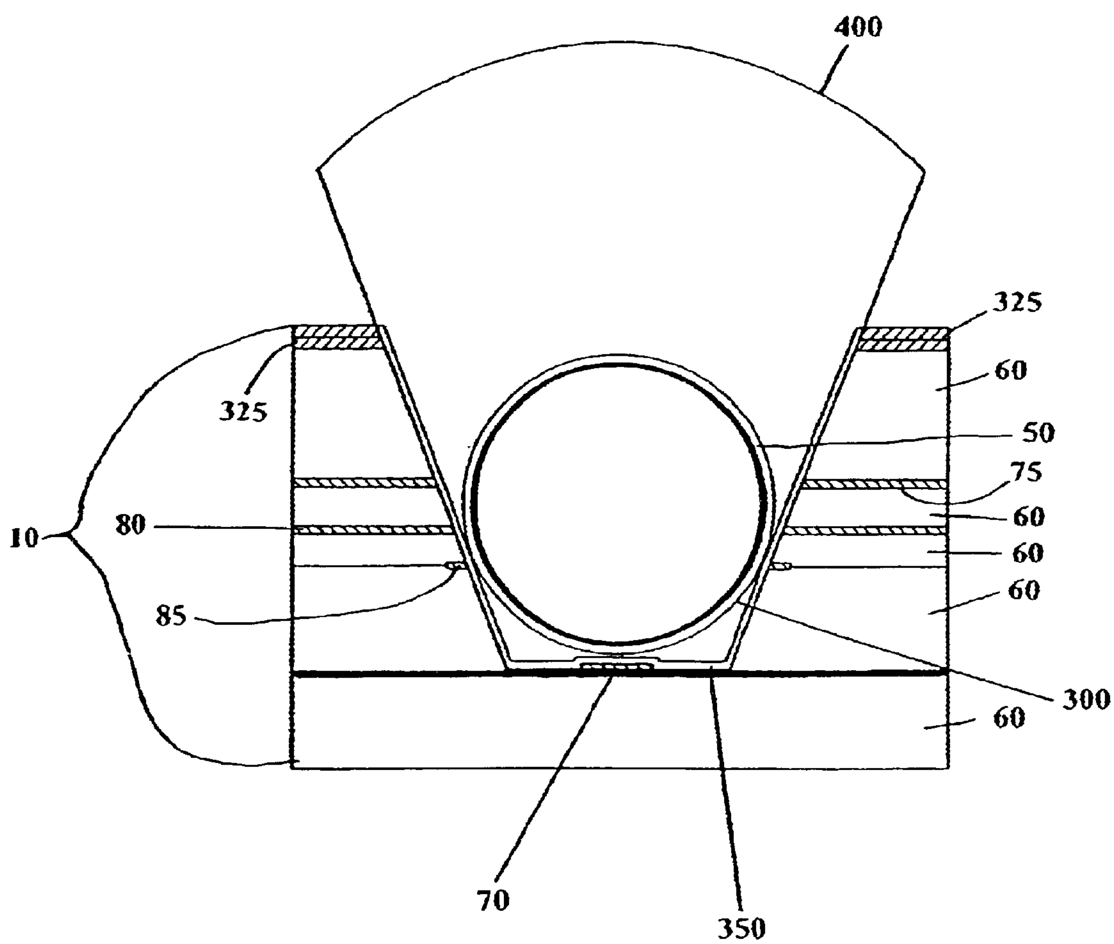


Fig. 5

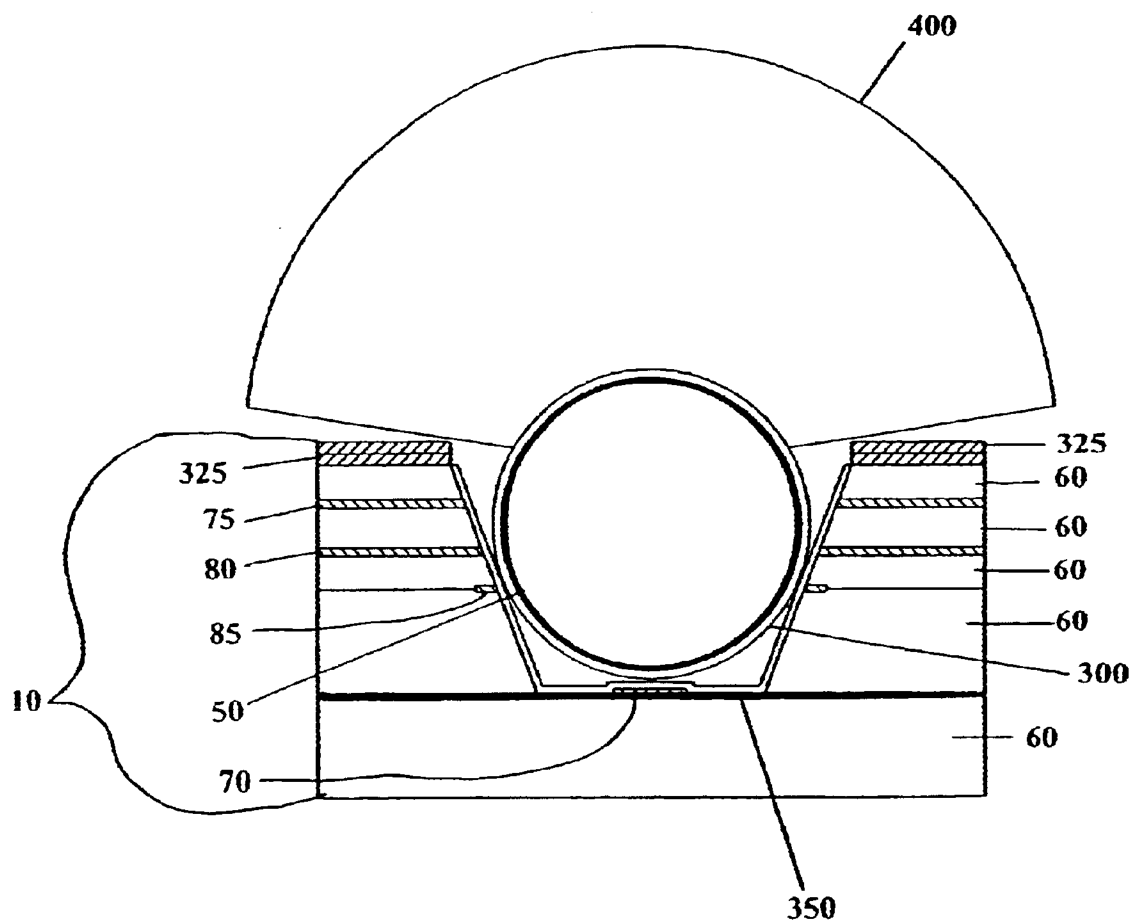


Fig. 6A

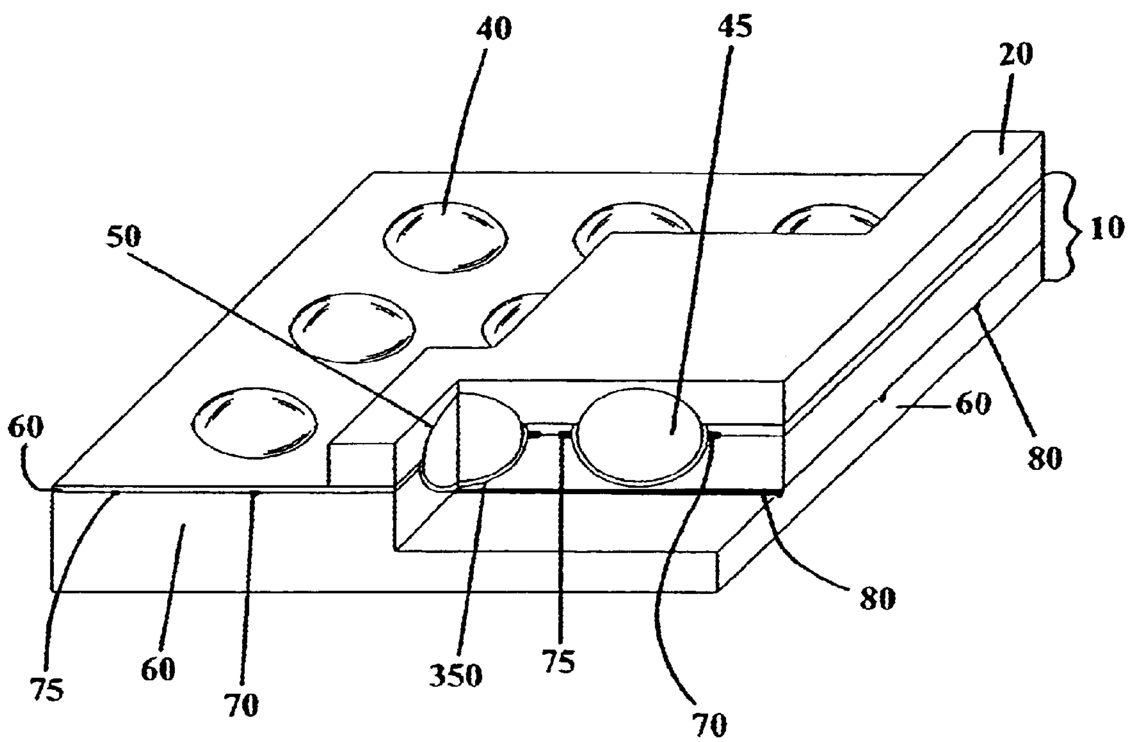


Fig. 6B

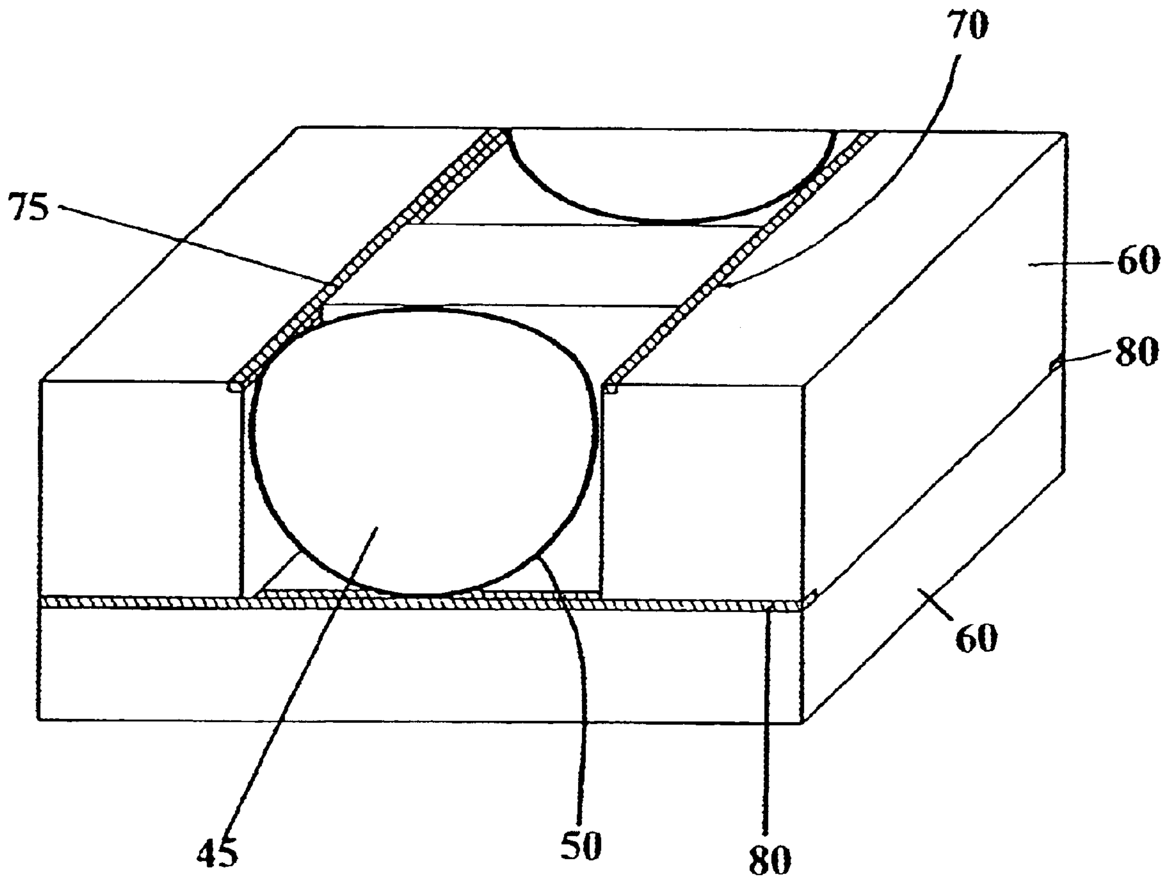


Fig. 7A

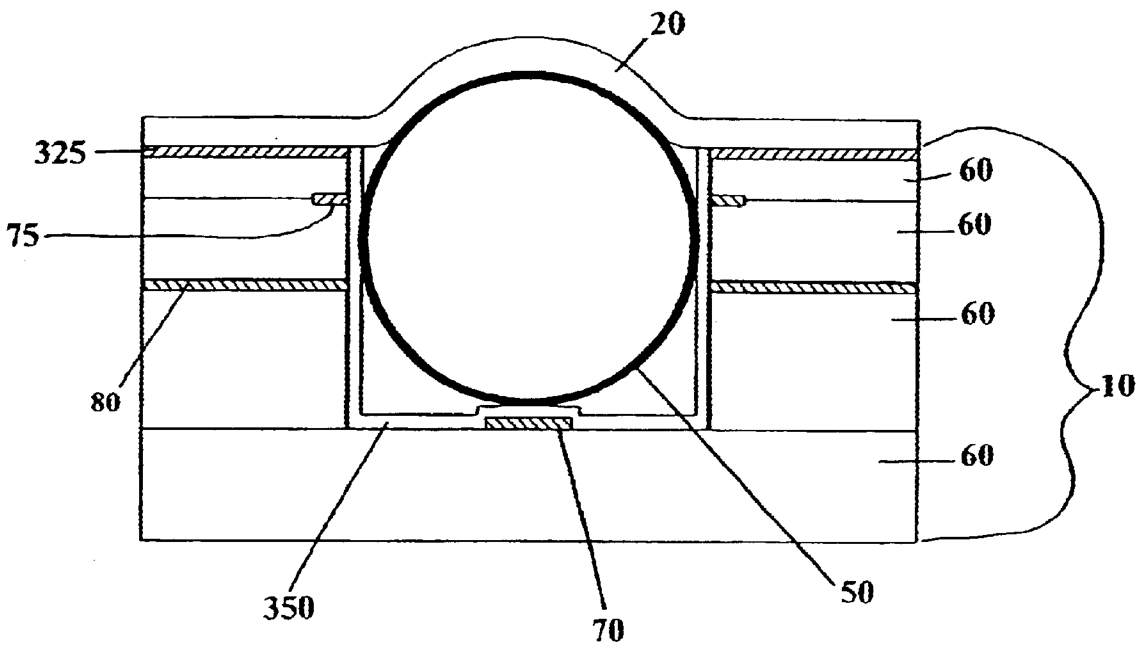


Fig. 7B

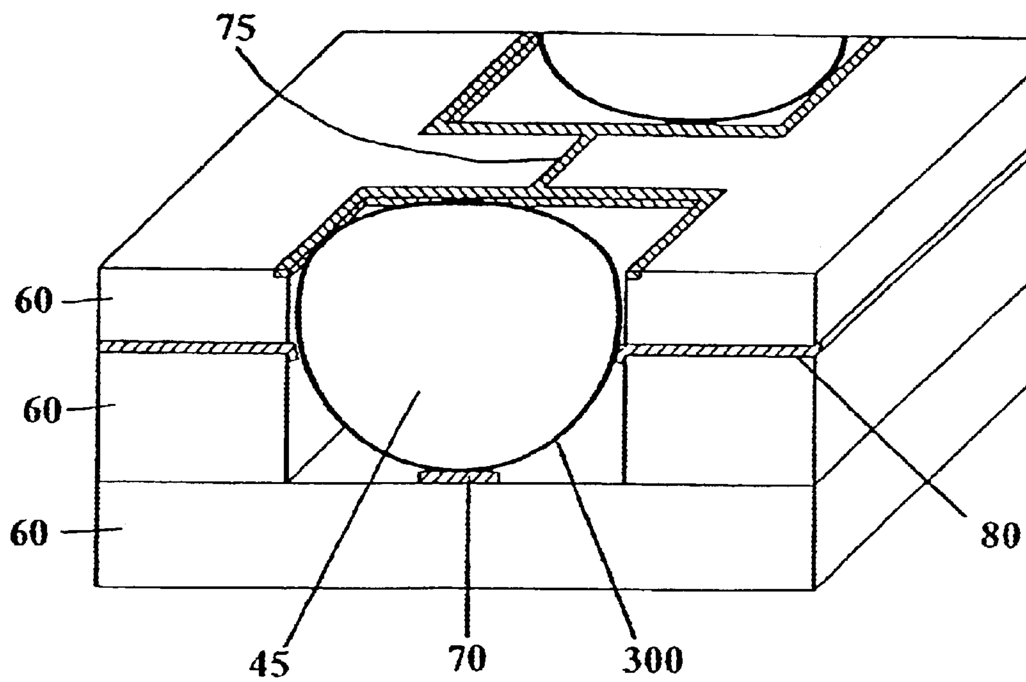


Fig. 8

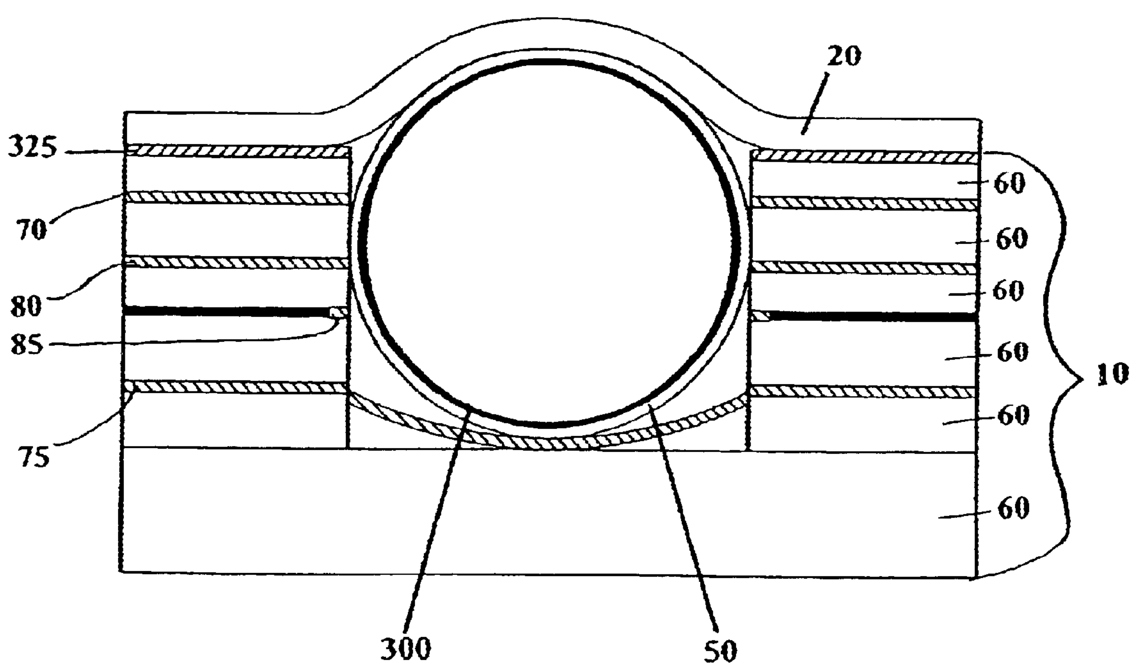


Fig. 9

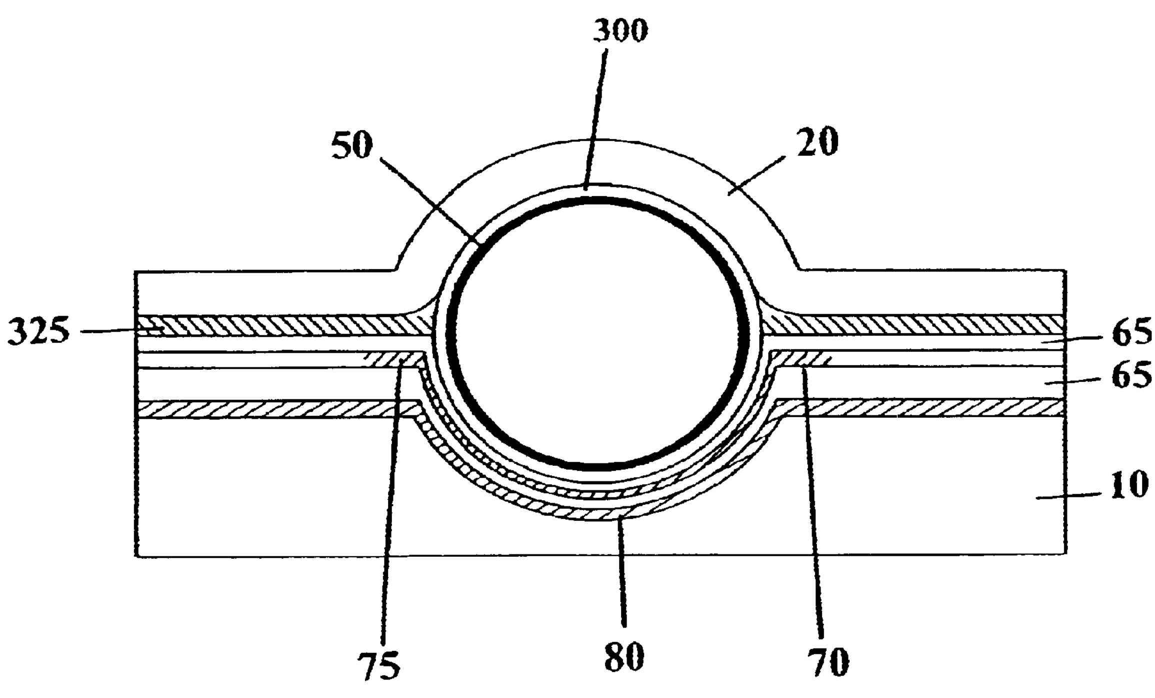


Fig. 10

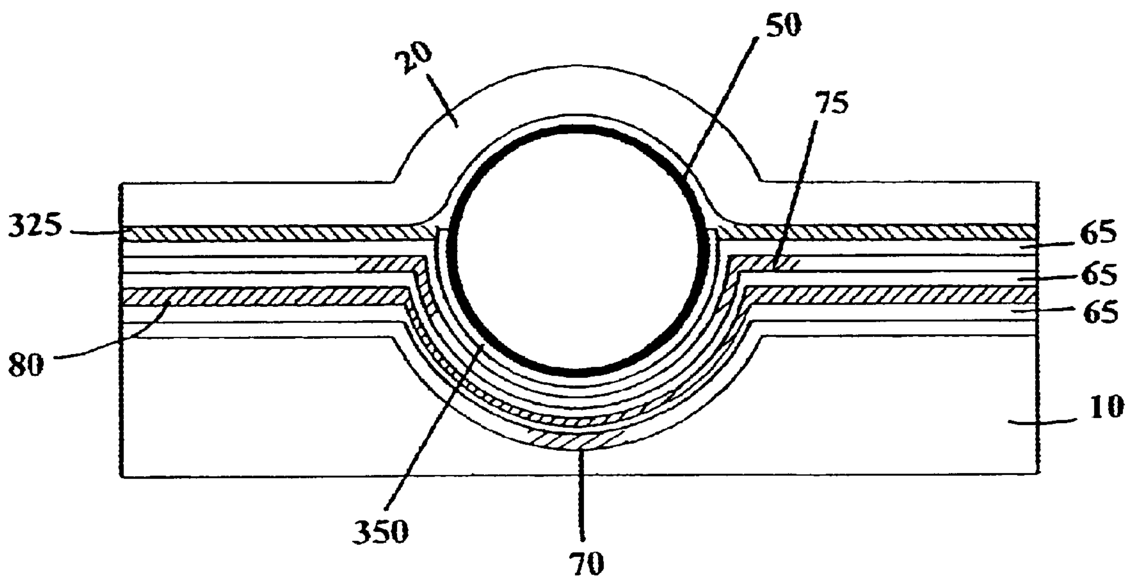
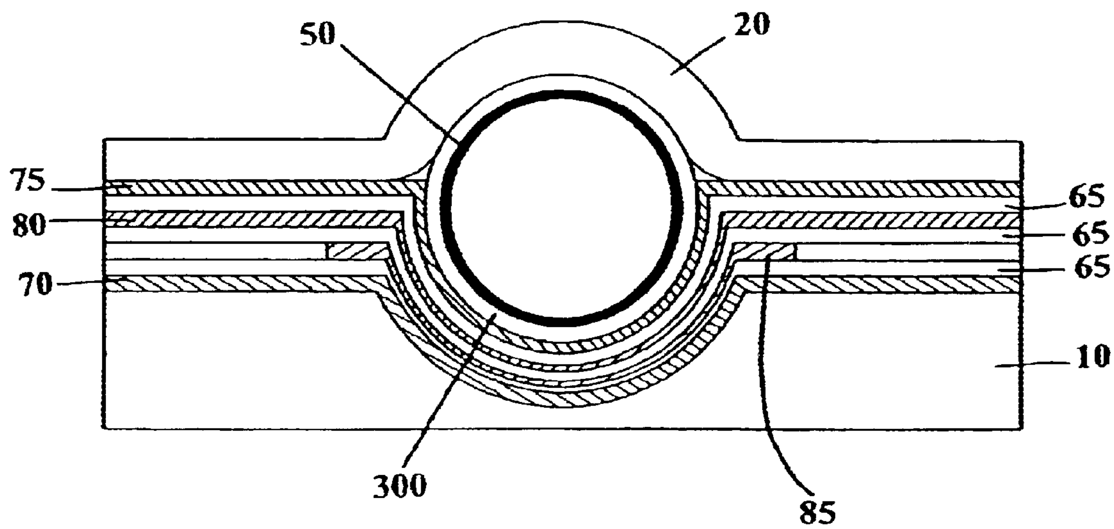


Fig. 11



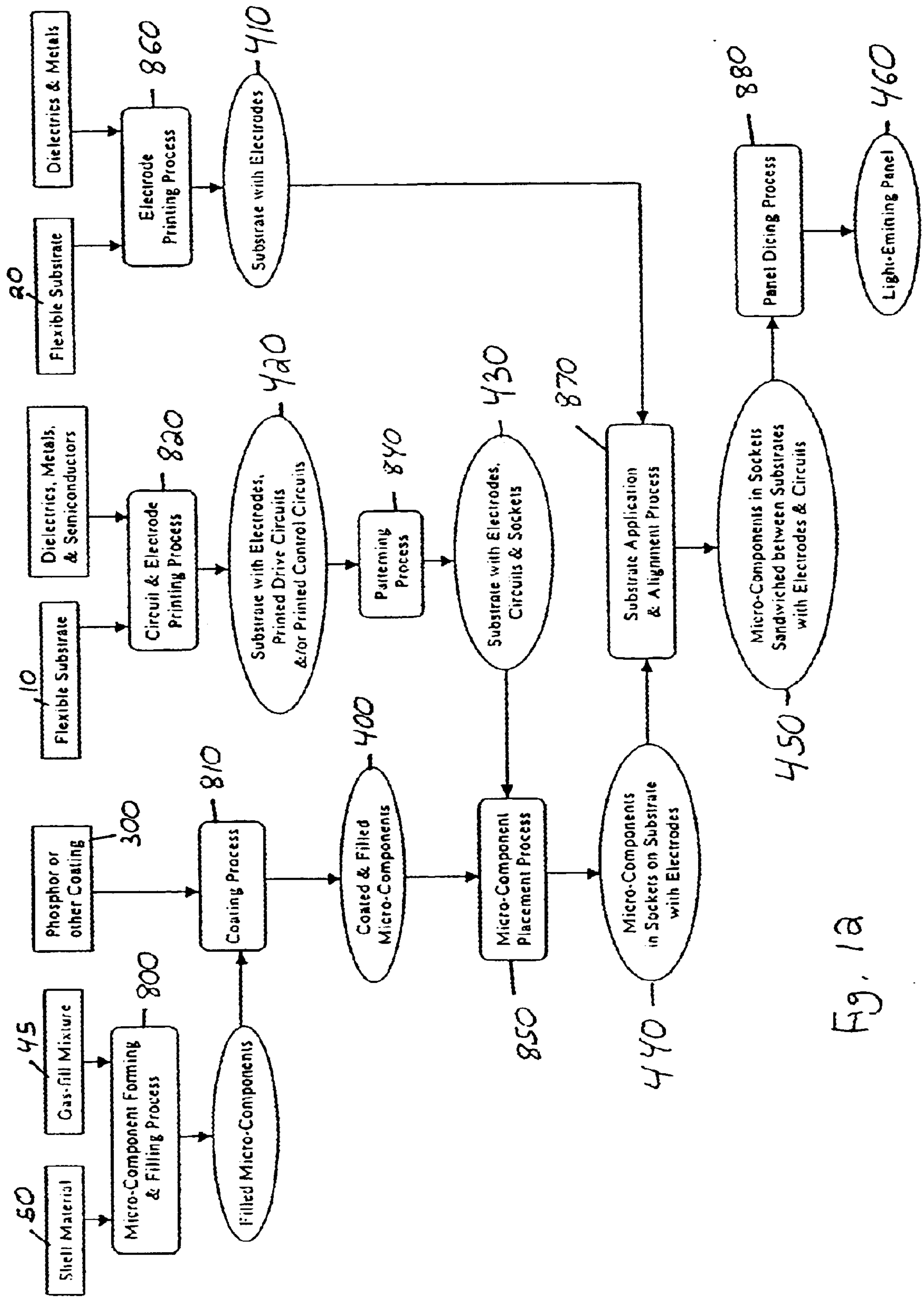
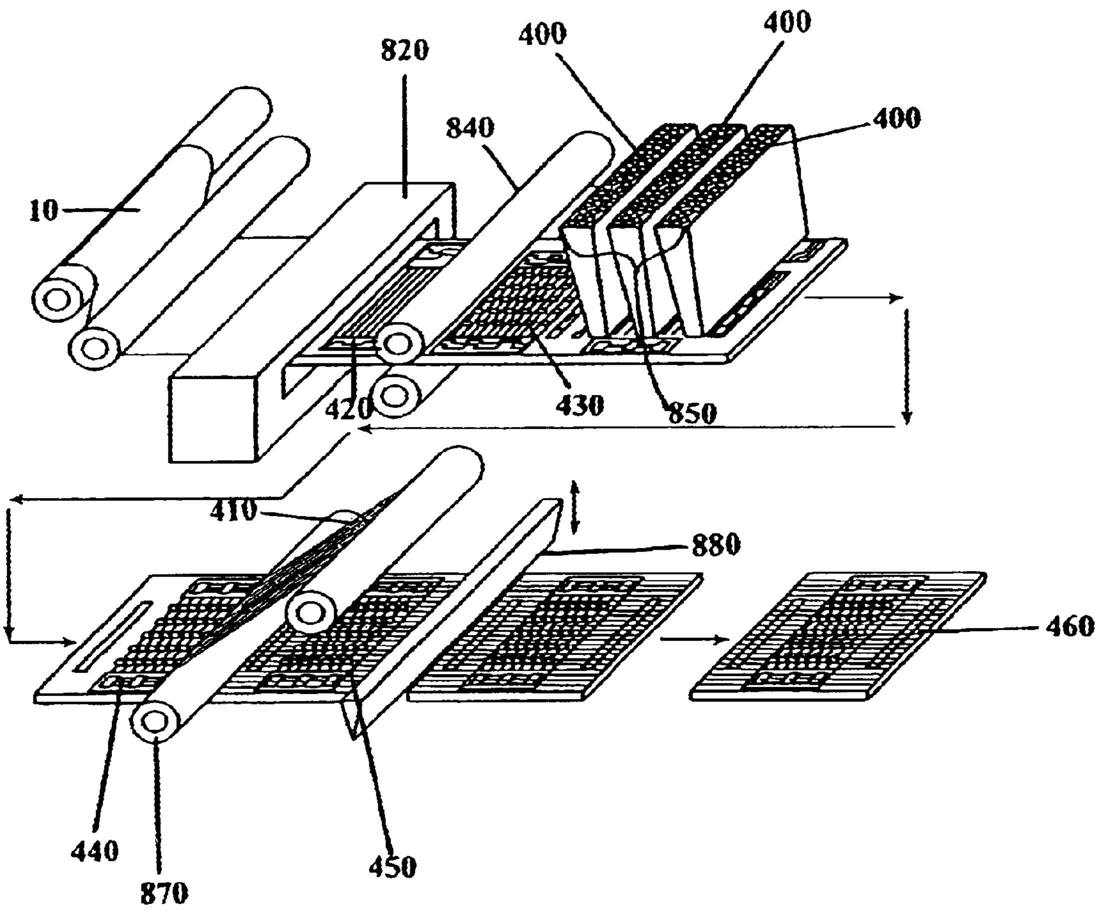

Shell Material
50
Gas-fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits &/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched between Substrates with Electrodes & Circuits
450
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Panel Dicing Process
880
Light-Emitting Panel
460

Fig. 1a

Fig. 13



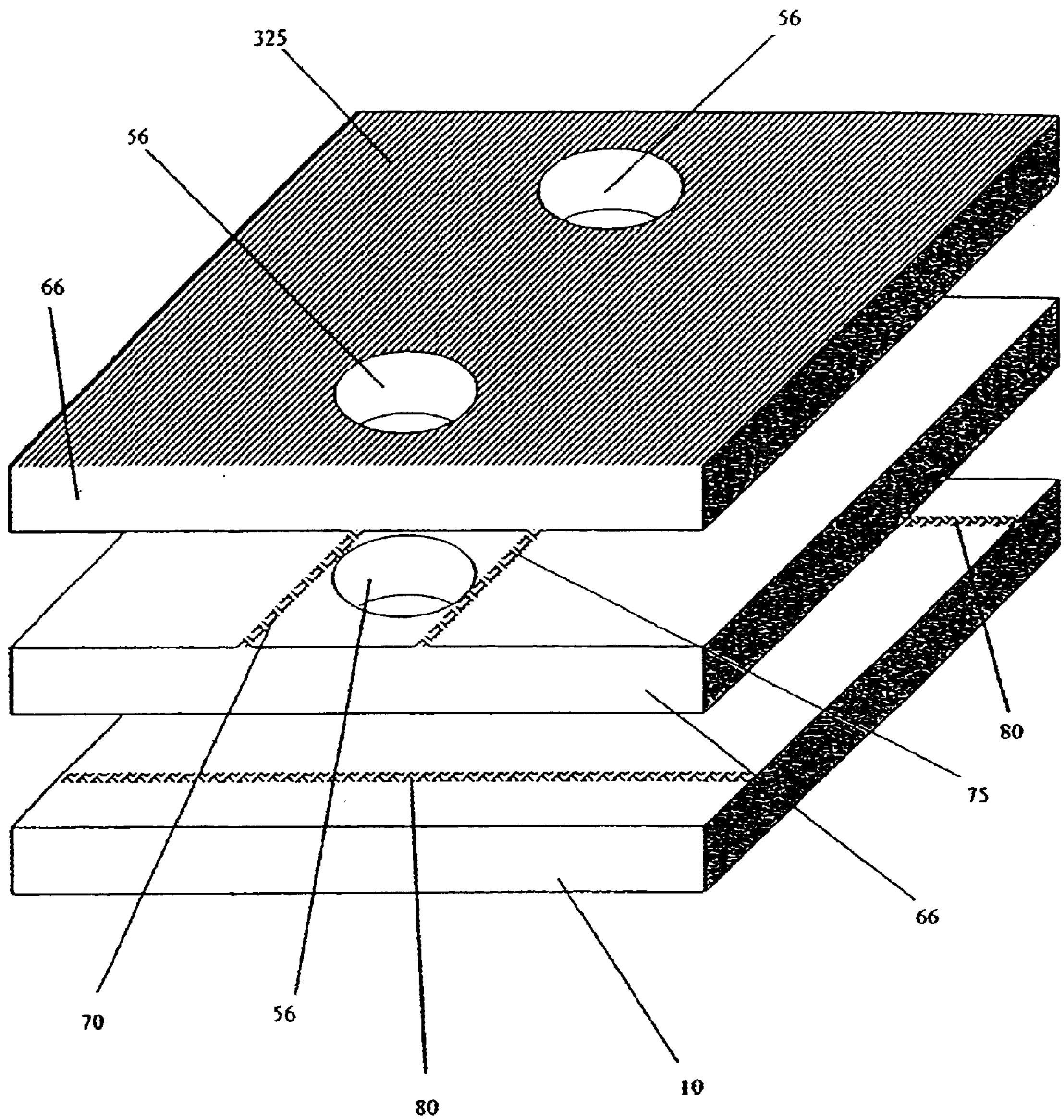



Fig. 14

Fig. 15

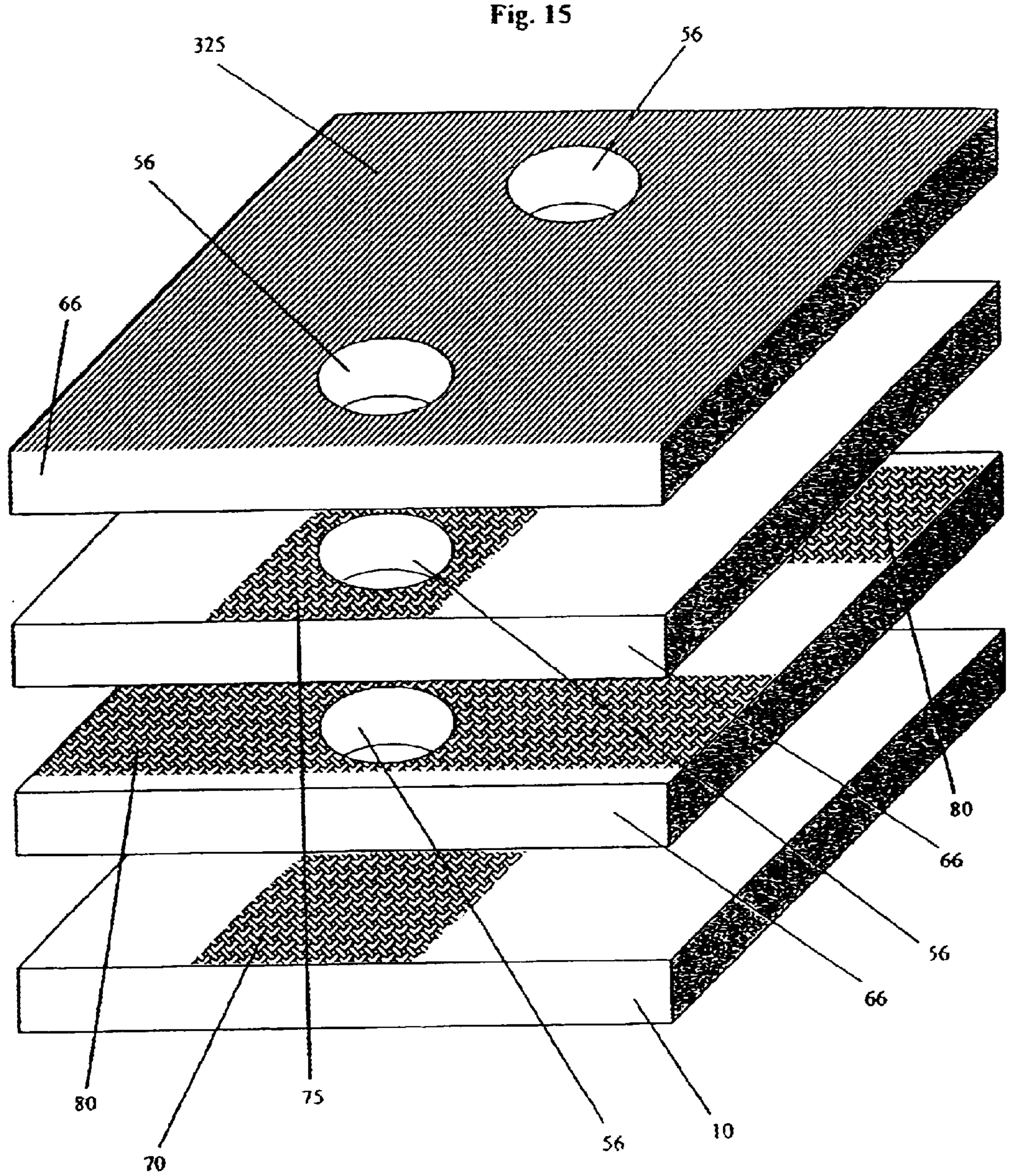


Fig. 16

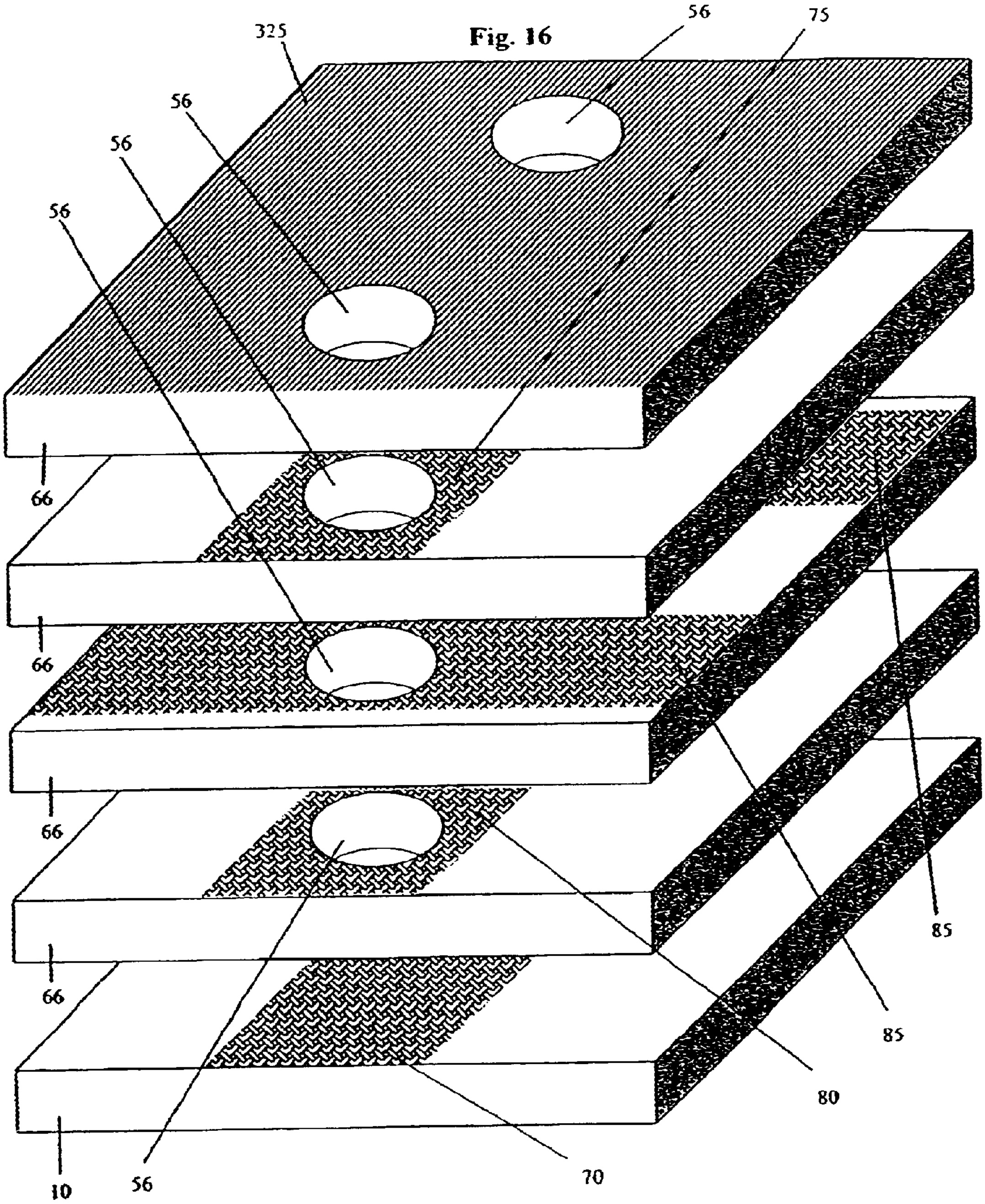


Fig. 17

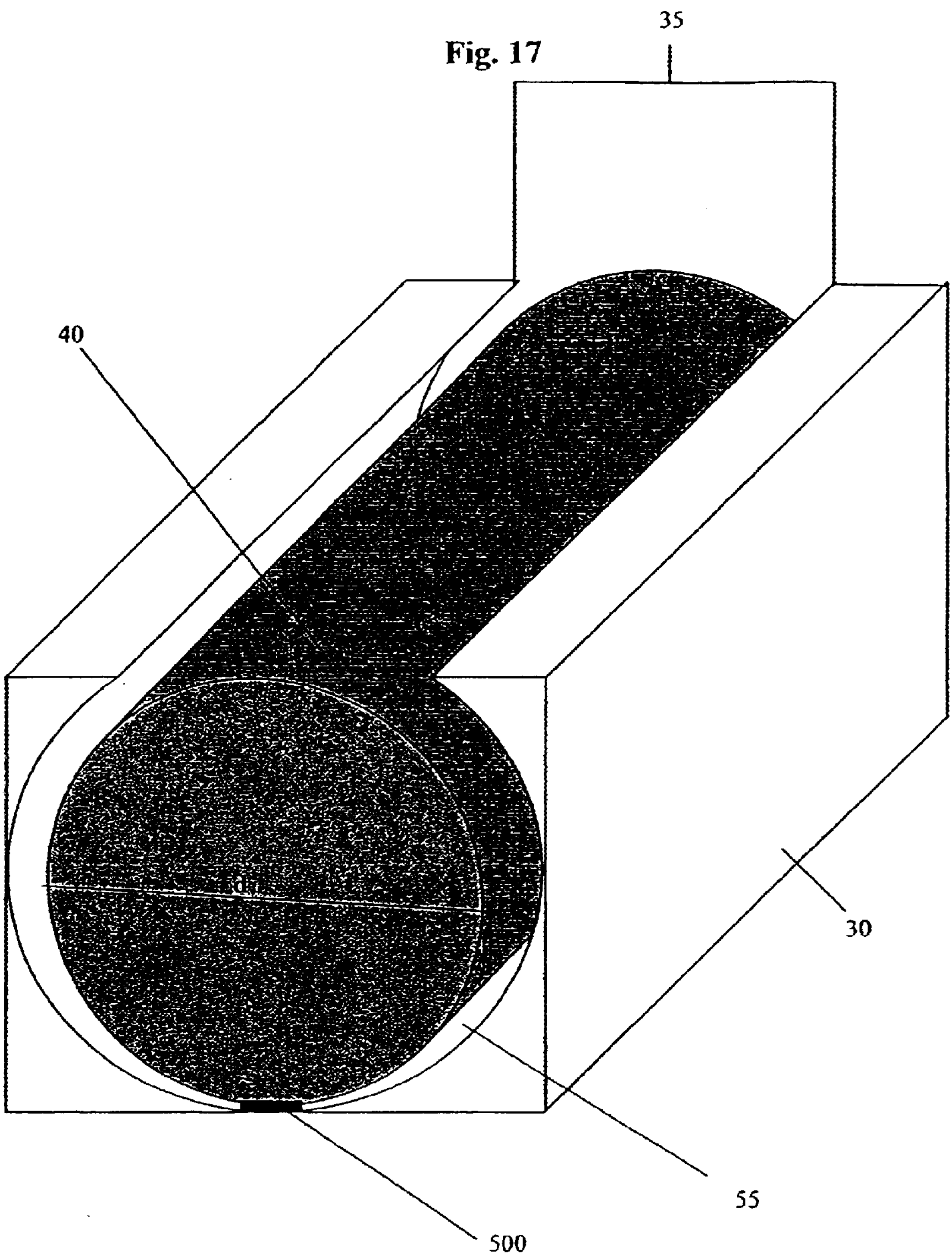


Fig. 18

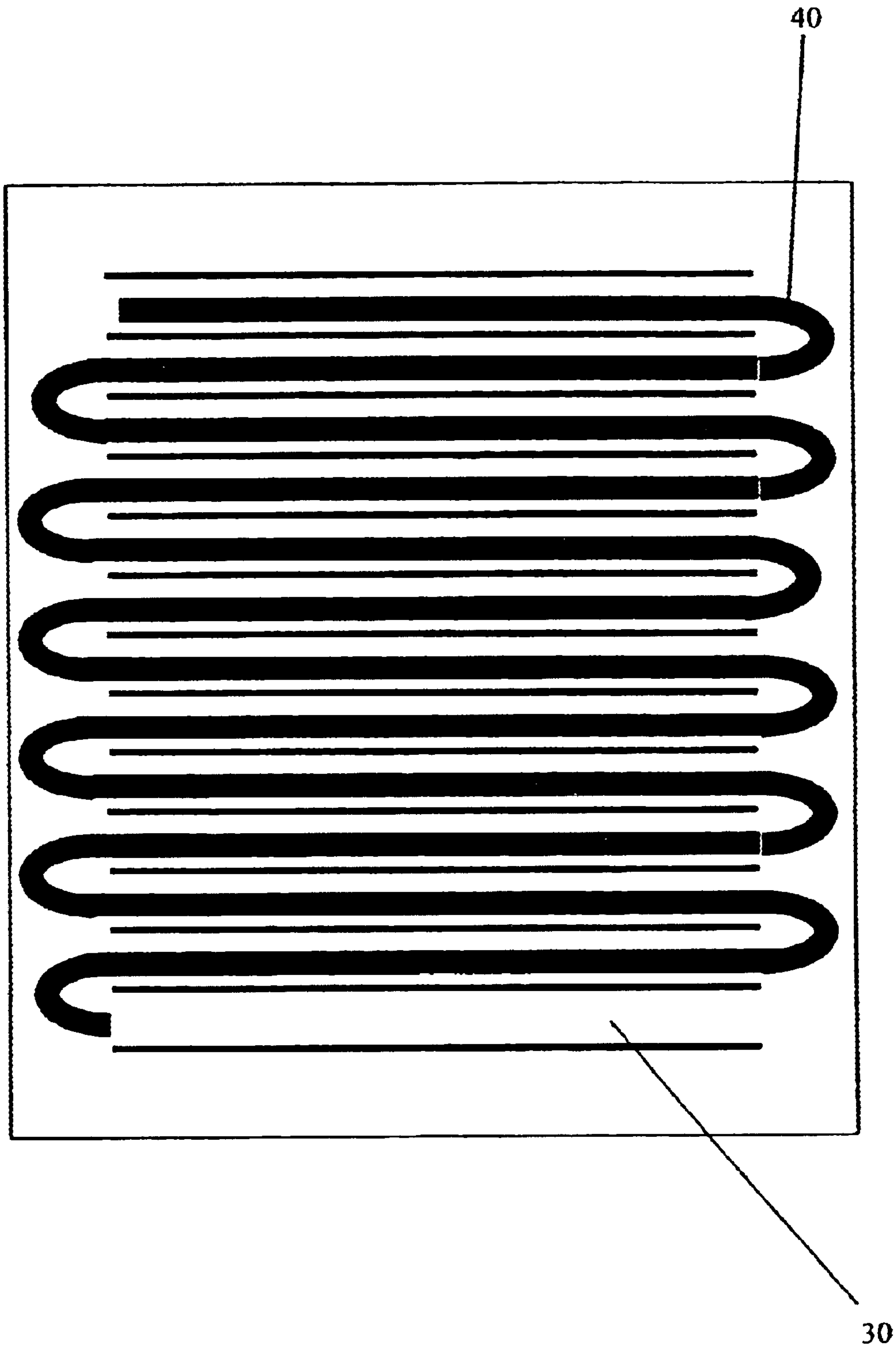
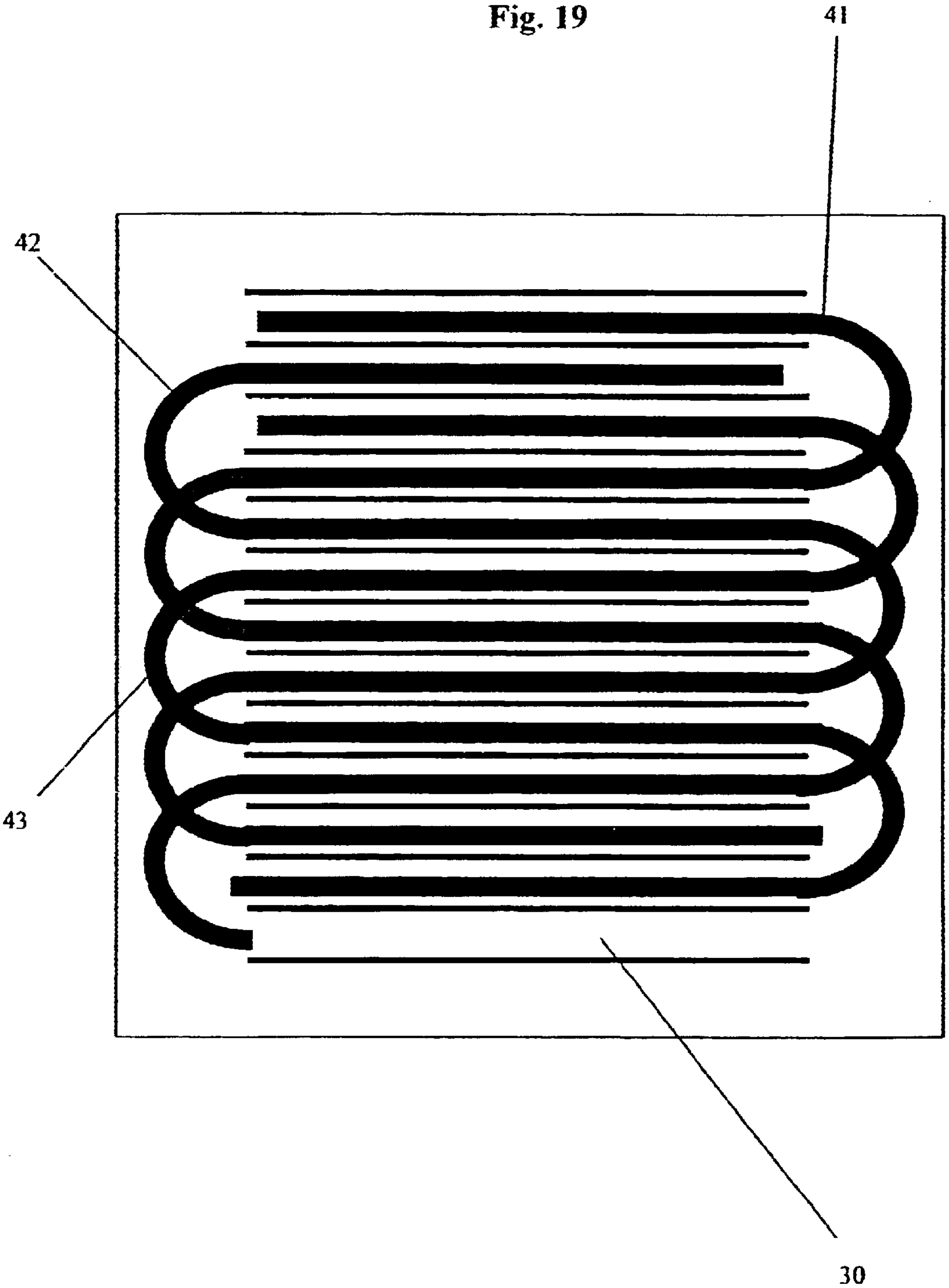


Fig. 19



# METHOD FOR MAKING A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,358 entitled *A Micro-Component for Use in a Light-Emitting Panel* filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled *A Method for Testing a Light-Emitting Panel and the Components Therein* filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled *A Method and System for Energizing a Micro-Component In a Light-Emitting Panel* filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,346 entitled *A Socket for Use in a Light-Emitting Panel* filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates.

This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.



## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In another embodiment of the present invention, at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, at least two electrodes are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In yet another embodiment, disposed in, or proximate to, each socket is at least one enhancement material.

Another preferred embodiment of the present invention is drawn to a web fabrication method for manufacturing light-emitting panels. In an embodiment, the web fabrication process includes providing a first substrate, disposing a plurality of micro-components on the first substrate, disposing a second substrate on the first substrate so the at the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrates to form individual light-emitting panels. In another embodiment, the web fabrication method includes the following process steps: a micro-component forming process; a micro-component coating process; a circuit and electrode printing process; a patterning process; a micro-component placement process; an electrode printing process; a second substrate application and alignment process; and a panel dicing process.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6A**, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6B** is a cut-away of FIG. **6A** showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7A**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7B** is a cut-away of FIG. **7A** showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the fist substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17**, and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

1. A web fabrication process for manufacturing a plurality of light-emitting panels, the process comprising the steps of:

providing a first substrate;

disposing a plurality of micro-components on the first substrate;

disposing a second substrate over the first substrate such that the plurality of micro components are sandwiched between the first substrate and the second substrate; and dicing the first substrate and the second substrate to form individual light-emitting panels.

2. The process of claim 1, wherein the first substrate, the second substrate or the first substrate and the second substrate are provided as rolls of material.

3. The process of claim 1, wherein the first substrate comprises a plurality of sockets.

4. The process of claim 1, further comprising the step of disposing at least two electrodes on the first substrate, the second substrate, or at least one electrode on each of the first substrate and the second substrate.

5. The process of claim 4, wherein each light-emitting panel comprises the at least two electrodes, wherein the at least two electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to each of the first substrate and the second substrate, and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

6. The process of claim 4, wherein each light-emitting panel comprises the at least two electrodes and wherein the two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout the field of view of the individual light-emitting panel without crossing the at least two electrodes.

7. The process of claim 1, further comprising the steps of forming a plurality of sockets in the first substrate and wherein the step of disposing a plurality of micro-components on the first substrate further comprises at least partially disposing at least one micro-component of the plurality of micro-components in each socket of the plurality of sockets.

8. The process of claim 7, wherein the first substrate comprises a plurality of material layers and wherein the step of forming a plurality of sockets in the first substrate comprises the steps of selectively removing a plurality of portions of the material layers to form a plurality of cavities.

9. The process of claim 7, wherein the step of forming a plurality of sockets in the first substrate comprises the steps of patterning the first substrate with a plurality of cavities.

10. The process of claim 9, further comprising the steps of disposing at least one material layer on the first substrate so that the at least one material layer conforms to the shape of each socket of the plurality of sockets and disposing at least one electrode between the first substrate and the at least one material layer.

11. The process of claim 9, further comprising the steps of disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to the shape of each socket of the plurality of sockets and disposing at least one electrode within the plurality of material layers.

12. The process of claim 7, wherein the step of providing a first substrate comprises the step of forming a first substrate by disposing a plurality of material layers and wherein the step of forming a plurality of sockets in the first substrate further comprises the step of selectively removing a plurality of portions of the material layers to form a plurality of cavities.

13. The process of claim 12, further comprising the step of disposing at least one electrode on the first substrate, the second substrate, or the first substrate and the second substrate.

14. The process of claim 13, wherein the at least one electrode is sandwiched between two material layers of the plurality of material layers.

15. The process of claim 1, further comprising the step of disposing at least one enhancement material in, or proximate to, each socket.

16. The process of claim 15, wherein the at least on enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

17. The process of claim 16, wherein the step of disposing the at least one enhancement material in or proximate to each socket comprises the steps of:

suspending the at least one enhancement material in liquid; and

flowing the liquid over the first substrate such that the at least one enhancement material settles in each socket.

18. The process of claim 16, wherein the sockets are of a corresponding shape to the at least one enhancement material and wherein the at least one enhancement material self-aligns in each socket.

19. The process of claim 16, further comprising the step of disposing a plurality of control electronics or drive electronics on the first substrate, the second substrate, or the first substrate and the second substrate.

20. The process of claim 16, wherein the web fabrication process is performed as a continuous high-speed inline process.

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US006620012B1

(12) **United States Patent**
**Johnson et al.**

(10) **Patent No.:** **US 6,620,012 B1**
(45) **Date of Patent:** **Sep. 16, 2003**

(54) **METHOD FOR TESTING A LIGHT-EMITTING PANEL AND THE COMPONENTS THEREIN**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 34 days.

(21) Appl. No.: **09/697,498**

(22) Filed: **Oct. 27, 2000**

(51) **Int. Cl.**[7] .................................................. **H01J 9/24**
(52) **U.S. Cl.** ............................................. **445/3**; 445/24
(58) **Field of Search** ...................................... 445/24, 25

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,559,190 A 1/1971 Blitzer et al. ............... 340/173
3,646,384 A 2/1972 Lay ......................... 313/109.5
3,704,052 A 11/1972 Coleman ..................... 316/17

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

JP 4-287397 10/1992 ............ H05K/9/00
JP 10-3869 1/1998 ............ H01J/31/12

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alien-technology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fludic Self Assembly,* Alien Technology Corp., Oct. 1999, pp. 1–7.

Rauf, S., Kushner, M.J., *Operation of a Coplanar–Electrode Plasma Display Panel Cell,* IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10–11.

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

JP 4-287397 10/1992 ............ H05K/9/00
JP 10-3869 1/1998 ............ H01J/31/12

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alien-technology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fludic Self Assembly,* Alien Technology Corp., Oct. 1999, pp. 1–7.

Rauf, S., Kushner, M.J., *Operation of a Coplanar–Electrode Plasma Display Panel Cell,* IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10–11.

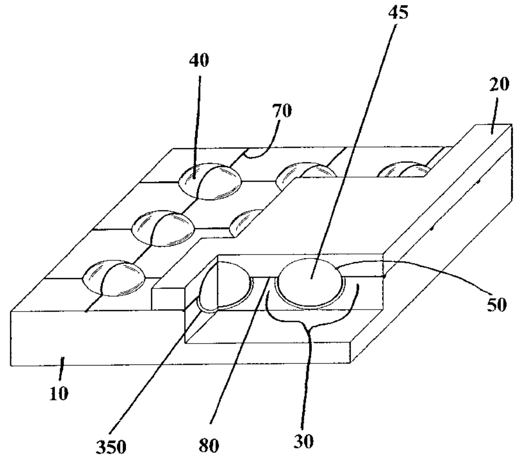
(List continued on next page.)

*Primary Examiner*—Kenneth J. Ramsey
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. A method of testing a light-emitting panel and the component parts therein is also disclosed, which uses a web fabrication process to manufacturing light-emitting panels combined with inline testing after the various process steps of the manufacturing process to produce result which are used to adjust the various process steps and component parts.

**29 Claims, 19 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,755,027 A | | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | | 7/1976 | Greeson, Jr. | |
| 3,990,068 A | | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | | 7/1977 | Roeber | 335/169 TV |
| 4,303,433 A | | 12/1981 | Torobin | 65/21.4 |
| 4,393,326 A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 A | | 11/1985 | Dick | 340/775 |
| 4,563,617 A | * | 1/1986 | Davidson | 313/522 |
| 4,591,847 A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 A | | 3/1987 | Shelton | 315/111.71 |
| 4,697,123 A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 A | | 3/1988 | Dick | |
| 4,833,463 A | | 5/1989 | Dick et al. | |
| 4,843,281 A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 A | | 12/1989 | Parker | 313/634 |
| 4,912,364 A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 A | | 7/1991 | Salavin et al. | |
| 5,062,916 A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 A | | 12/1991 | Deschamps et al. | |
| 5,126,632 A | | 6/1992 | Parker | 313/634 |
| 5,150,007 A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,837,221 A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 A | * | 1/1999 | Li | 700/108 |
| 5,865,657 A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 A | | 7/1999 | Jones | 257/40 |
| 5,945,174 A | | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 A | | 10/1999 | Kisner | 313/484 |
| 5,984,747 A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 A | | 3/2000 | Song | 349/43 |
| 6,039,619 A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,630 A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 A | | 6/2000 | Okajima | 313/581 |
| 6,080,606 A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,097,147 A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 B1 | | 9/2001 | Park et al. | 313/586 |
| 6,288,488 B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 B1 | | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 B1 | | 11/2001 | Amundson et al. | 438/99 |

OTHER PUBLICATIONS

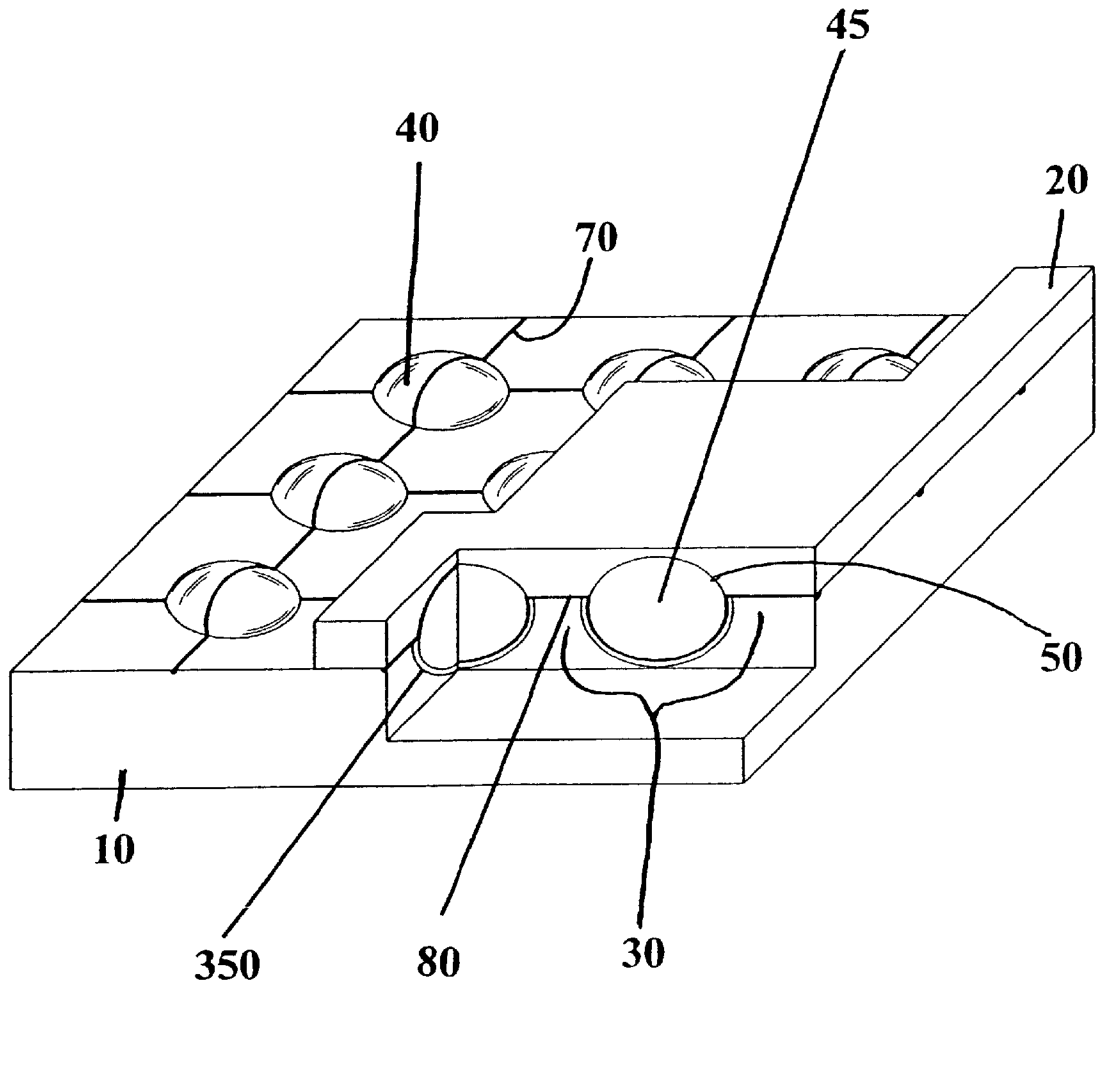
Shin, Y.K., Lee, J.K., Shon, C.H., *Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry,* IEEE Transactions on Plasma Science, vol. 27, No 1, Feb. 1999, pp. 14–15.

Kurihara, M. Makabe, T., *Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency,* IEEE Transactions on Plasma Science, vol. 27, No. 5, Oct. 1999, pp. 1372–1378.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.
"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.
"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.
"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.as?nSeqno=22.
"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.asp?nSeqno21.
"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.asp?nSeqNo=19&type=&word=.
"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.asp?nSeqNo=16&type=&word=.
"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [Retrieved on Nov. 7, 2001], 2 pp., retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.asp?nSeqNo=14&type=&word=.
"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e__read.asp?nSeqNo=13&type=&word.
"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001, [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.
"Runco PlasmaWall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.
"Runco PlasmaWall P1–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.
"Runco PlasmaWall™ PL–61cx" [online], Copyright 2002 [retrieved on Jan. 17, 2001], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report dated Sep. 23, 2002.
Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
Jacobson, et al., "The Last Book" [online], *IBM Systems Journal,* vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.
Peterson, "Rethinking Ink" [online], *Science News,* vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn__arc98/6__20__98/bob2.htm.
Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today,* Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.
"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http:www.rolltronics.com.
Preliminary Examination Report for Application No. PCT/US01/42787, dated Jun. 4, 2003 (mailing date).

* cited by examiner

Fig. 1



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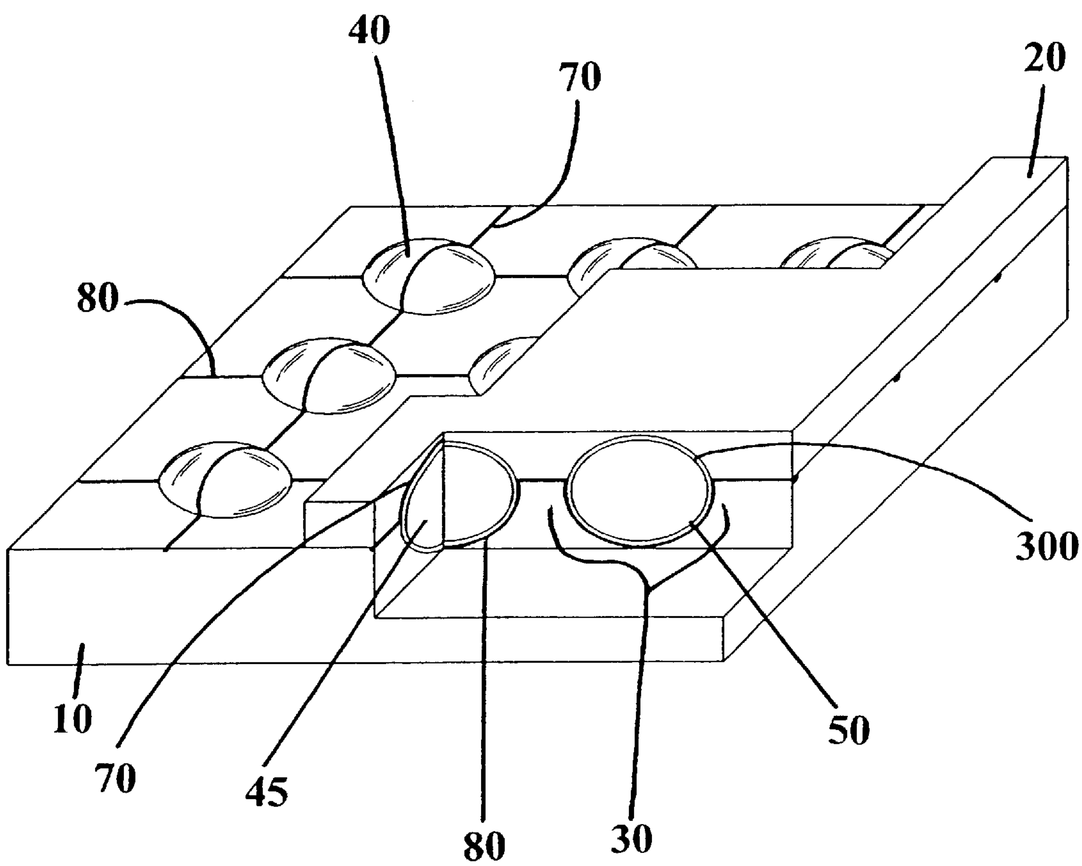

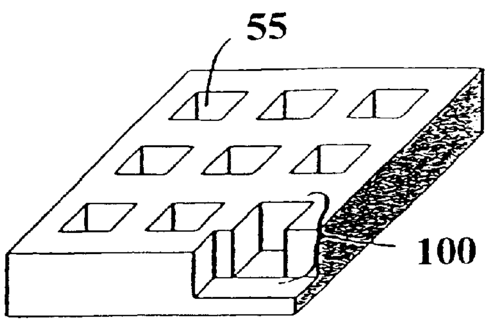


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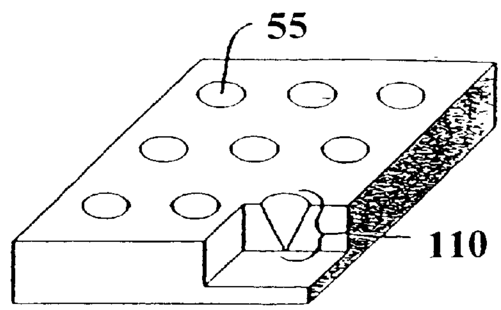


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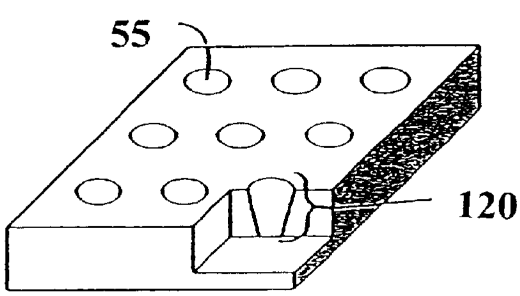


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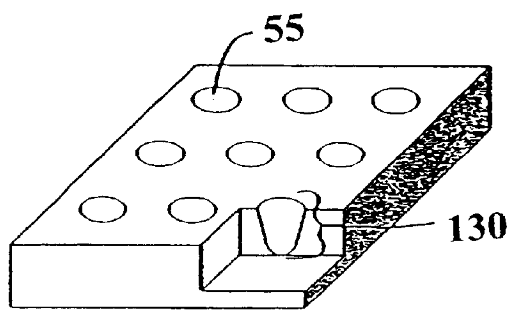


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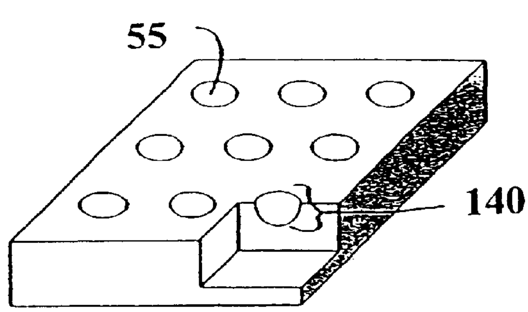


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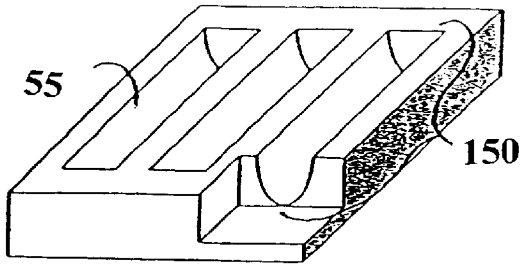


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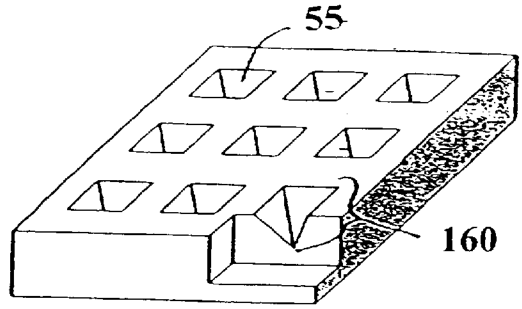


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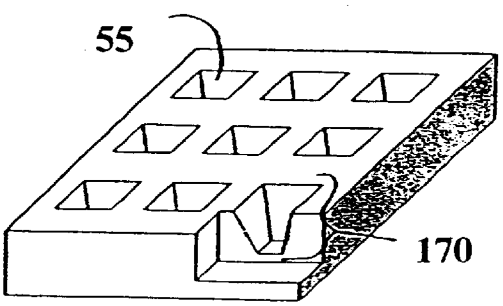


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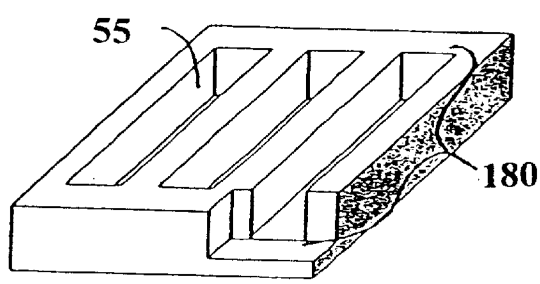


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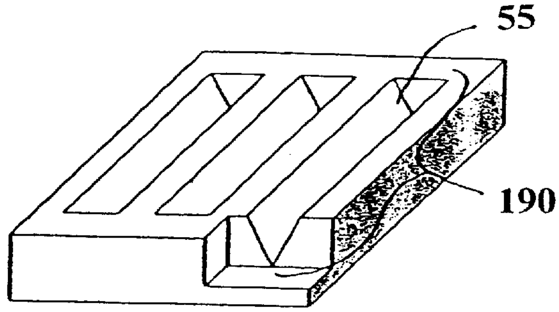
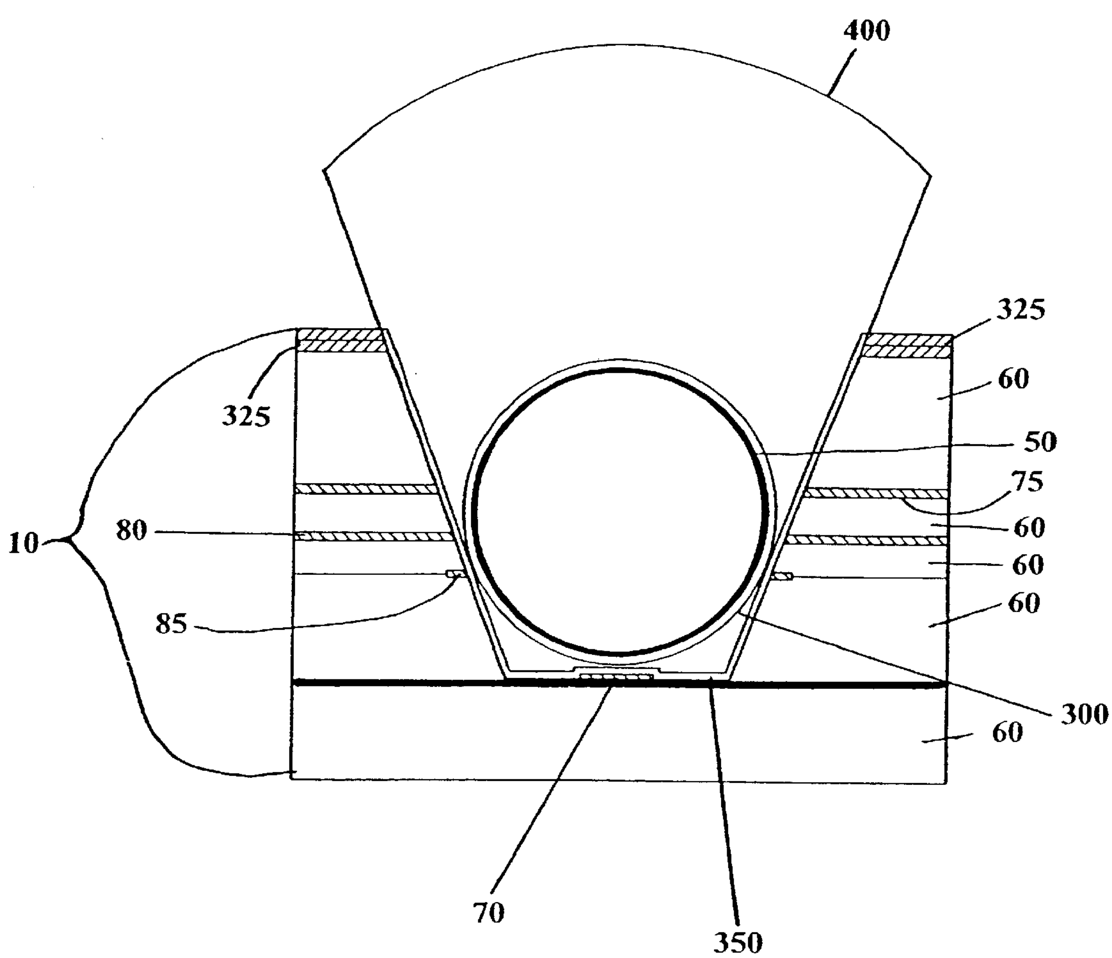



Fig. 3J

Fig. 4



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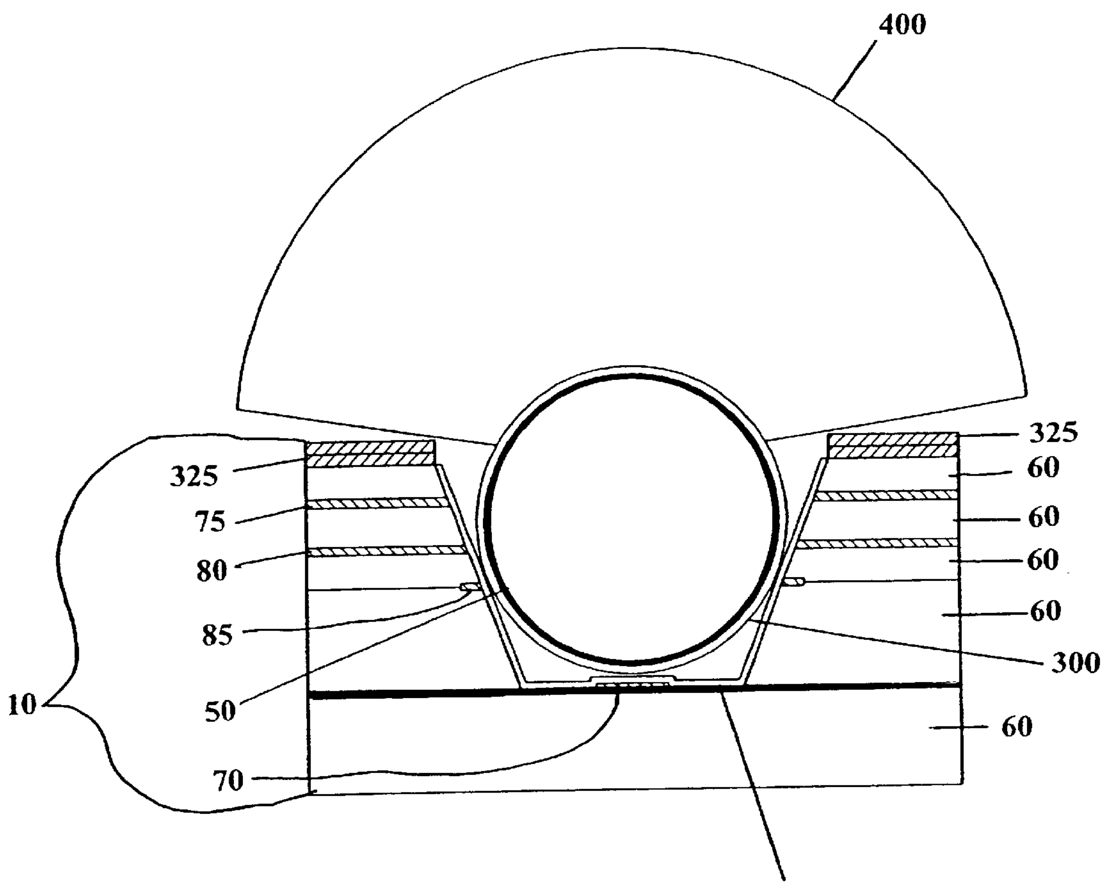

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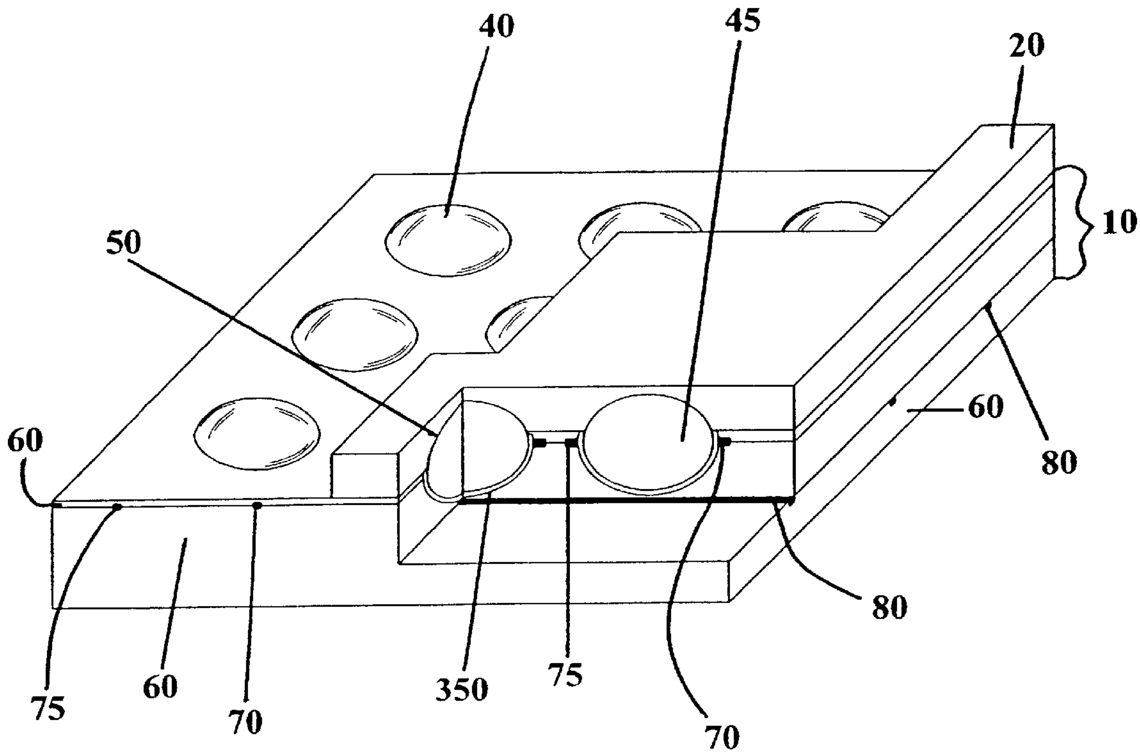

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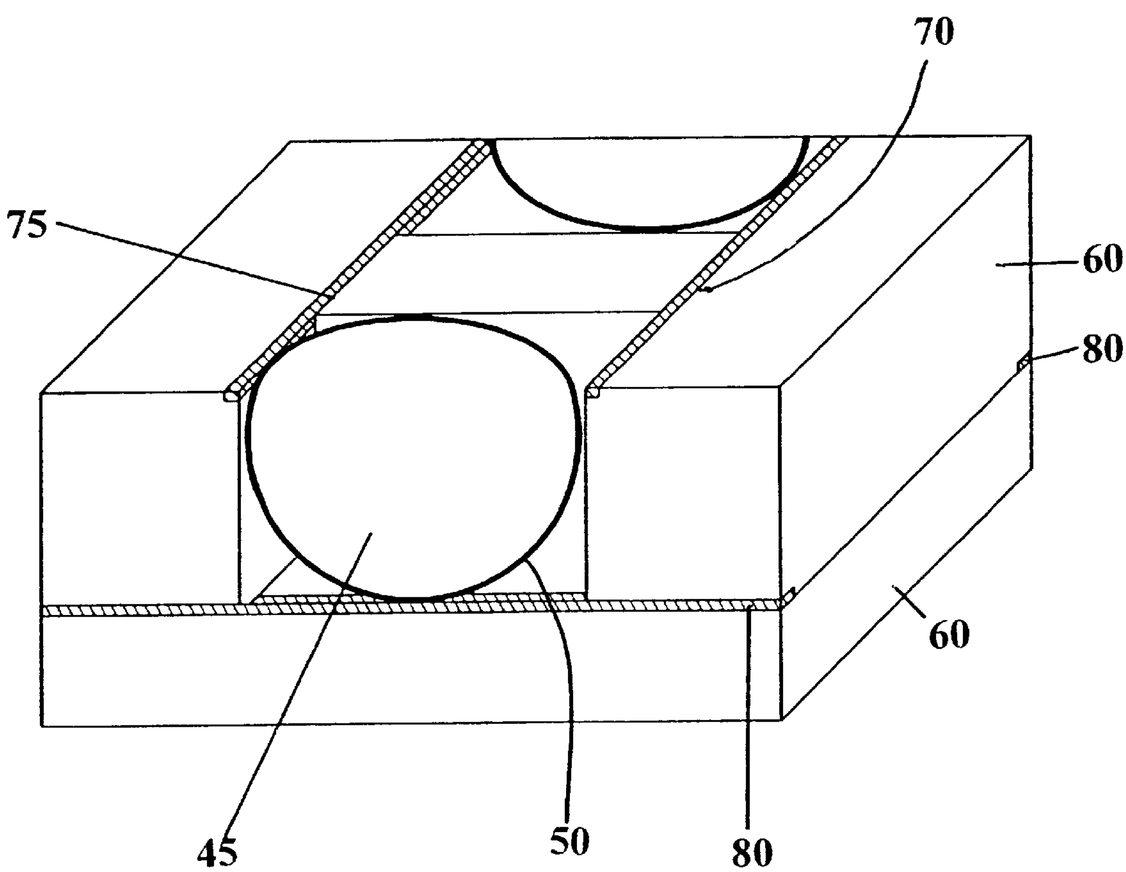

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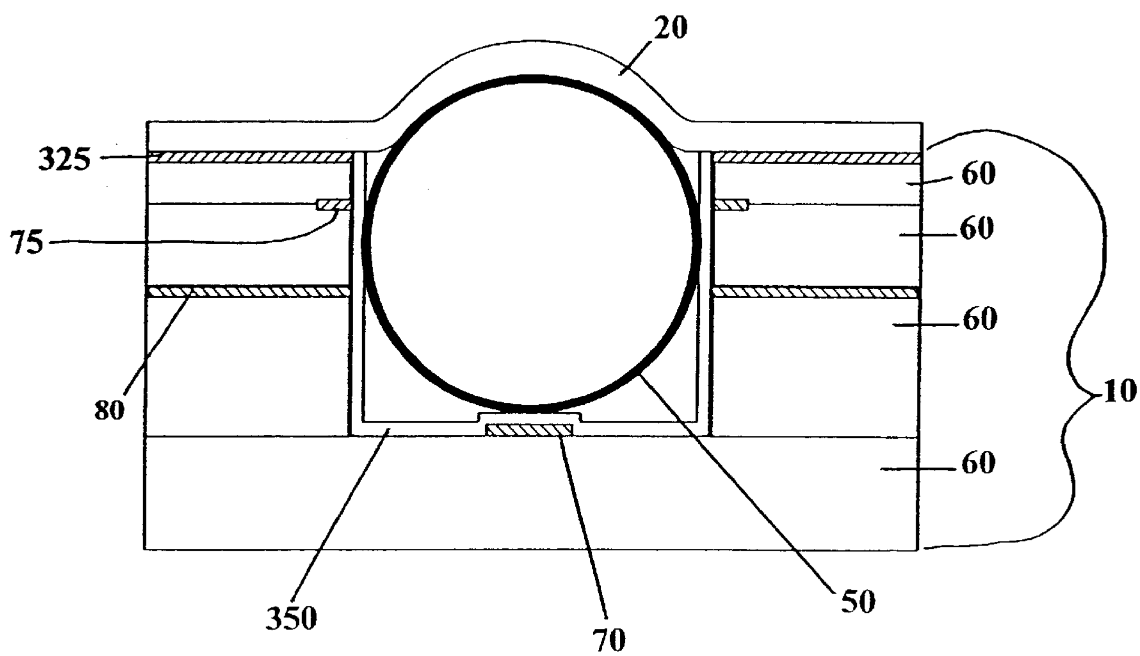

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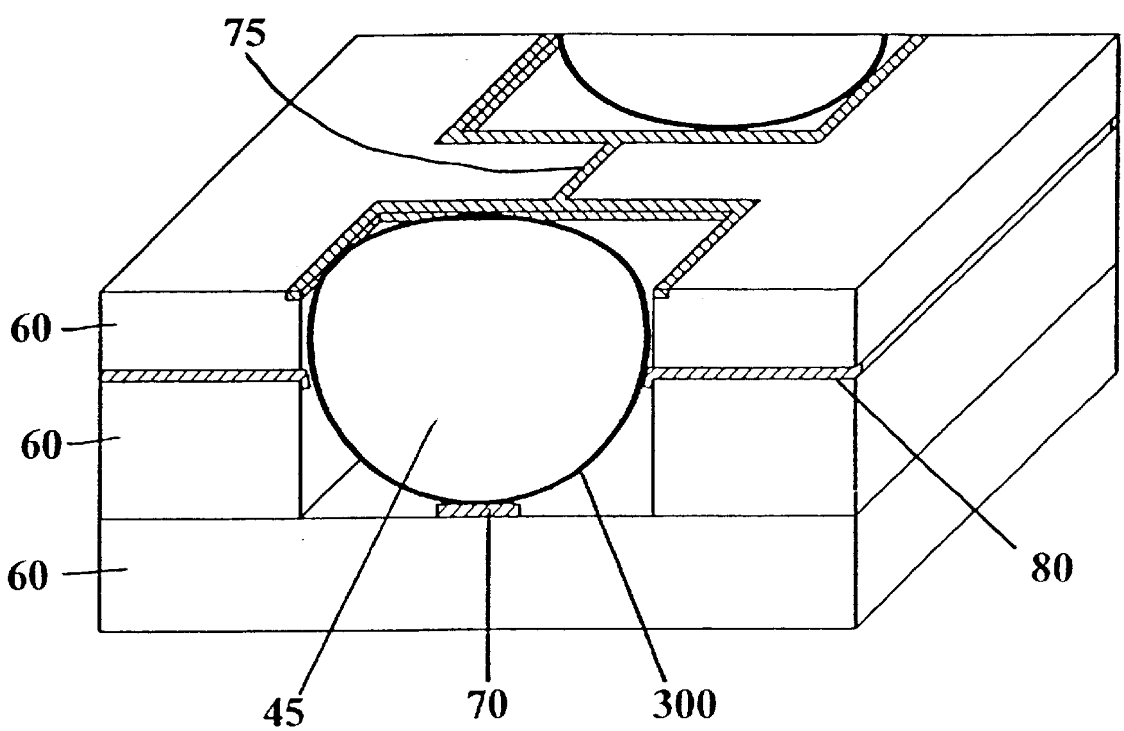

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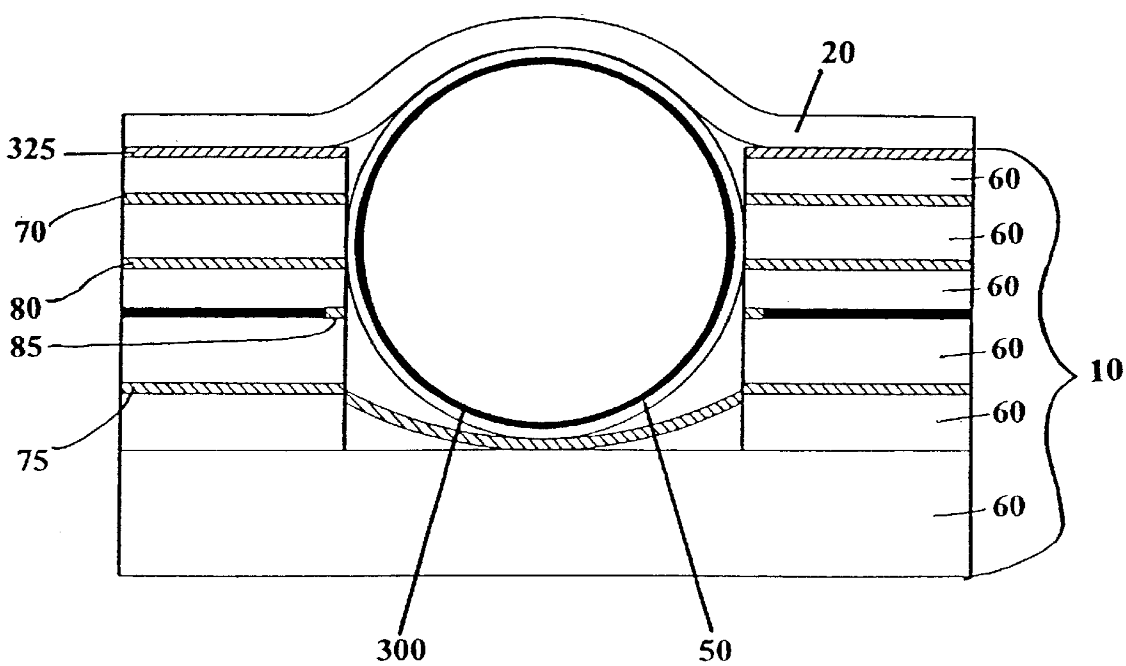

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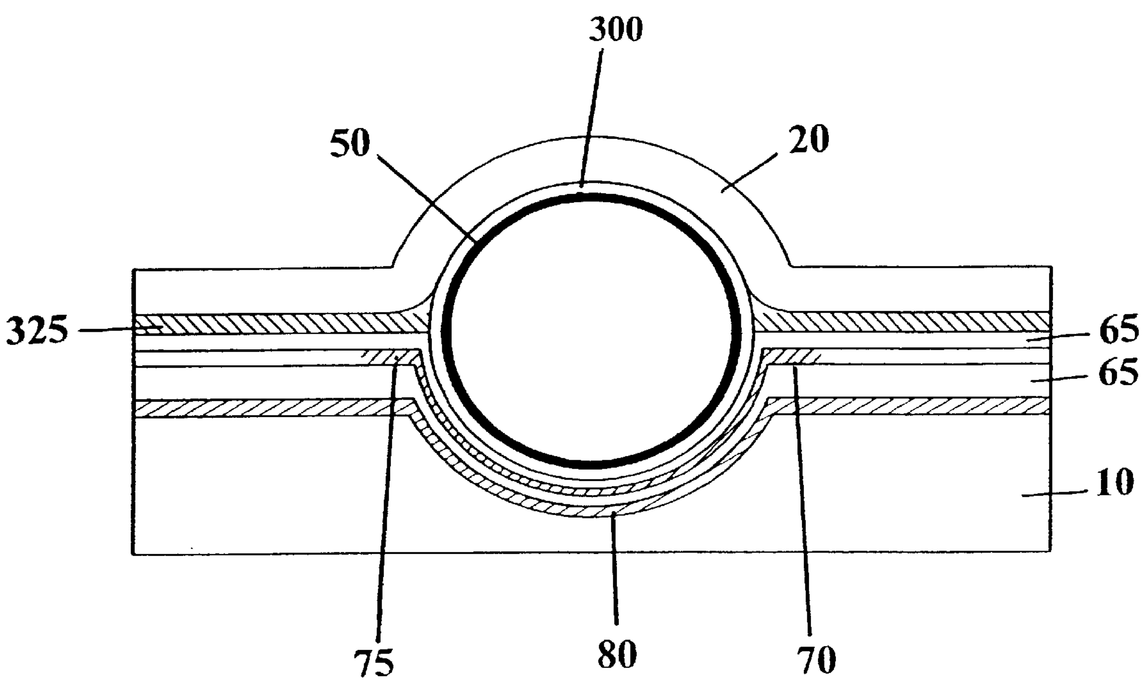

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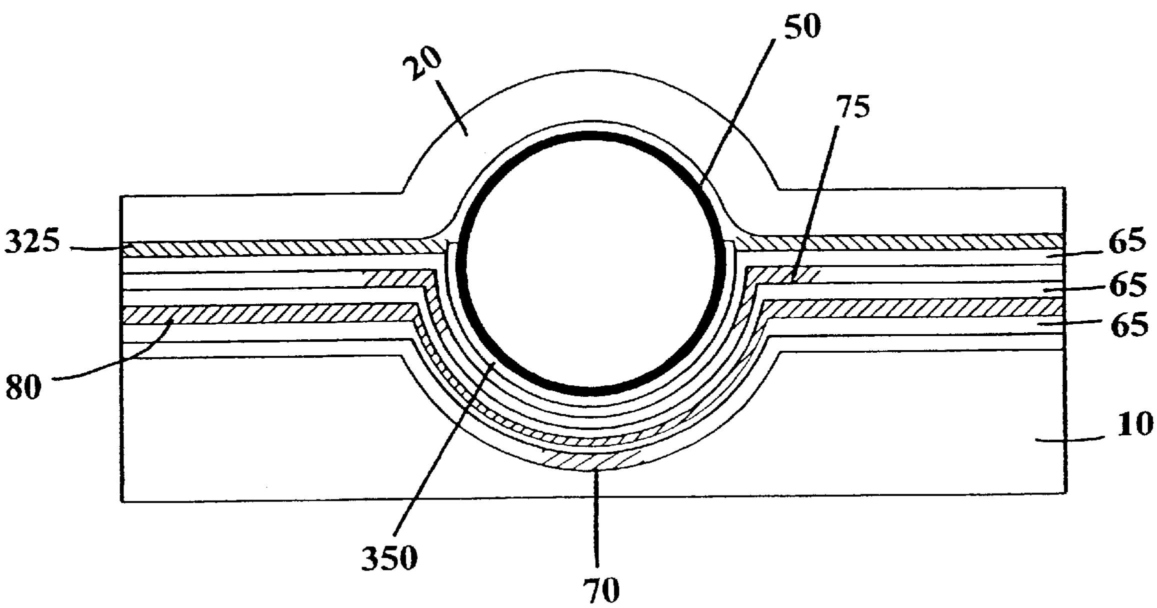

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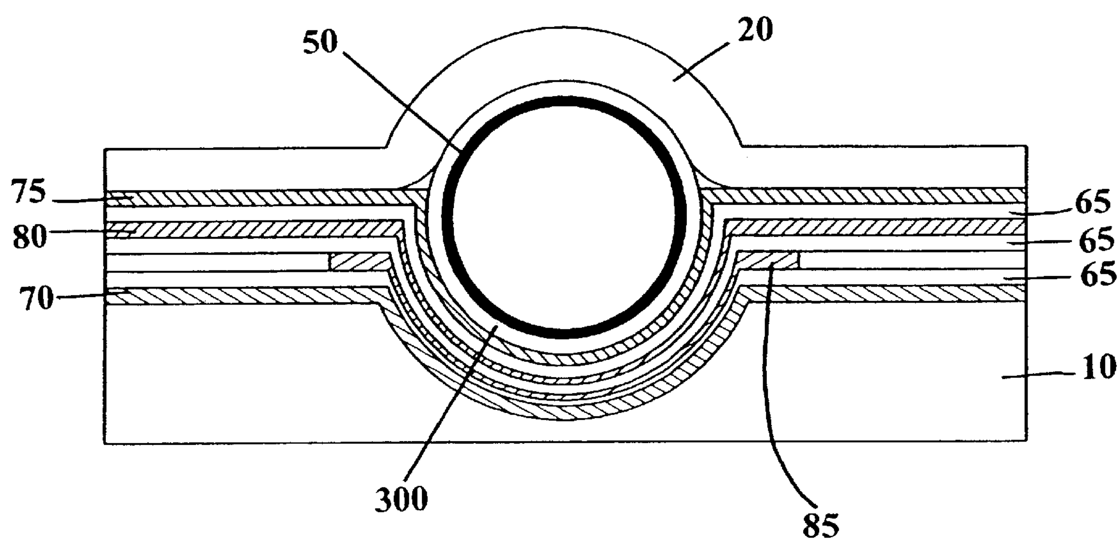

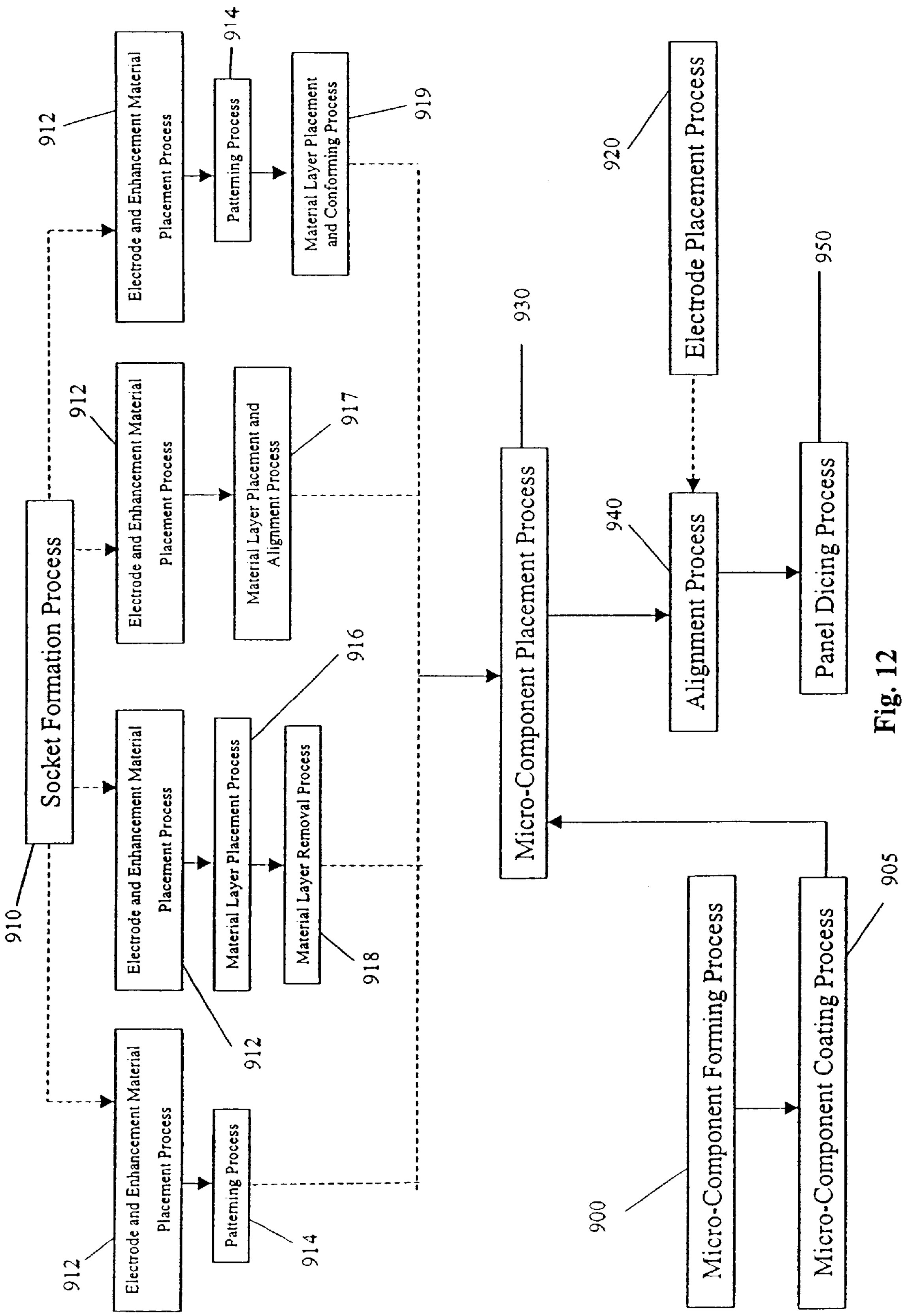
Socket Formation Process
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Electrode and Enhancement Material Placement Process
912
Patterning Process
914
Material Layer Placement and Conforming Process
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Material Layer Placement and Alignment Process
917
Material Layer Placement Process
916
Material Layer Removal Process
918
Micro-Component Placement Process
930
Electrode Placement Process
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Alignment Process
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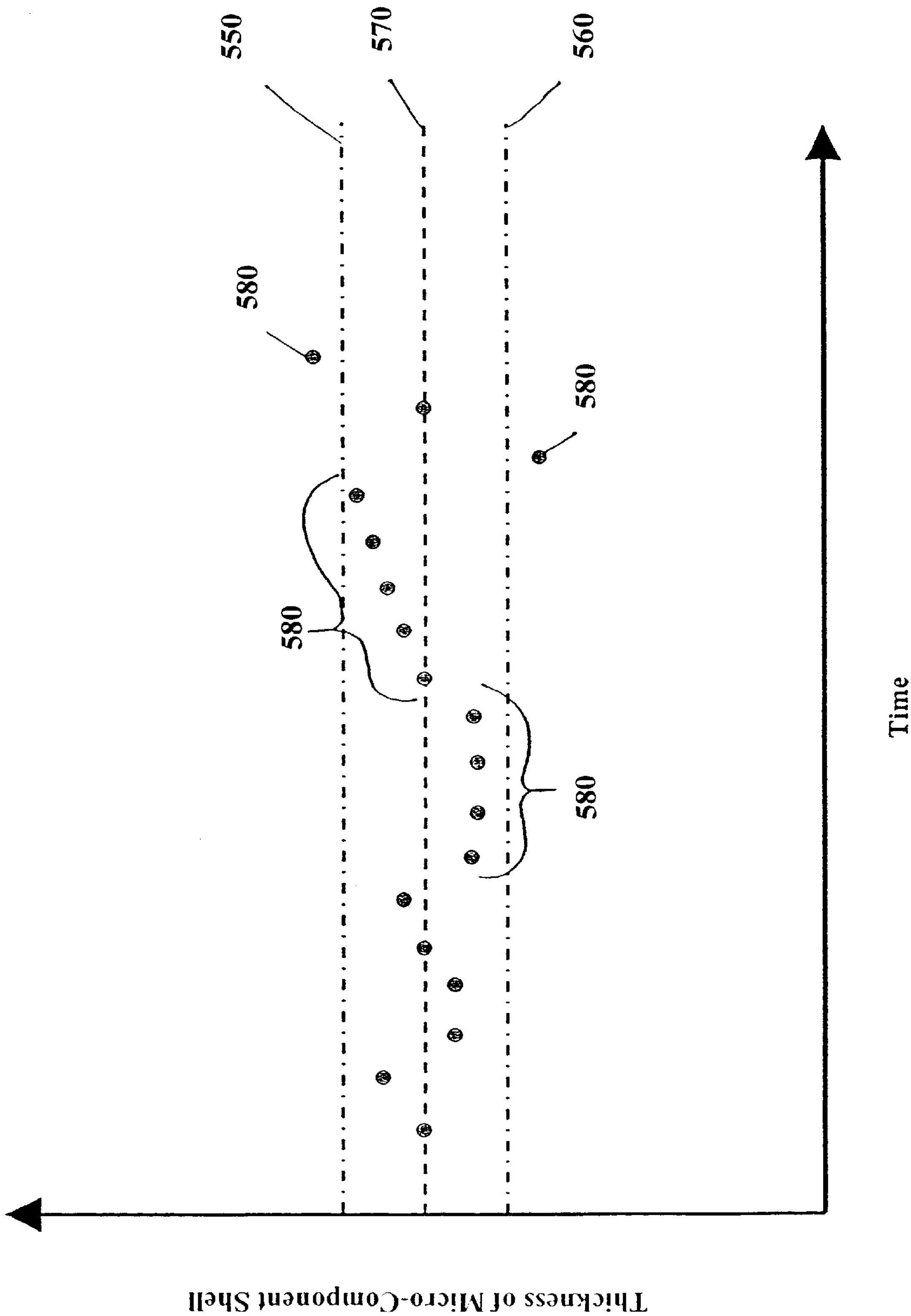
Panel Dicing Process
950
Micro-Component Forming Process
900
Micro-Component Coating Process
905

Fig. 12

Fig. 13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580
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580
Time
Thickness of Micro-Component Shell

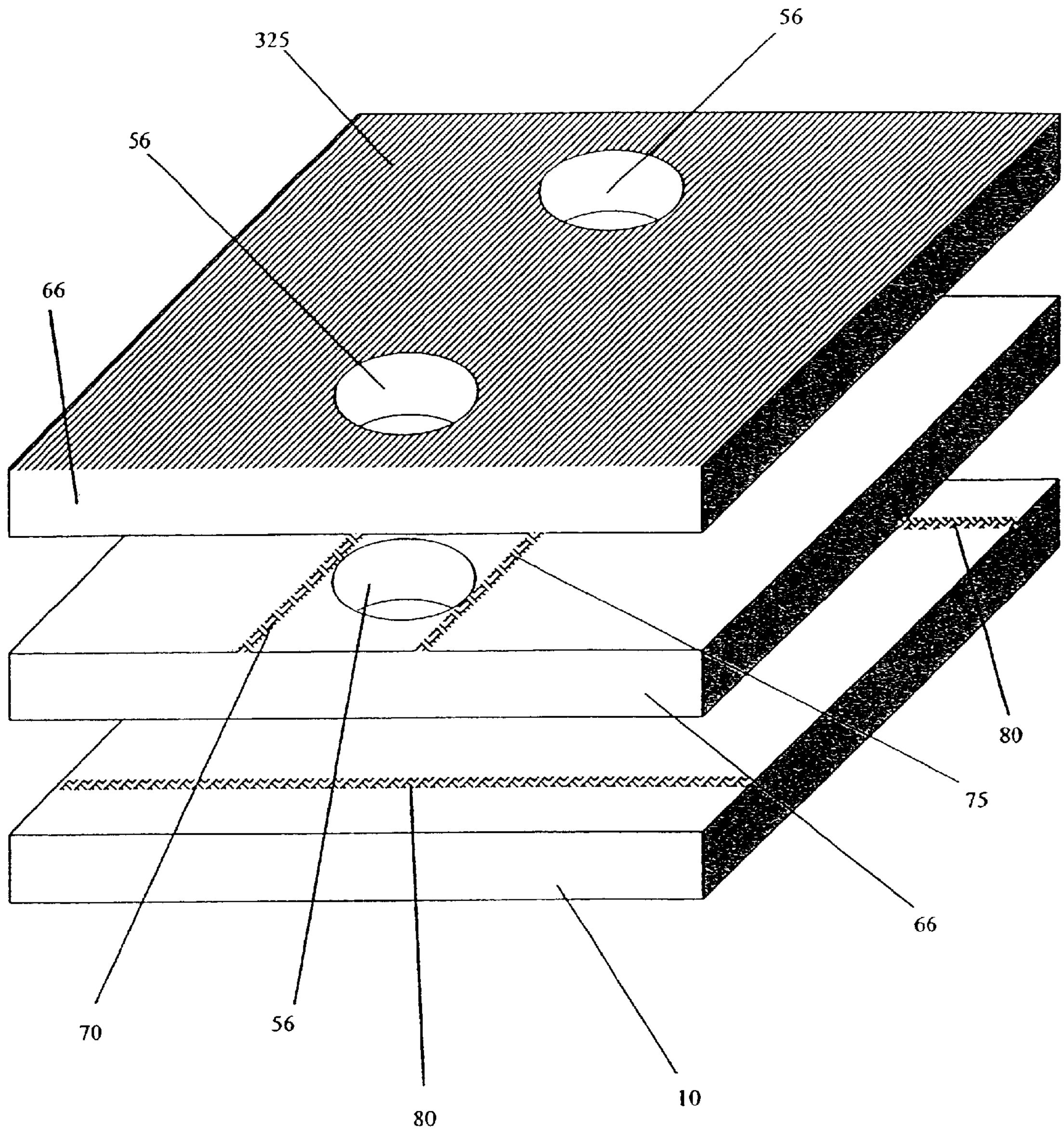



Fig. 14

Fig. 15

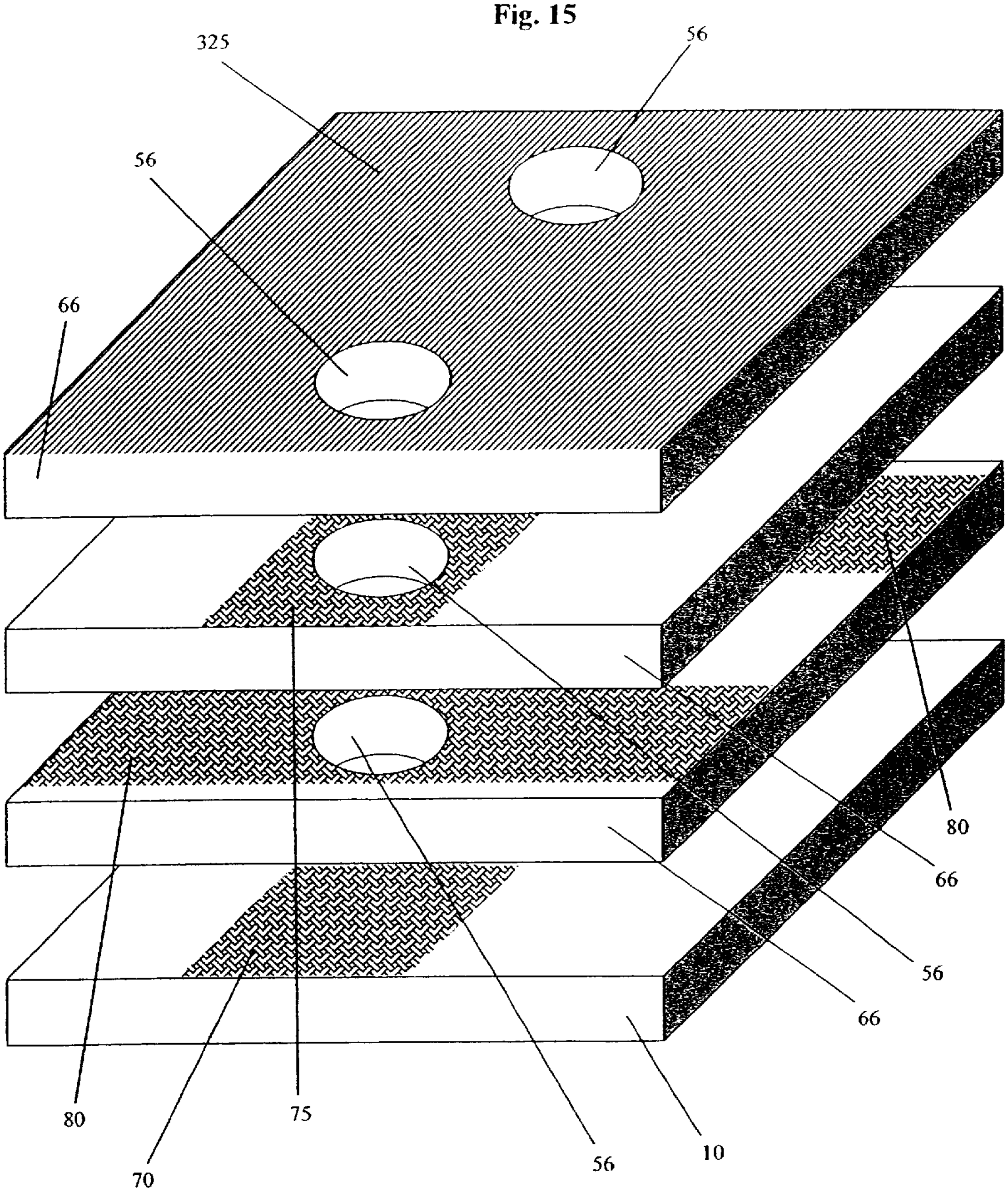
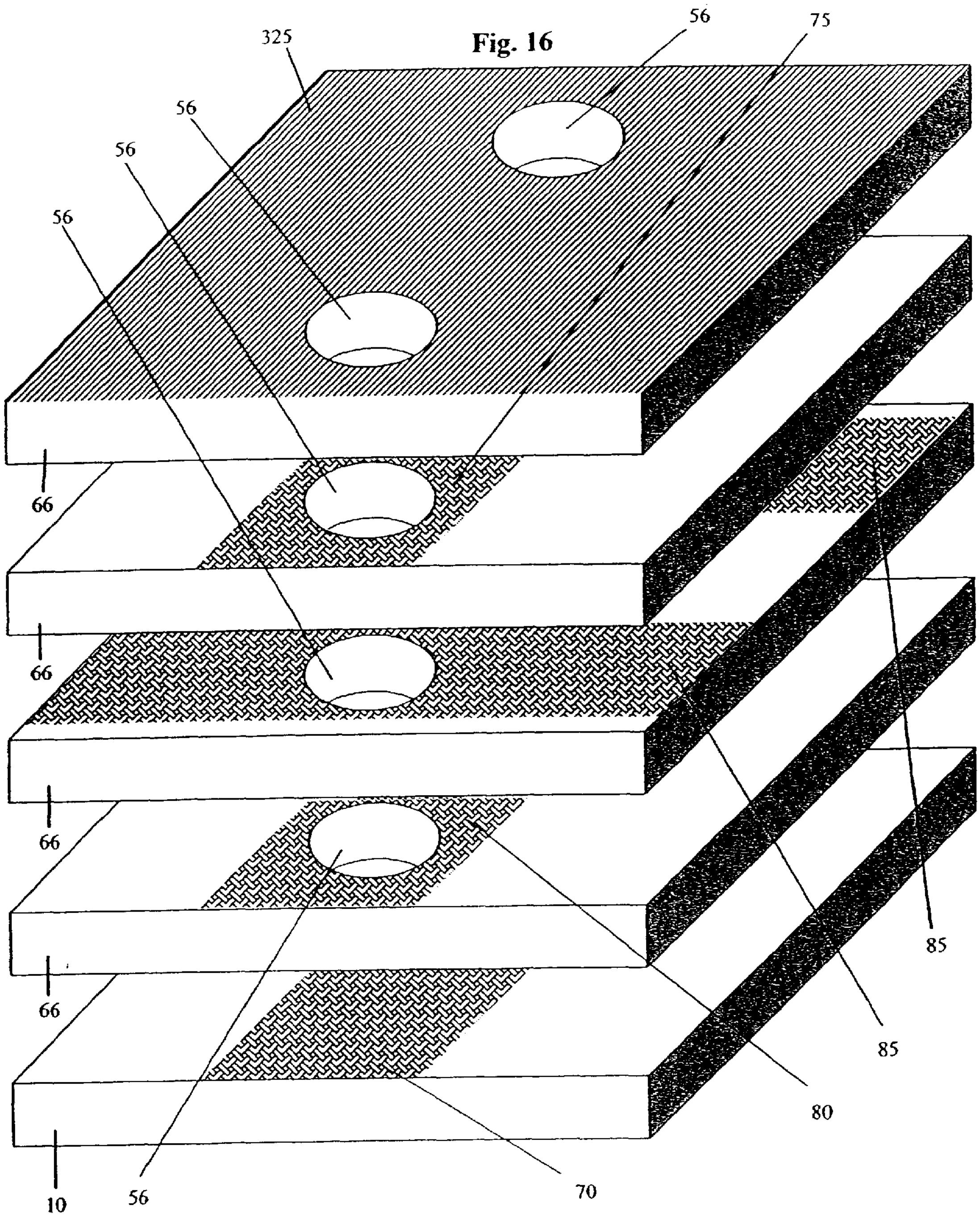


Fig. 16



# METHOD FOR TESTING A LIGHT-EMITTING PANEL AND THE COMPONENTS THEREIN

## CROSS-REFERENCE TO RELATED APPLICATIONS

The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use with a Micro-Component in a Light-Emitting Panel filed Oct. 27, 2000 U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a light-emitting display and methods of fabricating the same. The present invention further relates to a method for testing a light-emitting display and the components therein.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_S=V_W-V_{wall}$, where $V_S$ is the sustain voltage, $V_W$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates.

This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.



## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel.

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

According to another embodiment, a method for inline testing a plurality of light-emitting panels is disclosed. The method includes manufacturing a plurality of light-emitting panels in a web fabrication process that includes a plurality of process steps and component parts, testing a portion of one or more light-emitting panels after at least one process step is performed at least one time, processing data from the testing to produce at least one result; analyzing the results to determine whether the result is within acceptable tolerances and adjusting at least one of the process steps or at least one component part is the results are not within acceptable tolerances.

In another embodiment of the present invention, a method for forming a light-emitting panel includes providing a first substrate, forming a plurality of cavities on or within the first substrate, placing at least one micro-component in each cavity, providing a second substrate opposed to the first substrate such that at least one micro-component is sandwiched between the first and second substrates, disposing at least two electrodes so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation; and inline testing at least one of the first substrate, at least one cavity, at least one micro-component, at least one electrode, and the second substrate.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting panels and depicting various points throughout the method at which testing would take place as described in an embodiment of the present invention.

FIG. **13** is an example of data taken and stored after one of the fabrication process steps as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and a method for testing light-emitting panels and the components therein.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures -thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major-axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings 300 may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g., phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**,-or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The. plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor-deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting-panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. The electrodes may be disposed in the light-emitting panel using any technique know to one skilled in the art including, but not limited to, any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

According to one embodiment of the present invention, a process for testing a plurality of light-emitting panels comprises manufacturing a plurality of light-emitting panels in a web fabrication process. The web fabrication process includes a series of process steps and a plurality of component parts, as described in this application. A portion of a light-emitting panel is tested after one or more of the process steps. Data from the testing is processed and the results are analyzed to determine whether the results are within a specific target range of acceptable values for the portion of the light-emitting panel being tested. If the results are within acceptable ranges then no action is taken. If, however, the results fall outside the target range, then the results are used to adjust at least one of the process steps of the web fabrication process to bring the fabrication process back within acceptable tolerances. Although this embodiment contemplates at least one portion of a light-emitting panel being tested each time a process step is performed, it is contemplated in another embodiment that testing be performed at larger intervals. That is to say, by way of a non-limiting example, that it is contemplated that an electrode disposed as part of an electrode printing process may be tested either after each time the electrode printing process is performed or after every fifth time the electrode printing process is performed. It is also contemplated, in another embodiment of the present invention, that testing results may either be immediately used to adjust at least one process step of the manufacturing process and/or at least one component part of the light-emitting panel or the testing results may be stored. In the former case, as already described above, the testing results are analyzed to determine whether the results fall within a target range of acceptable values. If the results are acceptable no action is taken, however, if the results fall outside the target range, at least one process step and/or at least one component part is adjusted according to the results to bring the manufacturing process back within acceptable tolerances. In the latter case, the stored testing results are analyzed to determine whether a pattern of consistent non-conformity exists. FIG. **13** shows an example of data taken after the micro-component forming process regarding the thickness of the micro-component shell. The data was taken after each micro-component forming process operation and stored. FIG. **13** shows the upper target limit **550**, the lower target limit **560** and the target value **570**. In addition, FIG. **13** shows various non-limiting examples of what may constitute consistent non-conforming results **580**. If it is determined that a pattern of consistent non-conformity **580** exists then at least one process step and/or at least one component part is adjusted according to the analyzed results to bring the manufacturing process back within acceptable tolerances. If there is no consistent non-conformity then no action is taken. It is worth noting that it is contemplated that adjustments to process steps and/or component parts may be made manually or automatically.

The application, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment, as shown in FIG. **12**, a web fabrication process for manufacturing light-emitting panels includes the following process steps: a micro-component forming process **900**; a socket formation process **910**; an electrode placement process **920**; a micro-component placement process **930**; an alignment process **940**; and a panel dicing process **950**. It should be made clear that the process steps may be performed in any suitable order. Also where suitable, process steps may be performed in conjunction with other process steps such that two or more process steps are performed simultaneously. Furthermore, it is contemplated that two or more process steps may be combined into a single process step. Unless otherwise noted in this application, a testing method used to test a characteristic of a component part may be used regardless of the what component part is being tested. That is to say, unless otherwise noted, that the testing method is related to the characteristic being tested not the component part. Therefore, unless otherwise noted, testing methods for similar characteristics will not be repeatedly discussed.

During the micro-component forming process **900**, at least one micro-component is formed and at least partially filled with a plasma-producing gas. In another embodiment of the present invention, the micro-component forming process **900** also includes a micro-component coating process **905**. The micro-component coating process **905** may occur at any suitable place during or after the micro-component forming process **900**. After the micro-component forming process **900**, inline testing is performed on at least one micro-component. The characteristics of the one or more micro-components that may be tested include, but are not limited to, size, shape, impedance, gas composition and pressure, and shell thickness. The size of the micro-component may be tested using image capture, process, and analysis, laser acoustic analysis, expert system analysis or another method known to one of skill in the art. The shape of the micro-component may be tested using image capture, process and analysis, or another method known to one of skill in the art. The impedance of the micro-component, in the case where the micro-component shell is doped with a conductive material, may be tested using microwave excitation or another method known to one of skill in the art. The gas composition and pressure of the micro-component may be tested using microwave excitation and intensity measurements, ultraviolet spectral analysis or another method known to one of skill in the art. The shell thickness of the micro-component may be tested interferometricly, using laser analysis or using another method known to one of skill in the art. It is contemplated, in an embodiment, that preformed micro-components with/without coatings may be used in the web fabrication process thereby alleviating the need for a micro-component forming process **900** or micro-component coating process **905**.

During the socket formation process **910**, according to an embodiment, a plurality of sockets **30** are formed within or on a first substrate **10**. According to one embodiment, the socket formation process **910** includes an electrode and enhancement material placement process **912** and a patterning process **914**. In another embodiment, the socket formation process **910** includes an electrode and enhancement material placement process **912**, a material layer placement process **916**, and a material layer removal process **918**. In another embodiment, the socket formation process **910** includes an electrode and enhancement material placement process **912**, a patterning process **914**, and-a material layer placement and conforming process **919**. In another embodiment, the socket formation process **910** includes an electrode and enhancement material placement process **912** and a material layer placement and alignment process **917**.

After the socket formation process **910**, inline testing is performed on at least one socket. It is contemplated that since each embodiment of the socket formation process **910** includes a plurality of process steps that the inline testing may be performed after each of the process steps as opposed to inline testing after the socket is completely formed. After the electrode and enhancement material placement process **912**, inline testing is performed on at least one electrode and/or at least one enhancement material. The characteristics of the one or more electrodes and/or the one or more enhancement materials that may be tested include, but are not limited to, placement, impedance, size, shape, material properties and enhancement material functionality. The placement of the electrode and/or enhancement material may be tested using image capture, process and analysis or another method known to one of skill in the art. The impedance of the electrode and/or enhancement material, when applicable, may be tested using standard time domain analysis or another method known to one of skill in the art. The material properties of the electrode and/or enhancement material may be tested using light transmission and intensity measurements, expert system analysis, image capture, process and analysis, laser acoustic analysis or another method known to one of skill in the art. After the patterning process **914**, inline testing is performed on at least one cavity. The characteristics of the one or more cavities that may be tested include, but are not limited to, placement, impedance, size, shape, depth, wall quality and edge quality. The depth of the cavity may be tested using image capture, process and analysis, laser scanning and profiling, position-spatial frequency or another method known to one of skill in the art. After the material layer placement process **916**, inline testing is performed on at least one material layer. The characteristics of the one or more material layers that may be tested include, but are not limited to, size, shape, thickness and material properties. After the material layer removal process **918**, inline testing is preformed on at least one cavity formed in the plurality of material layers as a result of the material layer removal process. The characteristics of the one or more cavities includes, but is not limited to, size, shape, depth, wall quality and edge quality. After the material layer placement and conforming process **919**, inline testing is performed on at least one material layer. The characteristics of the one or more material layers that may be tested include, but are not limited to, size, shape, thickness and material properties.

During the electrode placement process **920**, at least one electrode and/or driving or control circuitry is disposed on or within the first substrate, on the second substrate, or any combination thereof. It is contemplated that the electrode placement process **920** may be performed as part of the electrode and enhancement material placement process **912** when an electrode is disposed on or within the first substrate or may be performed as a separate step when an electrode is disposed on the second substrate. After the electrode placement process **920**, inline testing is performed on at least one electrode. The characteristics of the one or more electrodes that may be tested include, but are not limited to, placement, impedance, size, shape, material properties and electrical component functionality.

During the micro-component placement process **930**, at least one micro-component is at least partially disposed in each socket. After the micro-component placement process **930**, inline testing is performed on at least one micro-component. The characteristics of the one or more micro-components that may be tested include, but are not limited to, position and orientation. The position of the micro-component may be tested using image capture, process and analysis, expert system analysis, spatial frequency analysis or anther method known to one of skill in the art. The orientation of the micro-component may be tested using image capture, process and analysis, expert system analysis, or another method known to one of skill in the art. In an embodiment of the present invention where the light-emitting panels being manufactured are color light-emitting panels, the additional characteristic of whether a proper color micro-component is placed in the proper socket may also be tested by using ultraviolet excitation and visible color imaging or another method known to one of skill in the art.

During the alignment process **940**, a second substrate **20** is positioned and placed, directly or indirectly, on the first substrate **10** so that one or more micro-components are sandwiched between the first and second substrates. After the alignment process **940**, inline testing is performed on the second substrate. The characteristics of the second substrate that may be tested include, but are not limited to, position and orientation.

During the panel dicing process **950**, the first and second "sandwiched" substrates are diced to form an individual light-emitting panel. After the dicing process **950**, inline testing is performed on the individual light-emitting panel. The characteristics of the individual light-emitting panel that may be tested include, but are not limited to, size, shape and luminosity. The luminosity, in both visible and non-visible regions, of the light-emitting display may be tested by pixel by pixel image analysis.

In another embodiment of the present invention, the method of testing a light-emitting panel includes manufacturing a light-emitting panel in a series of process steps, testing at least one component part of the light-emitting panel after at least one process step, analyzing the test data to produce at least one result and utilizing the at least one result to adjust one or more component parts of the light-emitting panel. It is contemplated in this embodiment, however, that the adjustment may be zero (i.e. no adjustment) if the results show that the fabrication process is within specified tolerances. According to this embodiment, the series of process steps includes providing a first substrate, forming a plurality of cavities on or within the first substrate, placing at least one micro-component at least partially in each cavity, providing a second substrate opposed to the first substrate such that the at least one micro-component is sandwiched between the first and second substrates, disposing at least two electrodes so that voltage applied to the electrodes causes one or more micro-components to emit radiation. Testing may be performed on the first substrate, at least one cavity, at least one micro-component, at least one electrode, and/or the second substrate. Adjustments, after testing and analysis, may be made to the first substrate, the formation of the first substrate, the formation of the plurality of cavities, the plurality of cavities, the at least one micro-component, the disposition of at least one of the at least two electrodes, one or more electrodes, the placement of the second substrate and/or the second substrate.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

1. A method for inline testing a plurality of light-emitting panels, comprising the steps of:

manufacturing the plurality of light-emitting panels in a web fabrication process, the web fabrication process comprising a plurality of process steps and a plurality of component parts, wherein the plurality of process steps are performed a plurality of times to manufacture the plurality of light-emitting panels, and further wherein the plurality of process steps comprise a micro-component forming process, a socket formation process, an electrode placement process a micro-component placement process, an alignment process, and a panel dicing process;

testing a portion of one or more light-emitting panels after at least one process step of the plurality of process steps is performed at least one time;

processing data from the testing to produce at least one result;

analyzing the at least one result to determine whether the at least one result is within a specific target range; and

adjusting the at least one process step or at least one component part of the plurality of component parts if the at least one result is not within the specific target range.

2. The method of claim 1, wherein the socket formation process comprises: an electrode and enhancement material printing process; and a material layer placement and alignment process.

3. The method of claim 2, wherein testing the portion of one or more light-emitting panels after the electrode and enhancement material placement process comprises testing at least one characteristic of at least one electrode or at least one enhancement material, wherein the at least one characteristic is selected from a group consisting of placement, impedance, size, shape, material properties and enhancement material functionality.

4. The method of claim 3, wherein testing the portion of one or more light-emitting panels after the material layer placement and alignment process comprises testing at least one characteristic of at least one material layer of a plurality of material layers, wherein the at least one characteristic is selected from a group consisting of size, shape, thickness, alignment and material properties.

5. The method of claim 1, wherein testing the portion of one or more light-emitting panels after the micro-component placement process comprises testing at least one characteristic of at least one micro-component, wherein the at least one characteristic is selected from a group consisting of position and orientation.

6. The method of claim 1, wherein: the one or more light-emitting panels comprise one or more color light-emitting panels and the step of testing the portion further comprises testing at least one characteristic of at least one micro-component, the at least one characteristic selected from a group consisting of position, orientation, and proper color micro-component for proper socket.

7. The method of claim 1, wherein testing the portion of one or more light-emitting panels after the alignment process comprises testing at least one characteristic of a second substrate, wherein the at least one characteristic is selected from a group consisting of position and orientation.

8. The method of claim 1, wherein testing the portion of one or more light-emitting panels after the dicing process comprises testing at least one characteristic of the light-emitting panel, wherein the at least one characteristic is selected from a group consisting of size, shape, and luminosity.

9. The method of claim 1, wherein the micro-component forming process comprises a micro-component coating process.

10. The method of claim 9, wherein testing the portion of one or more light-emitting panels after the micro-component coating process comprises testing whether at least one coating on at least one micro-component was properly applied or whether the at least one coating on the at least one micro-component provides its intended functionality.

11. The method of claim 1, wherein the socket formation process comprises:

an electrode and enhancement material placement process; and

a patterning process.

12. The method of claim 11, wherein testing the portion of one or more light-emitting panels after the electrode and enhancement material placement process comprises testing at least one characteristic of at least one electrode or at least one enhancement material, wherein the at least one characteristic is selected from a group consisting of placement, impedance, size, shape, material properties and enhancement material functionality.

13. The method of claim 11, wherein testing the portion of one or more light-emitting panels after the patterning process comprises testing at least one characteristic of at least one cavity, wherein the at least one characteristic is selected from a group consisting of placement, impedance, size, shape, depth, wall quality and edge quality.

14. The method of claim 1, wherein the socket formation process comprises:

an electrode and enhancement material placement process;

a material layer placement process; and

a material layer removal process.

15. The method of claim 14, wherein testing the portion of one or more light-emitting panels after the electrode and enhancement material placement process comprises testing at least one characteristic of at least one electrode or at least one enhancement material, wherein the at least one characteristic is selected from a group consisting of placement, impedance, size, shape, material properties and enhancement material functionality.

16. The method of claim 15, wherein testing the portion of one or more light-emitting panels after the material layer placement process comprises testing at least one characteristic of at least one material layer of a plurality of material layers, wherein the at least one characteristic is selected from a group consisting of size, shape, thickness and material properties.

17. The method of claim 16, wherein testing the portion of one or more light-emitting panels after the material layer removal process comprises testing at least one characteristic of a cavity formed in the plurality of material layers as a result of the material layer removal process, wherein the at least one characteristic is selected from a group consisting of size, shape, depth, wall quality and edge quality.

18. The method of claim 1, wherein the socket formation process comprises:

an electrode and enhancement material printing process;

a patterning process; and

a material layer placement and conforming process.

19. The method of claim 18, wherein testing the portion of one or more light-emitting panels after the electrode and enhancement material placement process comprises testing at least one characteristic of at least one electrode or at least one enhancement material, wherein the at least one charac-

teristic is selected from a group consisting of placement, impedance, size, shape, material properties and enhancement material functionality.

**20**. The method of claim **19**, wherein testing the portion of one or more light-emitting panels after the patterning process comprises testing at least one characteristic of at least one cavity, wherein the at least one characteristic is selected from a group consisting of placement, impedance, size, shape, depth, wall quality and edge quality.

**21**. The method of claim **20**, wherein testing the portion of one or more light-emitting panels after the material layer placement and conforming process comprises testing at least one characteristic of at least one material layer of a plurality of material layers, wherein the at least one characteristic is selected from a group consisting of size, shape, thickness and material properties.

**22**. A method for inline testing a plurality of light-emitting panels, comprising the steps of:

manufacturing the plurality of light-emitting panels in a web fabrication process, the web fabrication process comprising a plurality of process steps and a plurality of component parts, wherein the plurality of process steps are performed a plurality of times to manufacture the plurality of light-emitting panels;

testing a portion of one or more light-emitting panels after at least one process step of the plurality of process steps is performed at least one time;

processing data from the testing to produce at least one result;

analyzing the at least one result to determine whether the at least one result is within a specific target range; and

adjusting the at least one process step or at least one component part of the plurality of component parts if the at least one result is not within the specific target range,

wherein the step of testing the portion of one or more light-emitting panels, comprises the step of testing more than one light emitting panel, wherein the step of processing data, comprises the step of storing the at least one result after each time a light-emitting panel is tested to produce a plurality of stored results, wherein the step of analyzing the at least one result, comprises the step of analyzing the plurality of stored results to determine whether there is consistent nonconformity, and wherein the step of adjusting the at least one process step or the at least one component part, comprises the step of adjusting the at least one process step or the at least one component part if there is consistent nonconformity.

**23**. A method for forming a light-emitting panel, comprising the steps of:

providing a first substrate;

forming a plurality of cavities on or within the first substrate;

placing at least one micro-component in each cavity;

providing a second substrate opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate;

disposing at least two electrodes so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation; and

inline testing the first substrate, at least one cavity, at least one micro-component, at least one electrode, and optionally the second substrate.

**24**. The method of claim **23**, further comprising the steps of:

processing data from the inline testing to produce at least one result; and

utilizing the at least one result to adjust at least one of the first substrate, the formation of the plurality of cavities, the plurality of cavities, the placement of the at least one micro-component, the at least one micro-component, the disposition of at least one of the at least two electrodes, one or more electrodes, the placement of the second substrate and the second substrate.

**25**. The method of claim **24**, wherein the step of forming a plurality of cavities on or within the first substrate, comprises the step of patterning a plurality of cavities in the first substrate.

**26**. The method of claim **24**, wherein the first substrate comprises a plurality of material layers and wherein the step of forming a plurality of cavities on or within the first substrate, comprises the step of selectively removing a plurality of portions of the plurality of material layers.

**27**. The method of claim **24**, wherein the step of forming a plurality of cavities on or within the first substrate, comprises the steps of:

patterning a plurality of cavities in the first substrate; and

disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to the shape of the cavities.

**28**. The method of claim **1**, wherein testing the portion of one or more light-emitting panels after the micro-component forming process comprises testing at least one characteristic of at least one micro-component, wherein the at least one characteristic is selected from a group consisting of size, shape, impedance, gas composition and pressure, and shell thickness.

**29**. The method of claim **1**, wherein testing the portion of one or more light-emitting panels after the electrode placement process comprises testing at least one characteristic of at least one electrode, wherein the at least one characteristic is selected from a group consisting of placement, impedance, size, shape, material properties and electrical component functionality.

* * * * *

US006646388B2

(12) **United States Patent**
**George et al.**

(10) **Patent No.: US 6,646,388 B2**
(45) **Date of Patent: Nov. 11, 2003**

(54) **SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL**

(75) Inventors: **Edward Victor George**, Lake Arrowhead, CA (US); **Roger Laverne Johnson**, Encinitas, CA (US); **Albert Myron Green**, Springfield, VA (US); **Newell Convers Wyeth**, Oakton, VA (US)

(73) Assignee: **Science Applications International Corporation**, San Diego, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/318,150**

(22) Filed: **Dec. 13, 2002**

(65) **Prior Publication Data**

US 2003/0090213 A1 May 15, 2003

**Related U.S. Application Data**

(63) Continuation of application No. 09/697,346, filed on Oct. 27, 2000, now Pat. No. 6,545,422.

(51) **Int. Cl.**$^7$ ................................................ **G09G 3/10**
(52) **U.S. Cl.** ................................................ **315/169.3**
(58) **Field of Search** .............................. 315/169.3, 312, 315/324; 313/484, 485, 491, 502, 506; 445/24, 29, 33

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,559,190 A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | 11/1974 | MacIntyre, Jr. | 340/324 M |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.
"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.
"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

(List continued on next page.)

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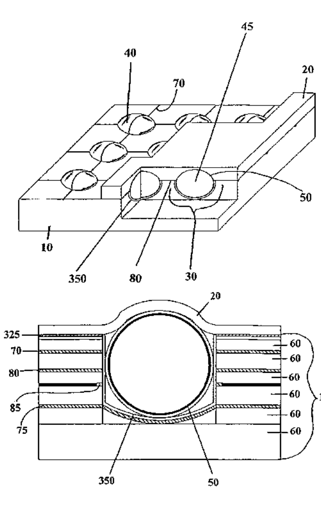
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components at least partially disposed in a socket and sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes.

**41 Claims, 18 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,969,651 | A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 | A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 | A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 | A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 | A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 | A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | 3/1990 | Hollo et al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Salavin et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,124,676 | A * | 9/2000 | Salavin et al. | 315/169.4 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |

OTHER PUBLICATIONS

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp-?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp-?nSeqNo=13&type=&word.

"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco Plasma Wall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco Plasma Wall P1–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco Plasma Wall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Alien Technology Corporation's Technology Overview; copyright © 2000,Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 14–15.

Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Kurihara, M., Makabe, T., "Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct., 1999, pp. 1372–1378.

Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

"Transparent Conductive Coatings," Copyright 1998, 4 pp.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep., 1997, pp. 1241–.

Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm-.com/journal/sj/363/Jacobson.html.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.

"Flat Panel Displays in Perspective," 44 pp., Sep., 1995.

Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

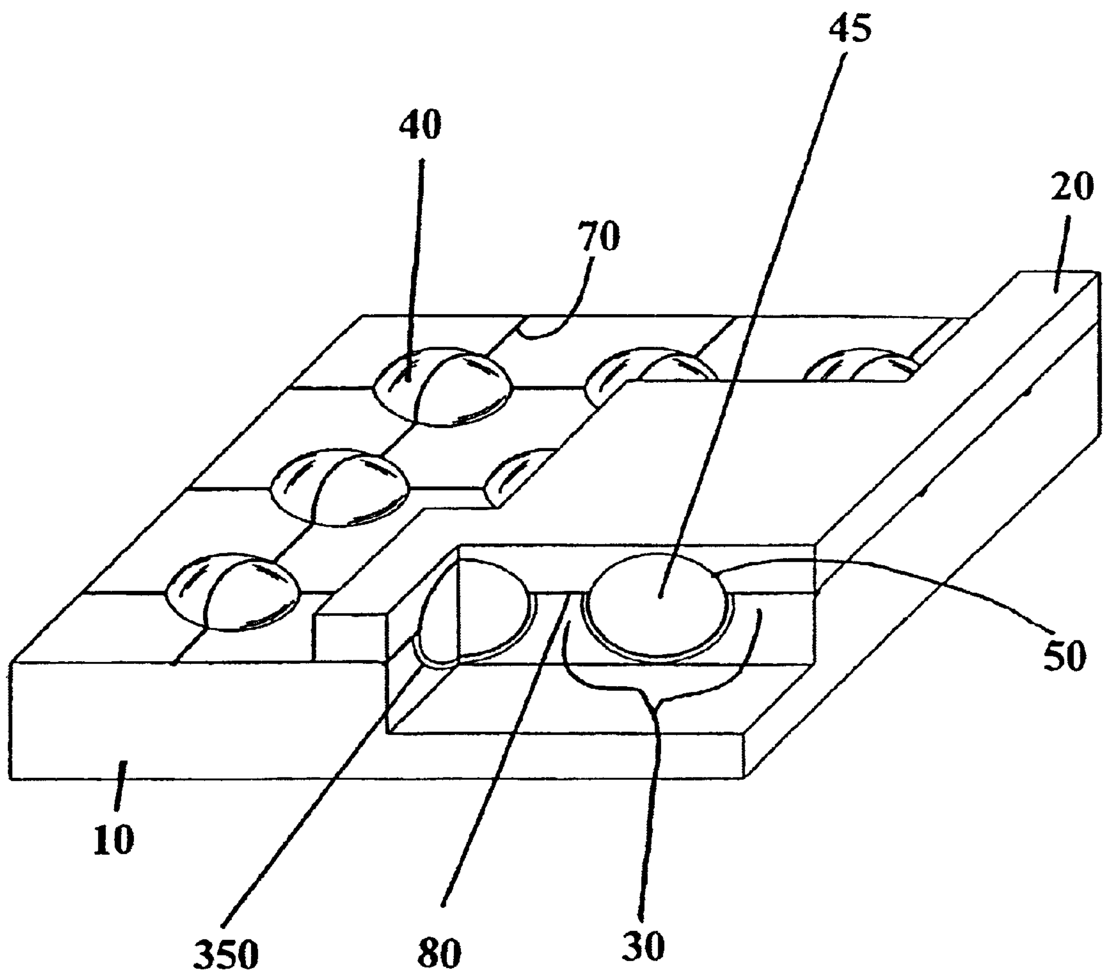
International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.

* cited by examiner

Fig. 1



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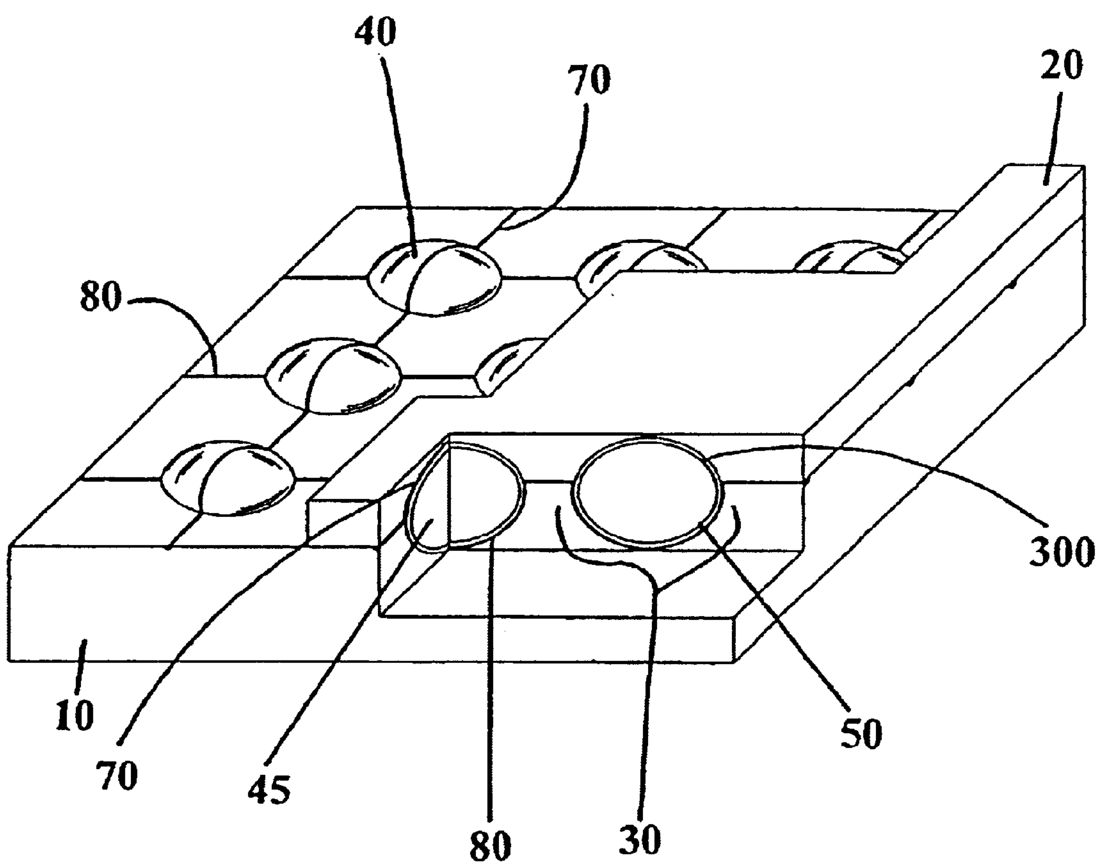

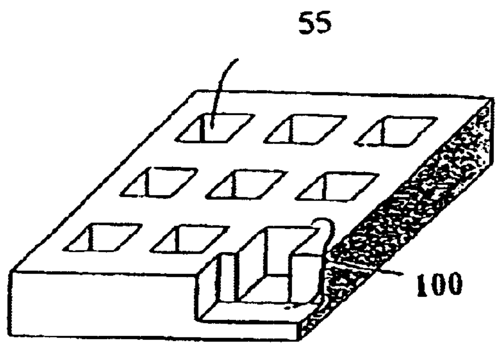


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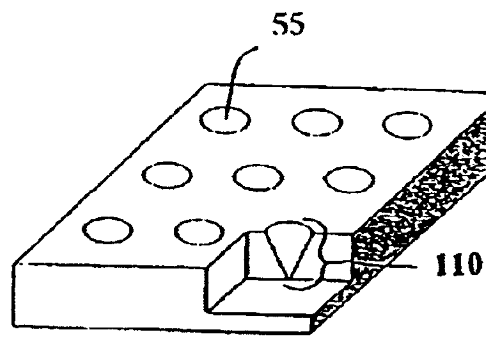


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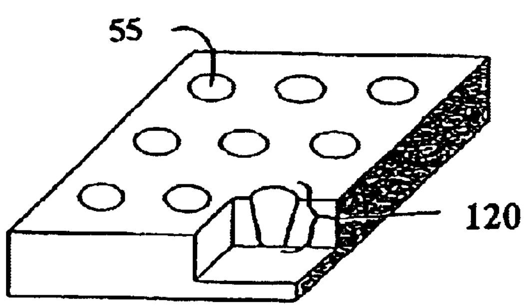


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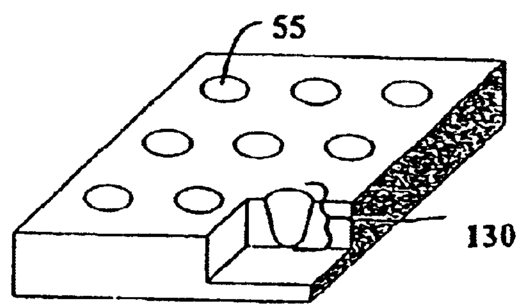


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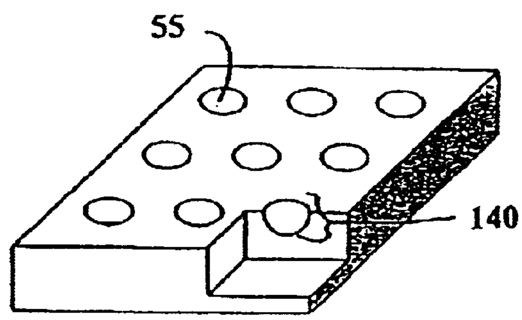


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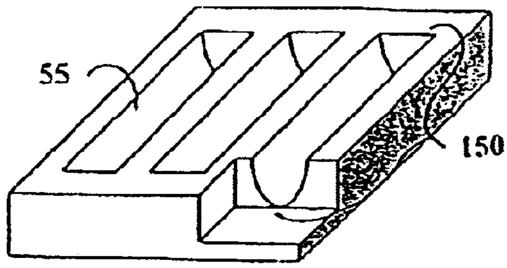


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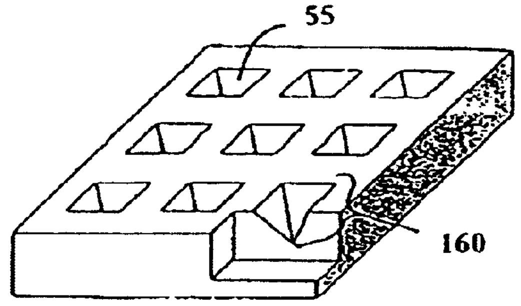


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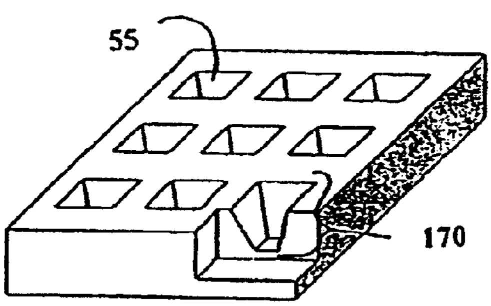


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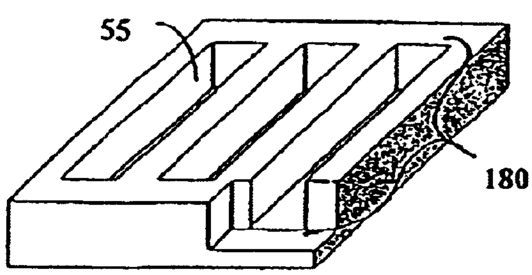


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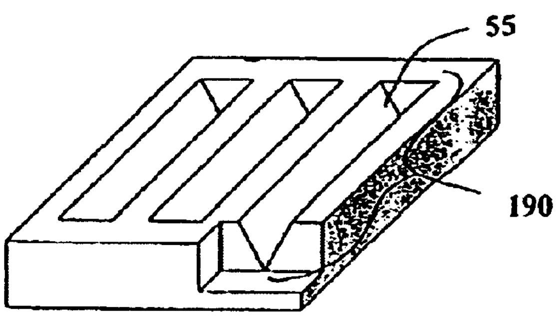
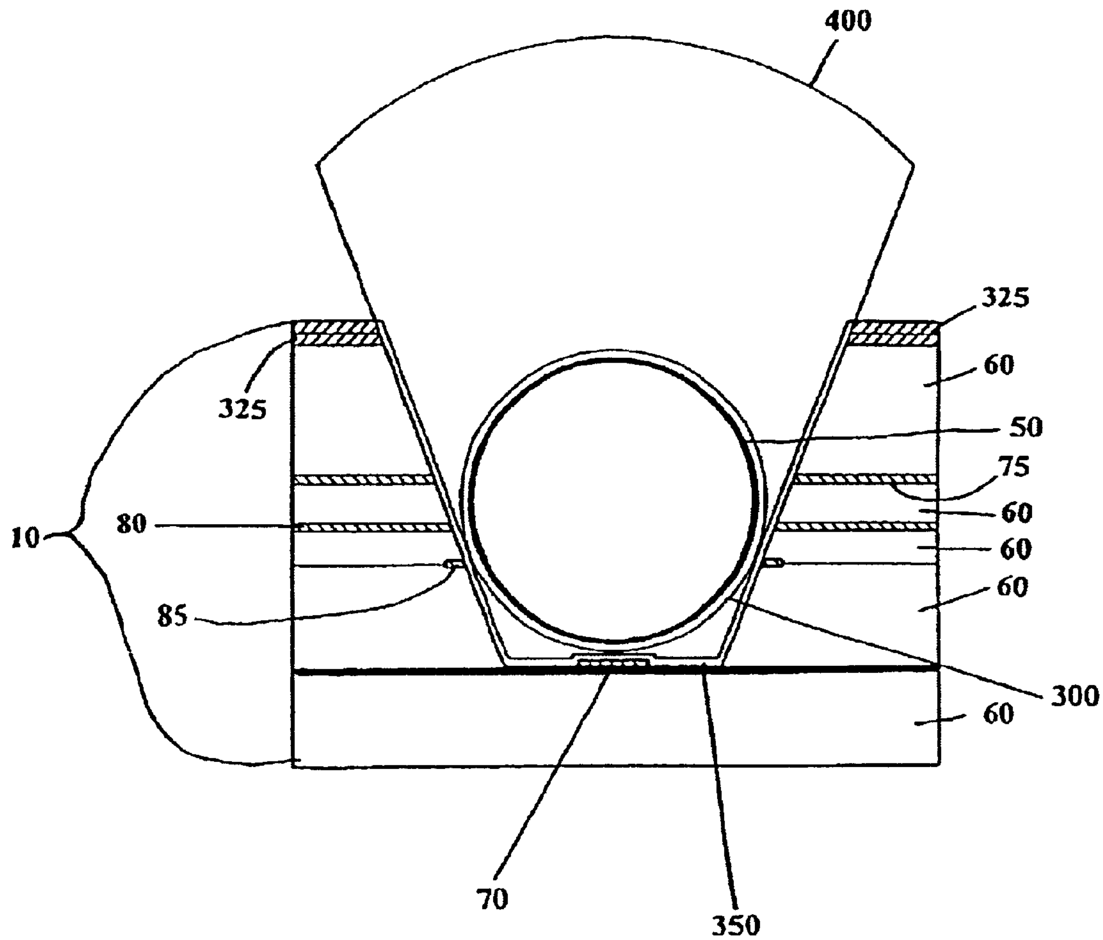



Fig. 3J

Fig. 4



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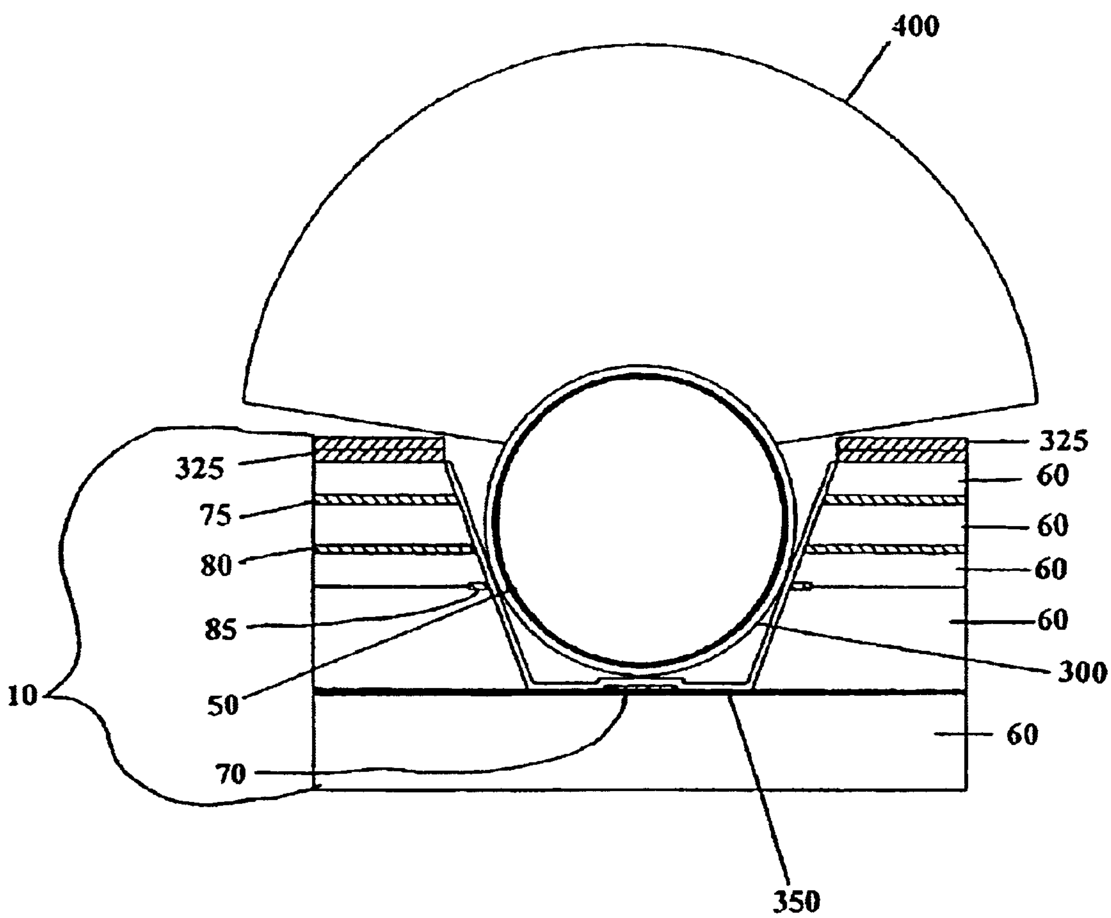


Fig. 6A

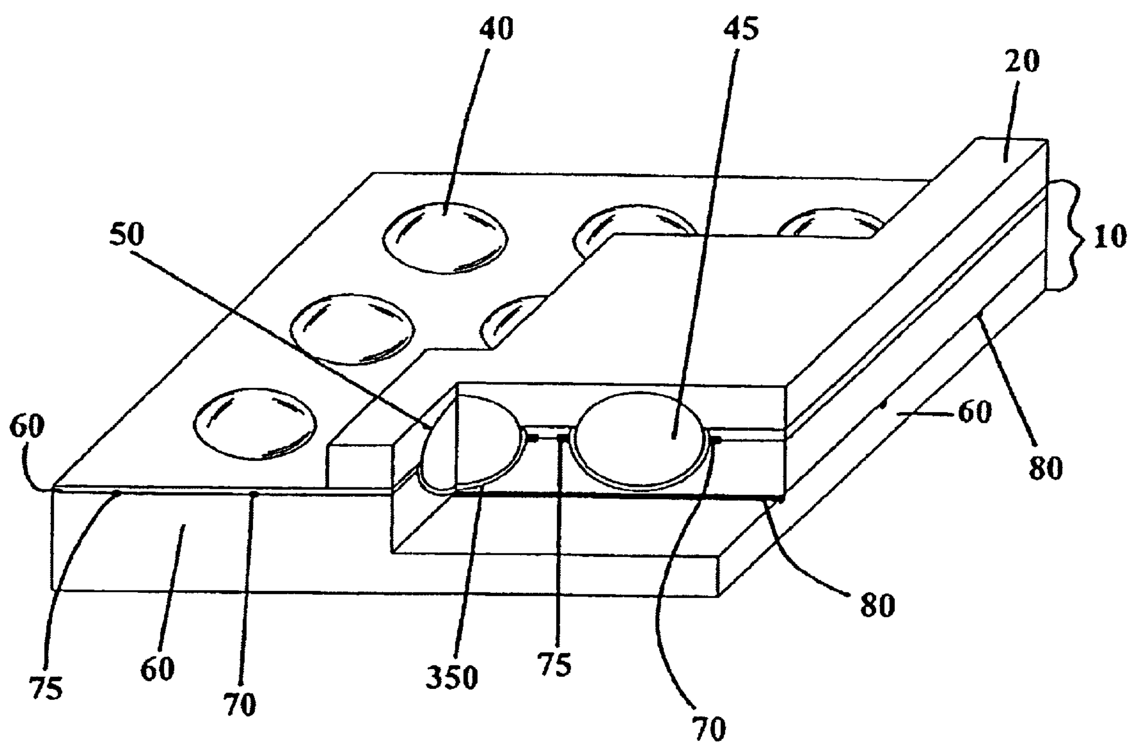


Fig. 6B

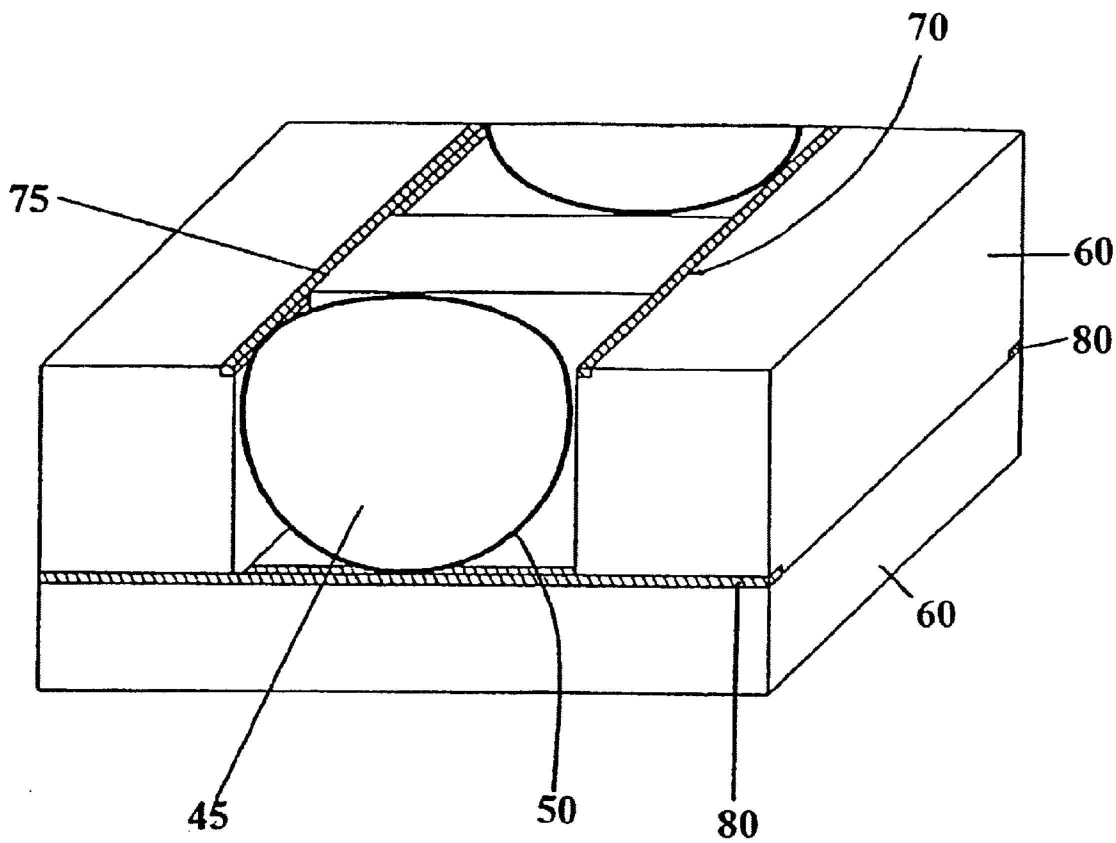


Fig. 7A

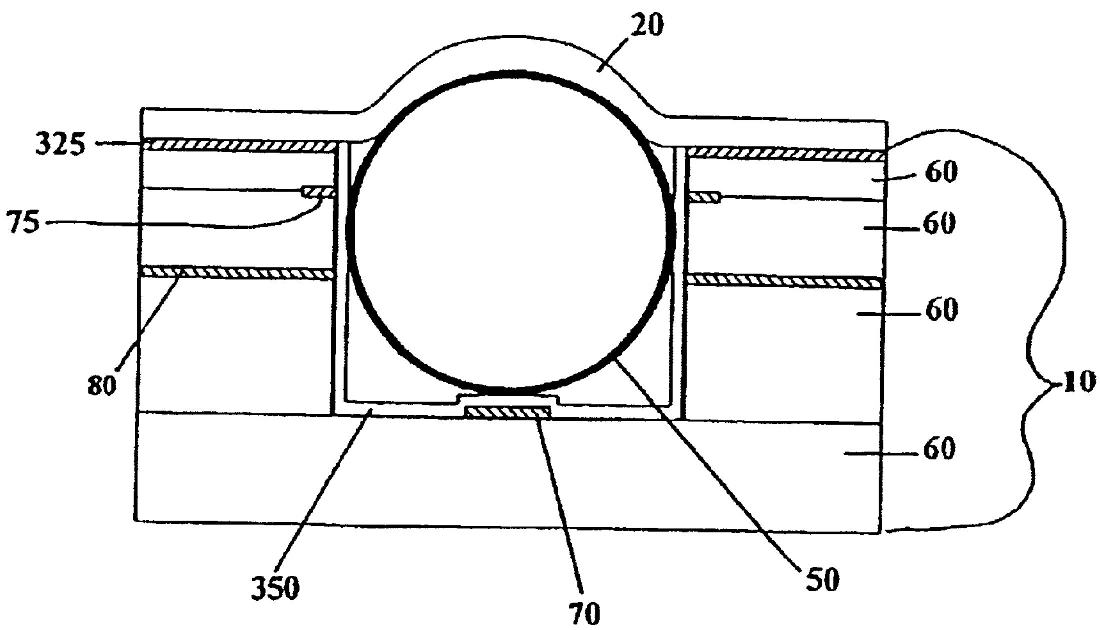


Fig. 7B

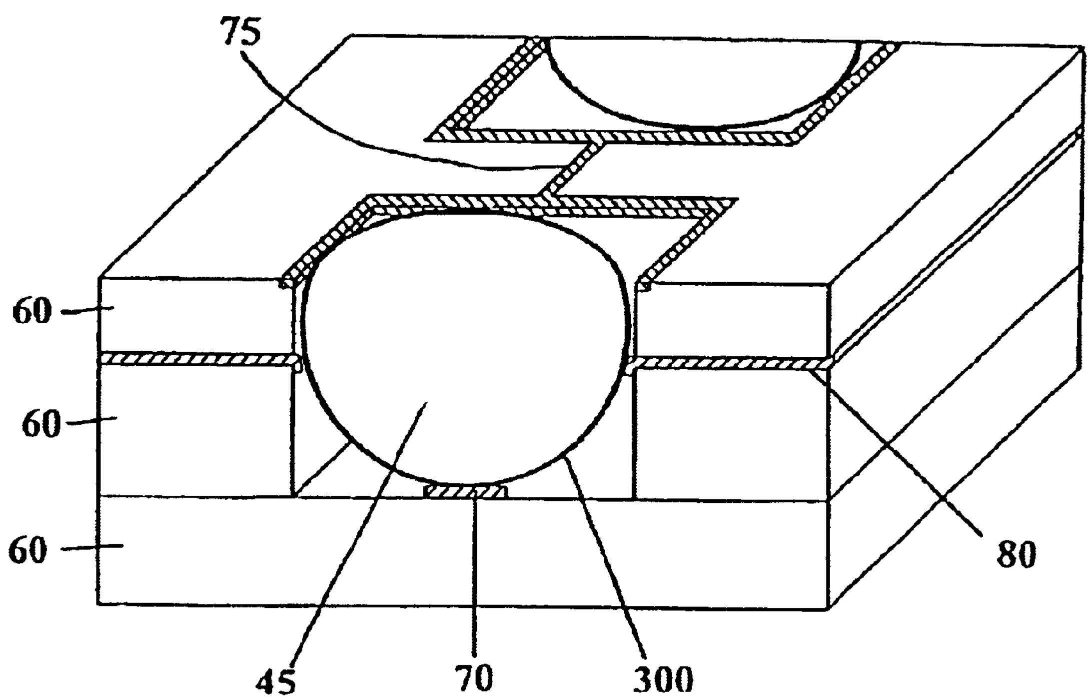


Fig. 8

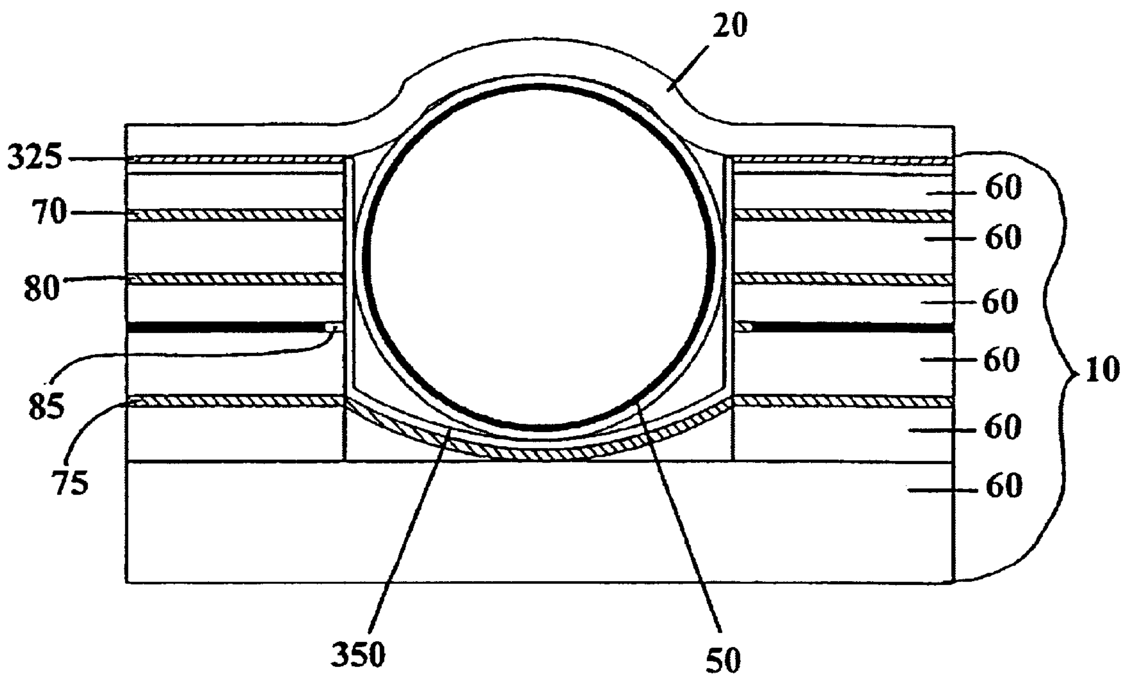


Fig. 9

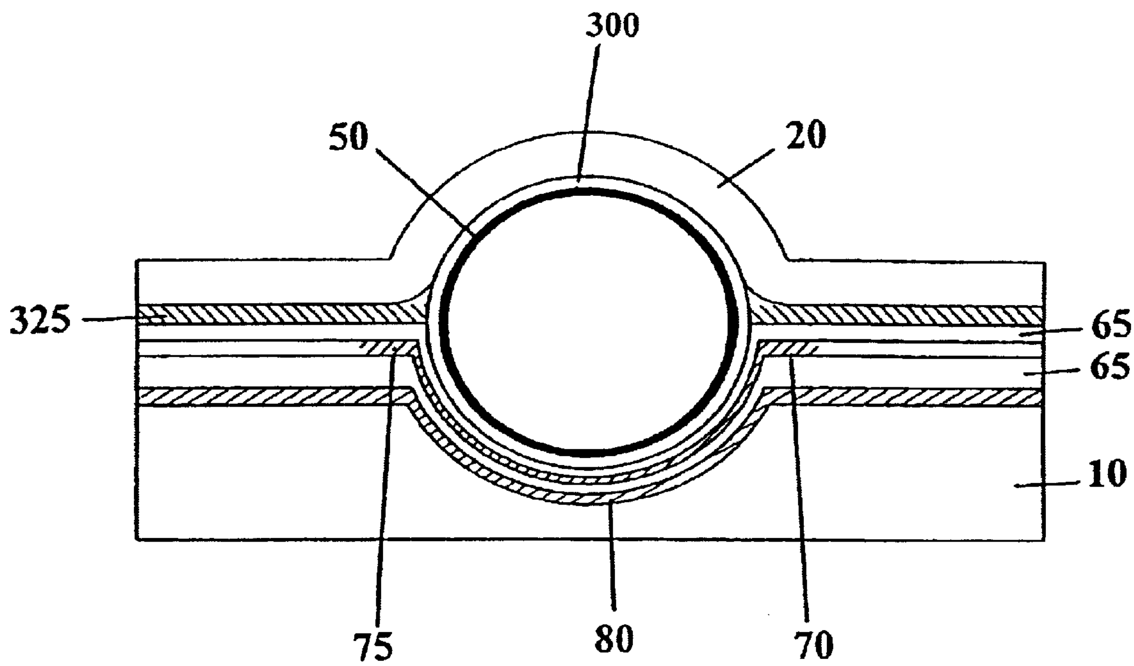


Fig. 10

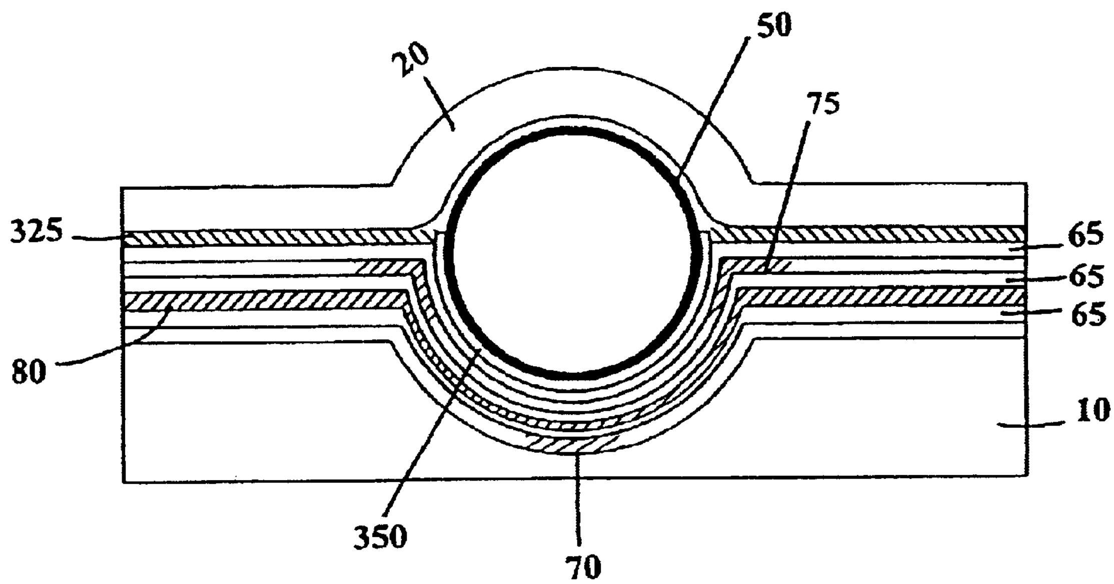


Fig. 11

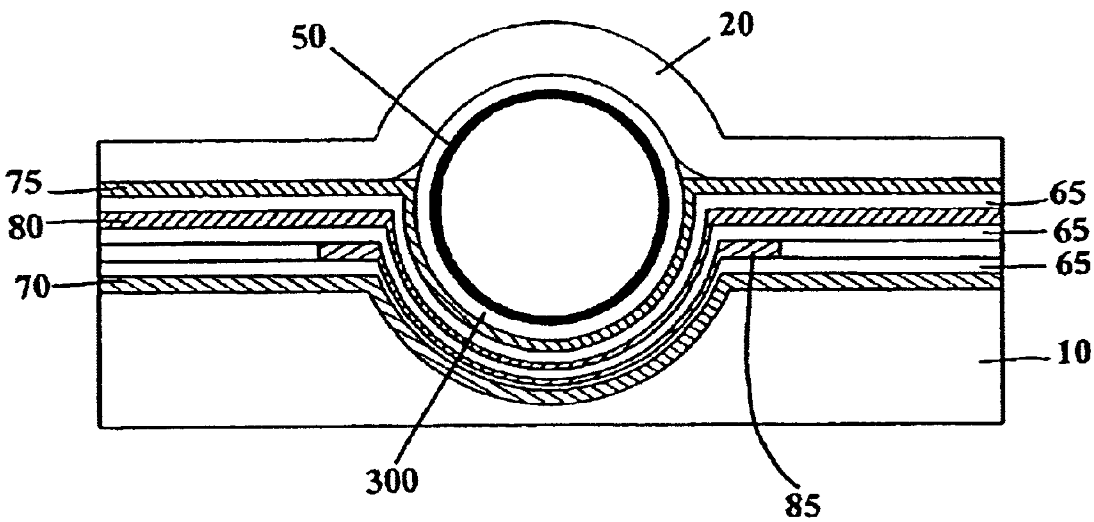


Fig. 12

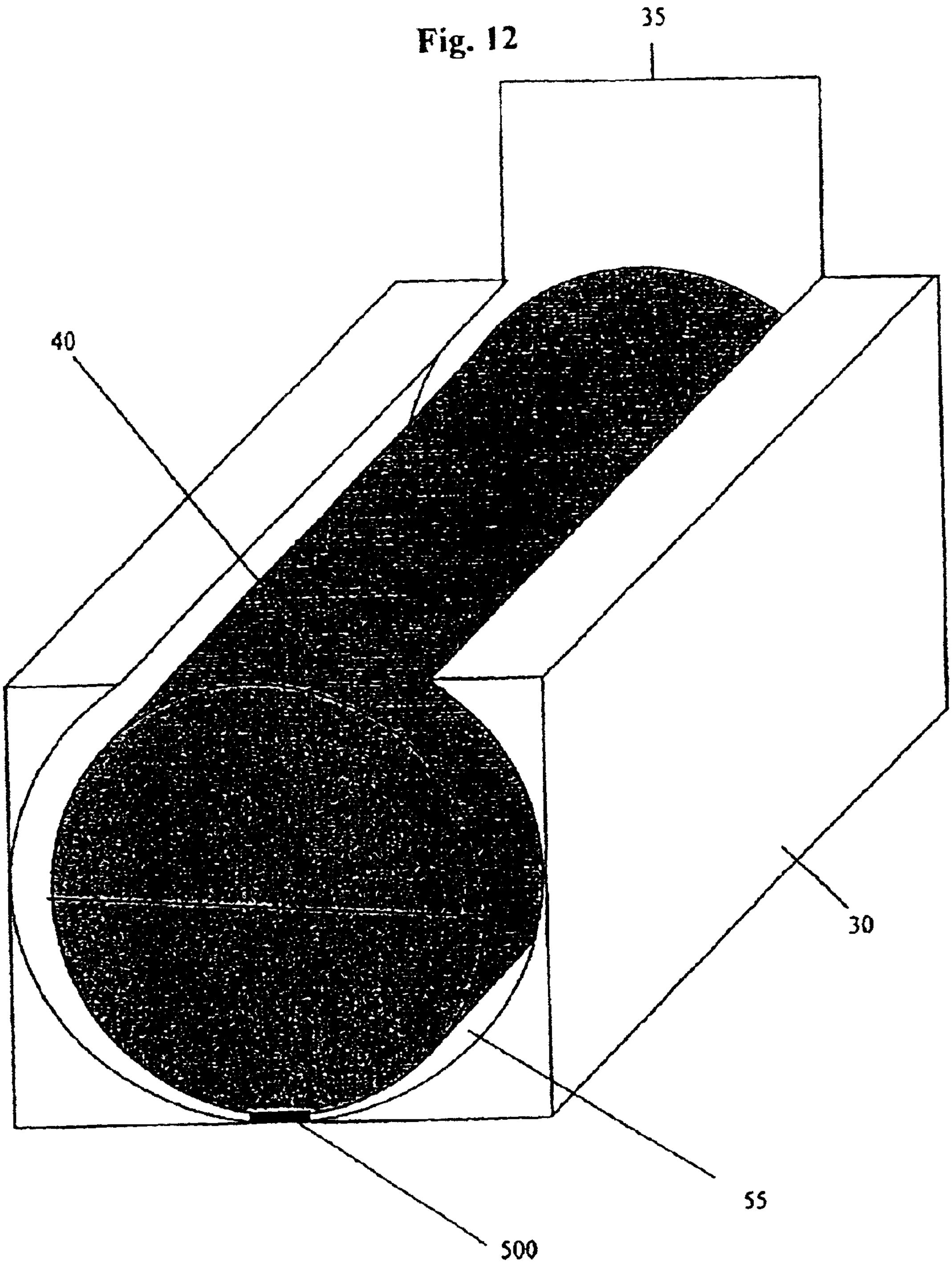


Fig. 13

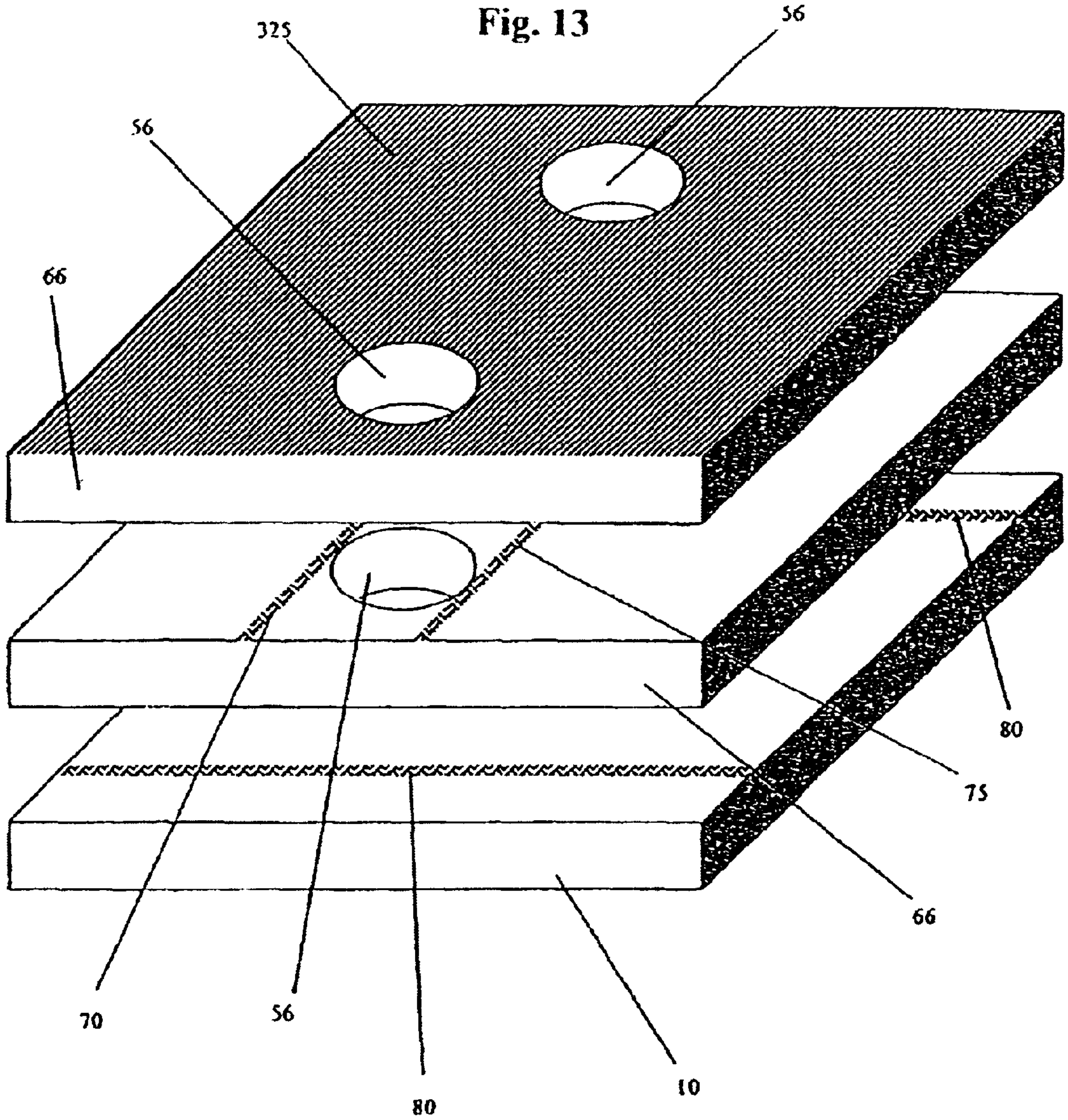


Fig. 14

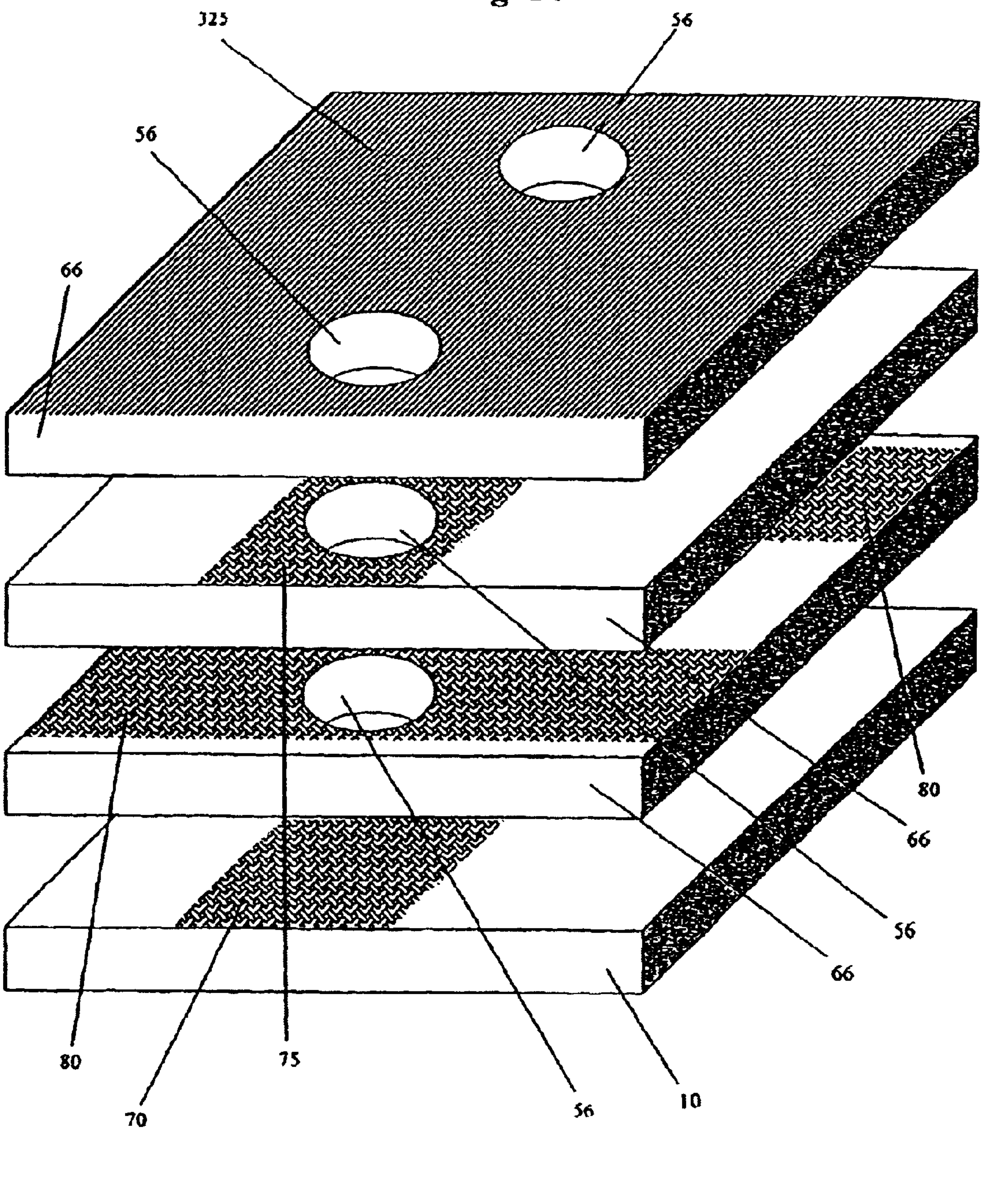
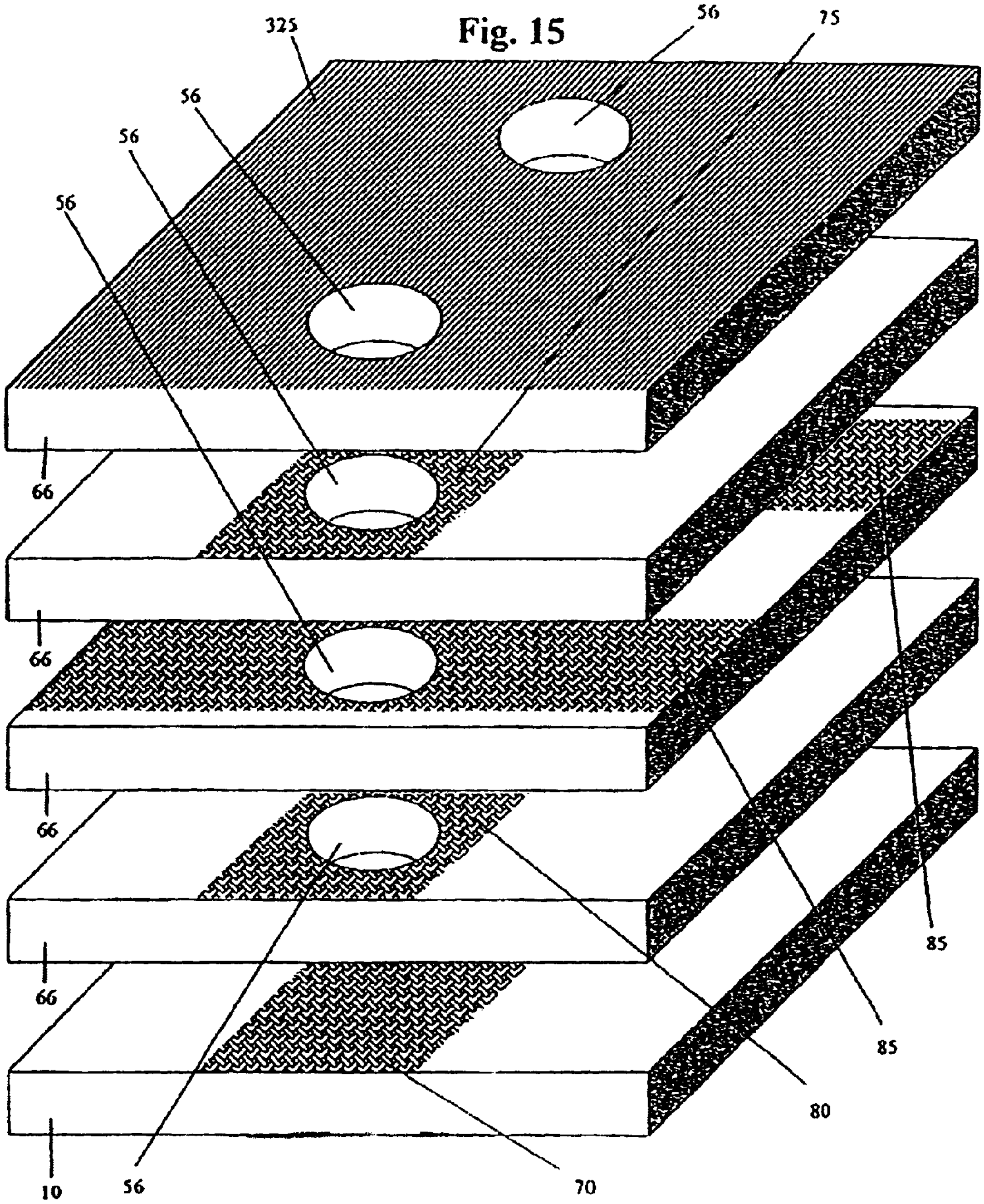


Fig. 15



# SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

"The current application is a continuation application of U.S. application Ser. No. 09/697,346, filed Oct. 27, 2000 and titled A Socket for Use in a Light-Emitting Panel which is now U.S. Pat. No. 6,545,422. The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000."

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a socket, for use in a light-emitting panel, in which a micro-component is at least partially disposed.

### 2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s = V_w - V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.



Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is

particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. Various embodiments of the present invention are drawn to different socket structures.

In one embodiment of the present invention, a cavity is patterned on a substrate such that it is formed in the substrate. In another embodiment, a plurality of material layers form a substrate and a portion of the material layers is selectively removed to form a cavity. In another embodiment, a cavity is patterned on a substrate so that the cavity is formed in the substrate and a plurality of material layers are disposed on the substrate such that the material layers conform to the shape of the cavity. In another embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity. Other embodiments are directed to methods for forming the sockets described above.

Each socket includes at least two electrodes that are arranged so voltage applied to the two electrodes causes one or more micro-components to emit radiation. In an embodiment of the present invention, the at least two electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to the first substrate and at least one electrode is adhered to the second substrate. In another embodiment, the at least two electrodes are arranged so that the radiation emitted from the micro-component when energized is emitted throughout the field of view of the light-emitting panel such that the radiation does not cross the two electrodes. In another embodiment, at least one electrode is disposed within the material layers.

A cavity can be any shape or size. In an embodiment, the shape of the cavity is selected from a group consisting of a cube, a cone, a conical frustum, a paraboloid, spherical, cylindrical, a pyramid, a pyramidal frustum, a parallelepiped, and a prism. In another embodiment, a socket and a micro-component are described with a male-female connector type configuration. In this embodiment, the micro-component and the cavity have complimentary shapes, wherein the opening of the cavity is smaller than the diameter of the micro-component so that when the micro-component is disposed in the cavity the micro-component is held in place by the cavity.

The size and shape of the socket influences the performance and characteristics of the display and may be chosen, for example, to optimize the panel's efficiency of operation. In addition, the size and shape of the socket may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. Further, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. In an embodiment, the inside of a socket is coated with a reflective material, which provides an increase in luminosity.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a socket capable of being used in the light-emitting panel and supporting at least one micro-component.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components **40** may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel, each cylindrical-shaped structure may hold micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

A cavity **55** formed within and/or on a substrate provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **50** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. In addition, in another embodiment of the present invention as shown in FIG. **12**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

The size and shape of the socket **30** influences the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and the electrodes disposed on or within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component that is deposited within a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

There are a variety of coatings **350** that may be at least partially added to a socket that also influence the performance and characteristics of the light-emitting panel. Types of coatings **350** include, but are not limited to, adhesives, bonding agents, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters. One skilled in the art will recognize that other coatings may also be used. The coatings **350** may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used. Alternatively, or in conjunction with the variety of socket coatings **350**, a micro-component **40** may also be coated with a variety of coatings **300**. These micro-component coatings **300** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may readily hold a micro-component or plurality of micro-components in a socket or may require additional activation energy to secure the micro-components or plurality of micro-components in a socket. In an embodiment of the present invention, where the micro-component is configured to emit UV light, the inside of each of the sockets **30** is at least partially coated with phosphor in order to convert the UV light to visible light. In a color light-emitting panel, in accordance with another embodiment, red, green, and blue phosphors are used to create alternating red, green, and blue, pixels/subpixels, respectively. By combining these colors at varying intensities all colors can be formed. In another embodiment, the phosphor coating may be combined with an adhesive so that the adhesive acts as a binder for the phosphor and also binds the micro-component **40** to the socket **30** when it is cured. In addition, the socket **30** may be coated with a reflective material, including, but not limited to, optical dielectric stacks, to provide an increase in luminosity, by directing radiation traveling in the direction of the substrate in which the sockets are formed out through the field of view **400** of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **65** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **65** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the cavities **55** are patterned on the first substrate **10** so that the cavities are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the cavities **55** are formed by selectively removing a portion of the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where the cavities **55** are patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **13**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **14**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **15**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket of the plurality of sockets comprises a cavity and wherein the cavity is patterned on the first substrate so as to be formed in the first substrate;

a plurality of micro-components, wherein at least two micro-components of the plurality of micro-components are at least partially disposed in each socket; and

a plurality of electrodes that are electrically but not physically in contact with the plurality of micro-components, wherein at least two electrodes of the plurality of electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode of the at least two electrodes is adhered to each of the first substrate and the second substrate and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**2**. The light-emitting panel of claim **1**, wherein the cavity is in a shape selected from a group consisting of a cube, a cone, a conical frustum, a paraboloid, a sphere, a cylinder, a pyramid, a pyramidal frustum, a parallelepiped, and a prism.

**3**. The light-emitting panel of claim **1**, wherein a depth of the cavity is selected to achieve a specific field of view for the light-emitting panel.

**4**. The light-emitting panel of claim **1**, wherein at least one socket is at least partially coated with phosphor.

**5**. The light-emitting panel of claim **1**, wherein at least one socket is at least partially coated with a reflective material.

**6**. The light-emitting panel of claim **1**, further comprising an adhesive or bonding agent disposed in the cavity.

**7**. The light-emitting panel of claim **1**, wherein at least one socket comprises at least one enhancement material selected from a group consisting of anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, and protective coatings.

**8**. The light-emitting panel of claim **1**, wherein at least one socket comprises at least one enhancement material selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**9**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, wherein each socket of the plurality of sockets comprises:

a cavity, wherein the cavity is patterned on the first substrate so as to be formed in the first substrate; wherein a depth of the cavity is selected to achieve a specific field of view for the light emitting panel and

a plurality of material layers, wherein the plurality of material layers are disposed on the first substrate such that the plurality of material layers conform to the shape of the cavity of each socket;

a plurality of micro-components, each containing a gas or gas-mixture, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket;

a plurality of electrodes, wherein at least one electrode of the plurality of electrodes is disposed within the material layers.

**10**. The light-emitting display of claim **9**, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout a field of view of the light-emitting panel without crossing the at least two electrodes.

**11**. The light-emitting panel of claim **9**, wherein the shape of the cavity is selected from a group consisting of a cube, a cone, a conical frustum, a paraboloid, a sphere, a cylinder, a pyramid, a pyramidal frustum, a parallelepiped, and a prism.

**12**. The light-emitting panel of claim **9**, wherein at least one socket is at least partially coated with phosphor.

**13**. The light-emitting panel of claim **9**, wherein at least one socket is at least partially coated with a reflective material.

**14**. The light-emitting panel of claim **9**, further comprising an adhesive or bonding agent disposed in each socket.

**15**. The light-emitting panel of claim **9**, wherein the material layers comprise at least one enhancement material selected from a group consisting of anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, and protective coatings.

**16**. The light-emitting panel of claim **9**, wherein the material layers comprise at least one enhancement material selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**17**. A light-emitting panel comprising:

a first substrate;

a second substrate opposed to the first substrate;

a plurality of sockets, each socket of the plurality of sockets comprising a cavity patterned on the first substrate so as to be formed in the first substrate, and further wherein each socket comprises at least one enhancement material selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits;

a plurality of micro-components, each containing a gas or gas-mixture, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

18. A socket for use in a light-emitting display, the socket comprising:

a cavity defined by a plurality of material layers, wherein the cavity is formed by selectively removing portions of the plurality of material layers;

at least one micro-component disposed in the cavity, the micro-component containing a gas or gas-mixture capable of emitting radiation when exposed to an electric potential of sufficient strength; and

a plurality of electrodes disposed in the cavity and arranged to expose the microcomponent to the electric potential.

19. The socket of claim 18, wherein the cavity comprises at least one of a cube, a cone, a conical frustum, a paraboloid, a sphere, a cylinder, a pyramid, a pyramidal frustum, a parallelepiped, and a prism.

20. The socket of claim 18, wherein the cavity and the micro-component comprise complementary mating shapes.

21. The socket of claim 18, further comprising a coating, the coating comprising at least one of a bonding agent, an adhesive, a coating to convert ultraviolet light to visible light, reflective material, a reflective filter, an optical dielectric stack, a ban-gap filter, and combinations thereof.

22. The socket of claim 18, further comprising an enhancement material, the

enhancement material comprising at least one of an anti-glare coating, a touch sensitive surface, a contrast enhancement coating, a protective coating, a transistor, an integrated circuit, a semi-conductor device, an inductor, a capacitor, a resistor, a diode, control electronics, drive electronics, pulse-forming networks, a pulse compressor, a pulse transformer, a tuned circuit and combinations thereof.

23. The socket of claim 18, wherein the plurality of electrodes are formed in the plurality of material layers.

24. The socket of claim 18, wherein at least one of the plurality of material layers comprises at least one of a dielectric material, a metal, an anti-glare coating, a touch sensitive surface, a contrast enhancement coating, a protective coating, a transistor, an integrated circuit, a semi-conductor device, an inductor, a capacitor, a resistor, a diode, control electronics, drive electronics, pulse-forming networks, a pulse compressor, a pulse transformer, a tuned circuit, and combinations thereof.

25. A socket for use in a light-emitting display, the socket comprising:

a substrate;

a plurality of material layers, each material layer comprising a preformed aperture extending through that material layer, the material layers disposed on the substrate and the apertures aligned to form a cavity in the socket and at least one micro-component containing a gas or gas-mixture disposed in the cavity.

26. The socket of claim 25, wherein at least one of the plurality of material layers comprises at least one of a dielectric material, a metal, an anti-glare coating, a touch sensitive surface, a contrast enhancement coating, a protective coating, a transistor, an integrated circuit, a semi-conductor device, an inductor, a capacitor, a resistor, a diode, control electronics, drive electronics, pulse-forming networks, a pulse compressor, a pulse transformer, a tuned circuit, and combinations thereof.

27. A method for making a socket for use in a light-emitting panel, the method comprising:

disposing a plurality of material layers on a substrate;

patterning a cavity on the substrate by selectively removing portions of the plurality of material layers;

disposing at least one micro-component in the cavity, the micro-component containing a gas or gas-mixture being capable of emitting radiation when exposed to an electric potential of sufficient strength; and

disposing at least two electrodes on the substrate arranged to expose the micro-component to an electric potential.

28. The method of claim 27, further comprising disposing a plurality of micro-components in die cavity, the electrodes arranged to expose each one of the plurality of micro-components to an electric potential.

29. The method of claim 28, further comprising adding at least one coating to the socket, the coating comprising at least one of a bonding agent, an adhesive, a coating to convert ultraviolet light to visible light, reflective material, a reflective filter, an optical dielectric stack, a band-gap filter, and combinations thereof.

30. The method of claim 28, further comprising adding at least one enhancement material to the socket, the enhancement material comprising at least one of an anti-glare coating, a touch sensitive surface, a contrast enhancement coating, a protective coating, a transistor, an integrated circuit, a semi-conductor device, an inductor, a capacitor, a resistor, a diode, control electronics, drive electronics, pulse-forming networks, a pulse compressor, a pulse transformer, a tuned circuit, and combinations thereof.

31. The method of claim 27, wherein the step of disposing the material layers comprises at least one of photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, and deposition using ink-jet technology.

32. The method of claim 27, wherein the step of selectively removing portions of each material layer comprises at least one of wet etching, dry etching, photolithography, laser beat treatment, thermal forming, mechanical punching, embossing, stamping, drilling, electroforming, dimpling, and combinations thereof.

33. The method of claim 27, further comprising disposing a plurality of micro-components in the cavity, the electrodes arranged to expose each one of the plurality of micro-components to an electric potential.

34. The method of claim 27, further comprising adding at least one coating to the socket, the coating comprising at least one of a bonding agent, an adhesive, a coating to convert ultraviolet light to visible light, reflective material, a reflective filter, an optical dielectric stack, a band-gap filter, and combinations thereof.

35. The method of claim 27, father comprising adding at least one enhancement material to the socket, the enhancement material comprising at least one of an anti-glare coating, a touch sensitive surface, a contrast enhancement coating, a protective coating, a transistor, an integrated circuit, a semi-conductor device, an inductor, a capacitor, a resistor, a diode, control electronics, drive electronics, pulse-forming networks, a pulse compressor, a pulse transformer, a tuned circuit, and combinations thereof.

36. A method for making a socket for use in a light-emitting panel, the method comprising:

disposing a plurality of material layers on a substrate, each material layer comprising a preformed aperture extending through that material layer; aligning the apertures in the material layers to form a cavity on the first substrate;

disposing at least one micro-component in the cavity, the micro-component containing a gas or gas-mixture capable of emitting radiation when exposed to an electric potential of sufficient strength; and

disposing at least two electrodes within the socket arranged to expose the micro-component to an electric potential.

37. The method of claim 36, wherein the step of disposing the material layers comprises at least one of photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, and deposition using ink-jet technology.

38. The method of claim 36, further comprising disposing a plurality of micro-components in the cavity, the electrodes arranged to expose each one of the plurality of micro-components to an electric potential.

39. The method of claim 36, further comprising adding at least one coating to the socket, the coating comprising at least one of a bonding agent, an adhesive, a coating to convert ultraviolet light to visible light reflective material, a reflective filter, an optical dielectric stack, a band-gap filter, and combinations thereof.

40. The method of claim 36, further comprising adding at least one enhancement material to the socket, the enhancement material comprising at least one of an anti-glare coating, a touch sensitive surface, a contrast enhancement coating, a protective coating, a transistor, an integrated circuit, a semi-conductor device, an inductor, a capacitor, a resistor, a diode, control electronics, drive electronics, pulse-forming networks, a pal so compressor, a pulse transformer, a tuned circuit, and combinations thereof.

41. The method of claim 36, wherein the two electrodes are disposed on at least one of the substrate, the material layers, and combinations thereof.

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US006762566B1

(12) **United States Patent**
**George et al.**

(10) **Patent No.: US 6,762,566 B1**

(45) **Date of Patent: Jul. 13, 2004**

(54) **MICRO-COMPONENT FOR USE IN A LIGHT-EMITTING PANEL**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 114 days.

(21) Appl. No.: **09/697,358**

(22) Filed: **Oct. 27, 2000**

(51) **Int. Cl.**[7] .................................................. **G09G 3/10**

(52) **U.S. Cl.** ....................... **315/169.3**; 313/586; 345/70

(58) **Field of Search** ............................... 315/64, 169.1, 315/169.3, 312, 169.4; 313/513, 514, 522, 586; 445/27, 48; 345/70, 72

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 A | | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | | 7/1976 | Greeson, Jr. | |
| 3,990,068 A | | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 A | | 12/1981 | Torobin | 65/21.4 |
| 4,393,326 A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 A | | 11/1985 | Dick | 340/775 |
| 4,563,617 A | * | 1/1986 | Davidson | 315/312 |
| 4,591,847 A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 A | | 3/1987 | Shelton | 315/111.71 |
| 4,697,123 A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 A | | 3/1988 | Dick | |
| 4,833,463 A | | 5/1989 | Dick et al. | |
| 4,843,281 A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 A | | 12/1989 | Parker | 313/634 |
| 4,912,364 A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 A | | 7/1991 | Salavin et al. | |
| 5,062,916 A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 A | | 12/1991 | Deschamps et al. | |
| 5,126,632 A | | 6/1992 | Parker | 313/634 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/34665 | 6/2000 | G02F/1/167 |
| WO | WO 00/36465 | 6/2000 | G06F/1/167 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

(List continued on next page.)

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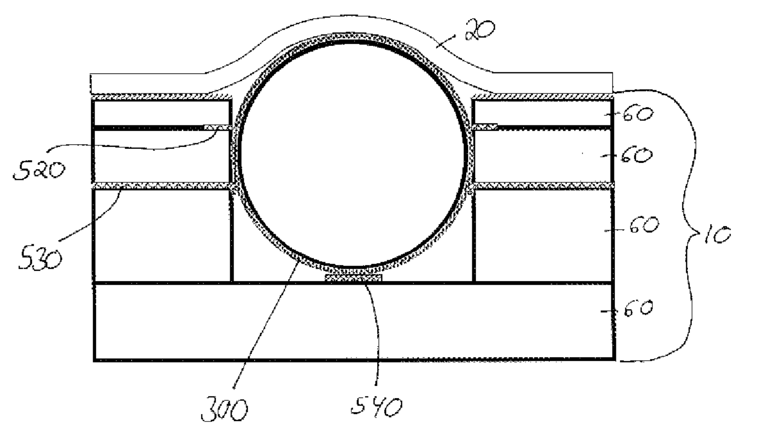
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. Several improved methods of forming micro-components are also disclosed.

**24 Claims, 9 Drawing Sheets**



## U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.3 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,545,422 | B1 * | 4/2003 | George et al. | 315/169.3 |

## OTHER PUBLICATIONS

Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco PlasmaWall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco PlasmaWall Pl–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco PlasmaWall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

Rauf, S., Kushner, M.J., *Operation of a Coplanar–Electrode Plasma Display Panel Cell*, IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Shin, Y.K., Lee, J.K., Shon, C.H., *Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry*, IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 14–15.

Kurihara, M. Makabe, T., *Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency*, IEEE Transactions on Plasma Science, vol. 27, No. 5, Oct. 1999, pp. 1372–1378.

Alien Technology Corporation's Technology Overview; copyright ©2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

International Search Report dated Sep. 23, 2002.

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

* cited by examiner

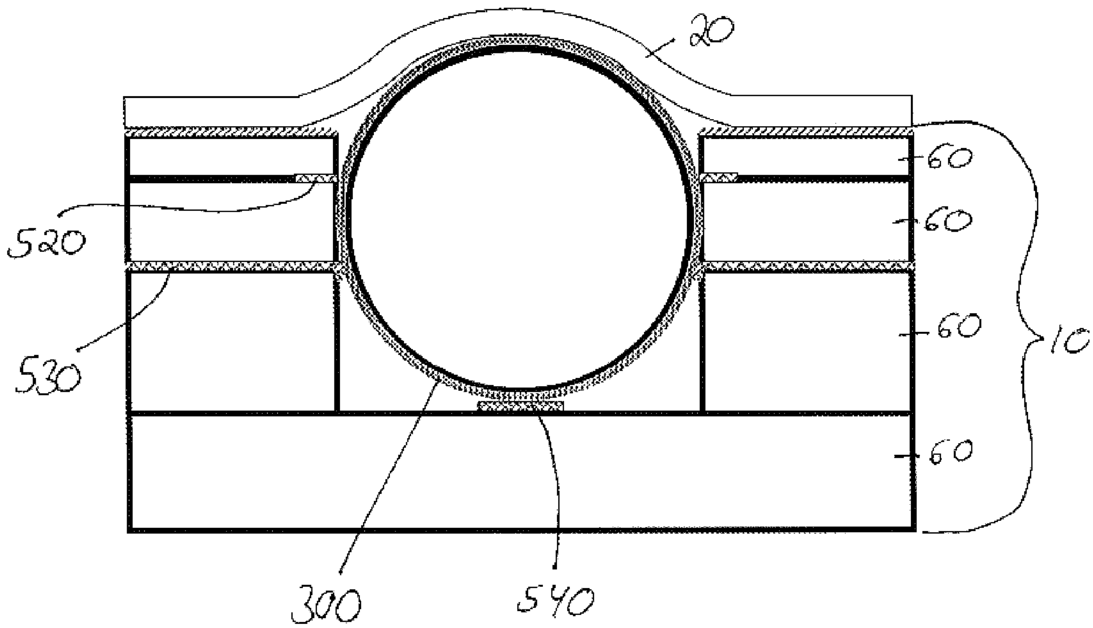



Fig. 1

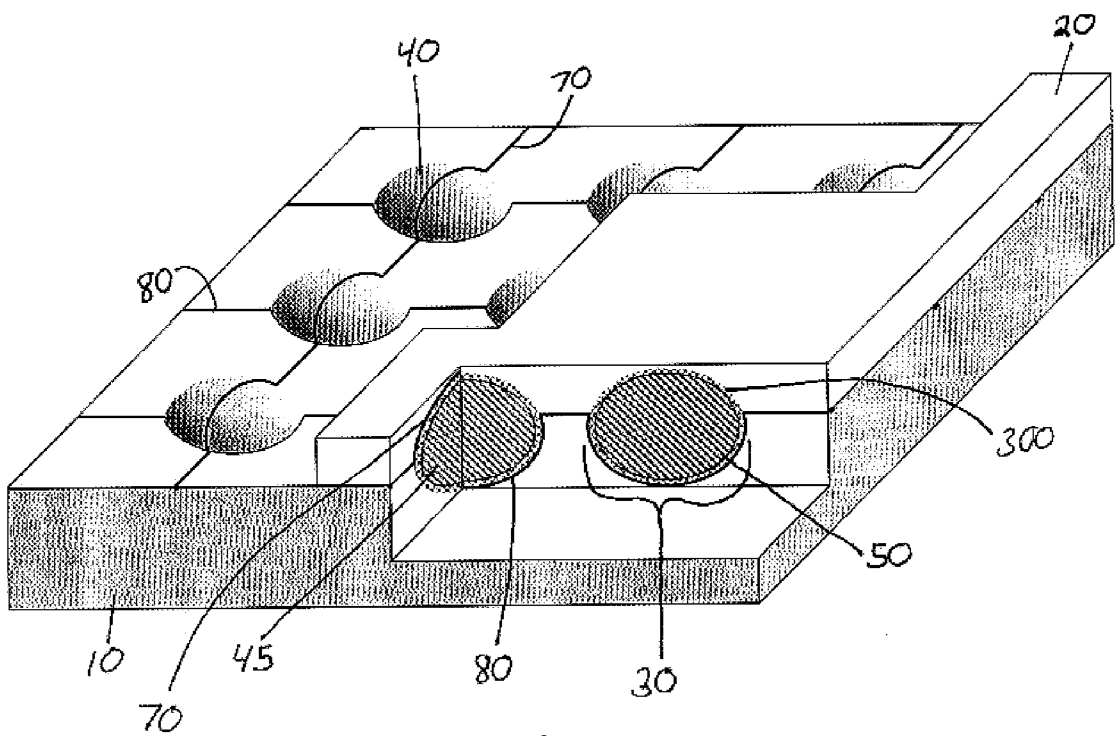



Fig. 2

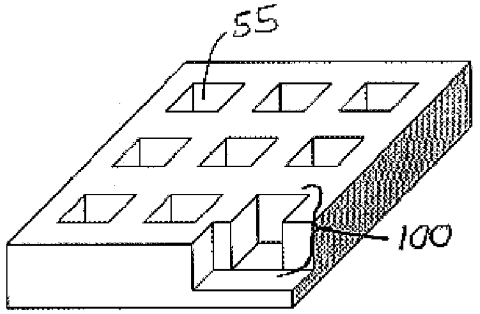



Fig. 3A

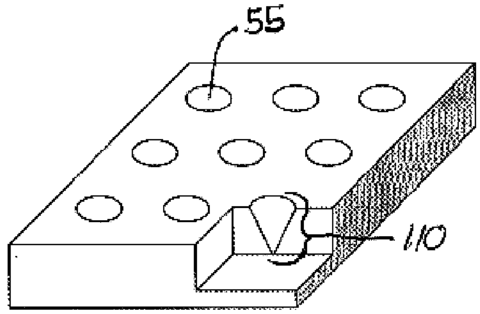



Fig. 3B

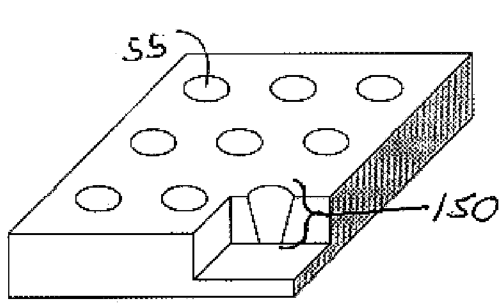



Fig. 3C

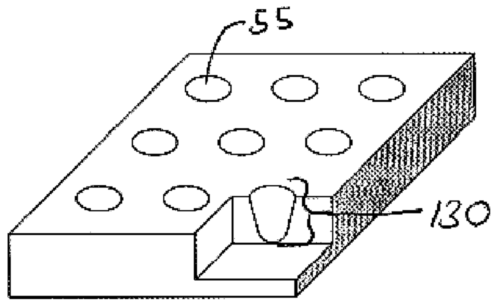



Fig 3D

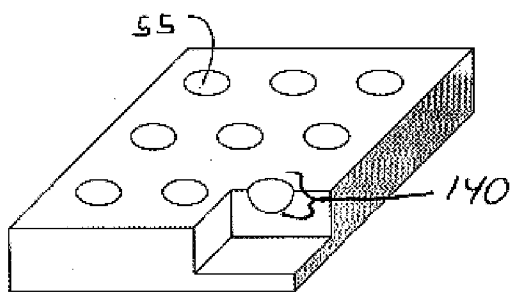
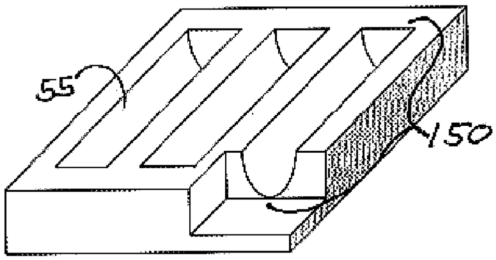



Fig. 3E

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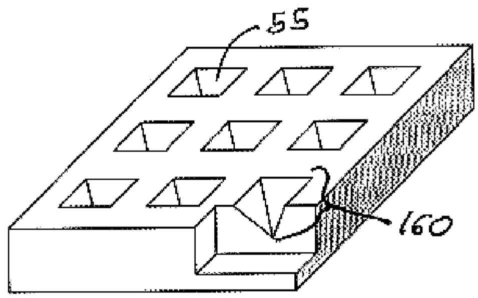



Fig. 3G

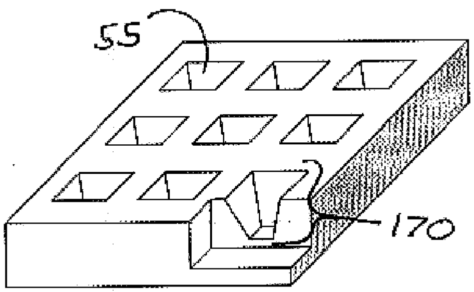



Fig. 3H

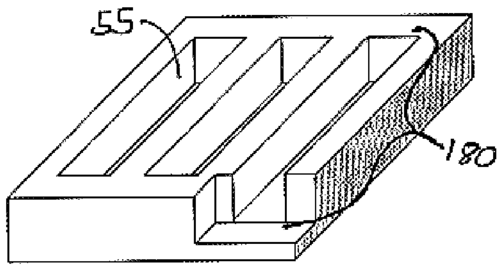



Fig. 3I

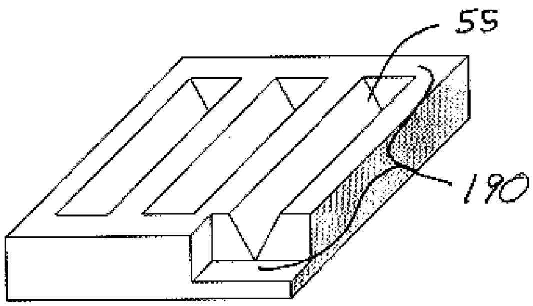
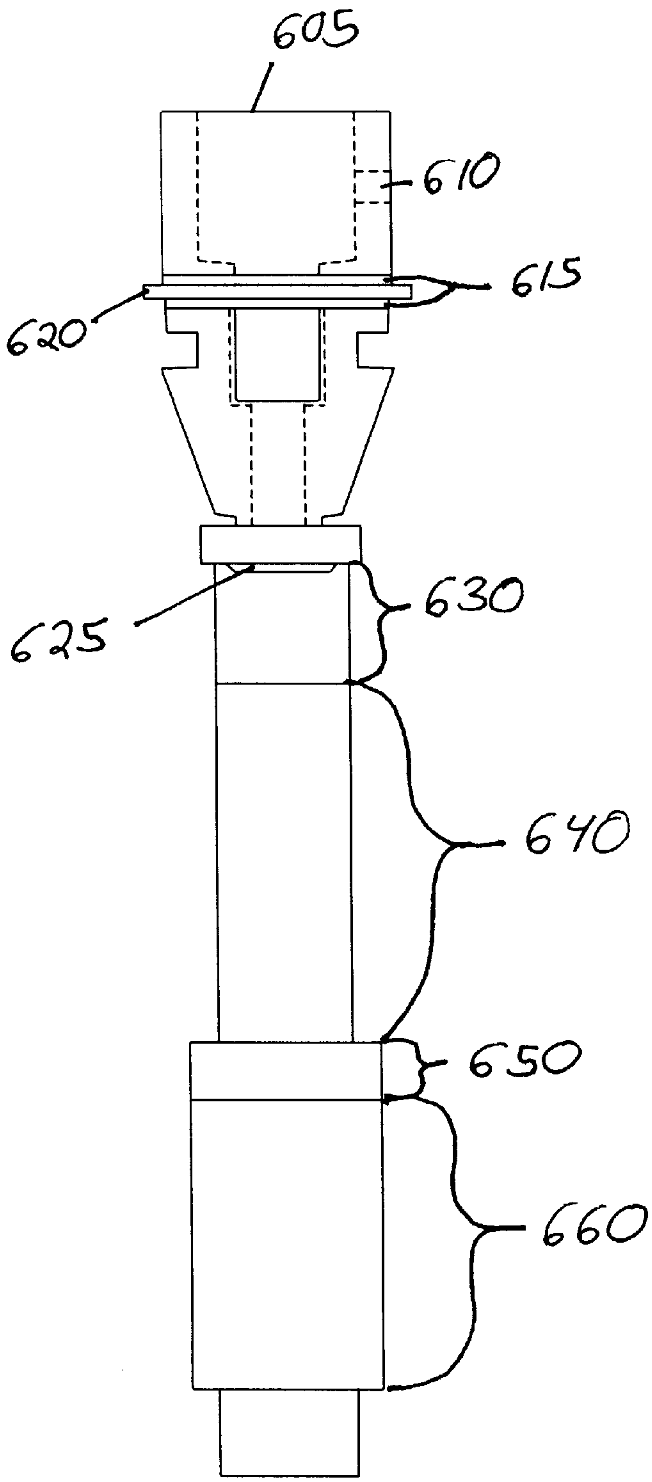



Fig. 3J

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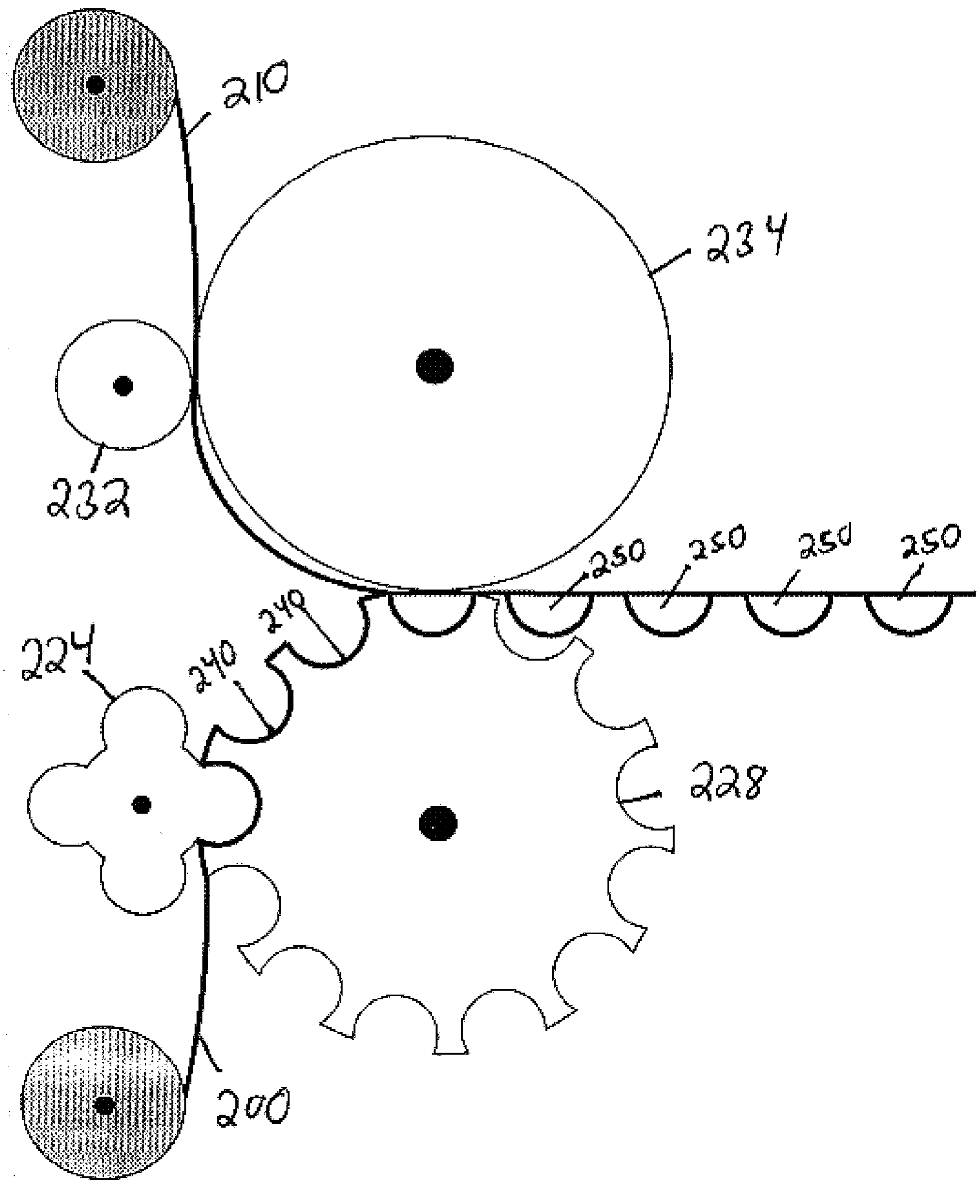


Fig. 5

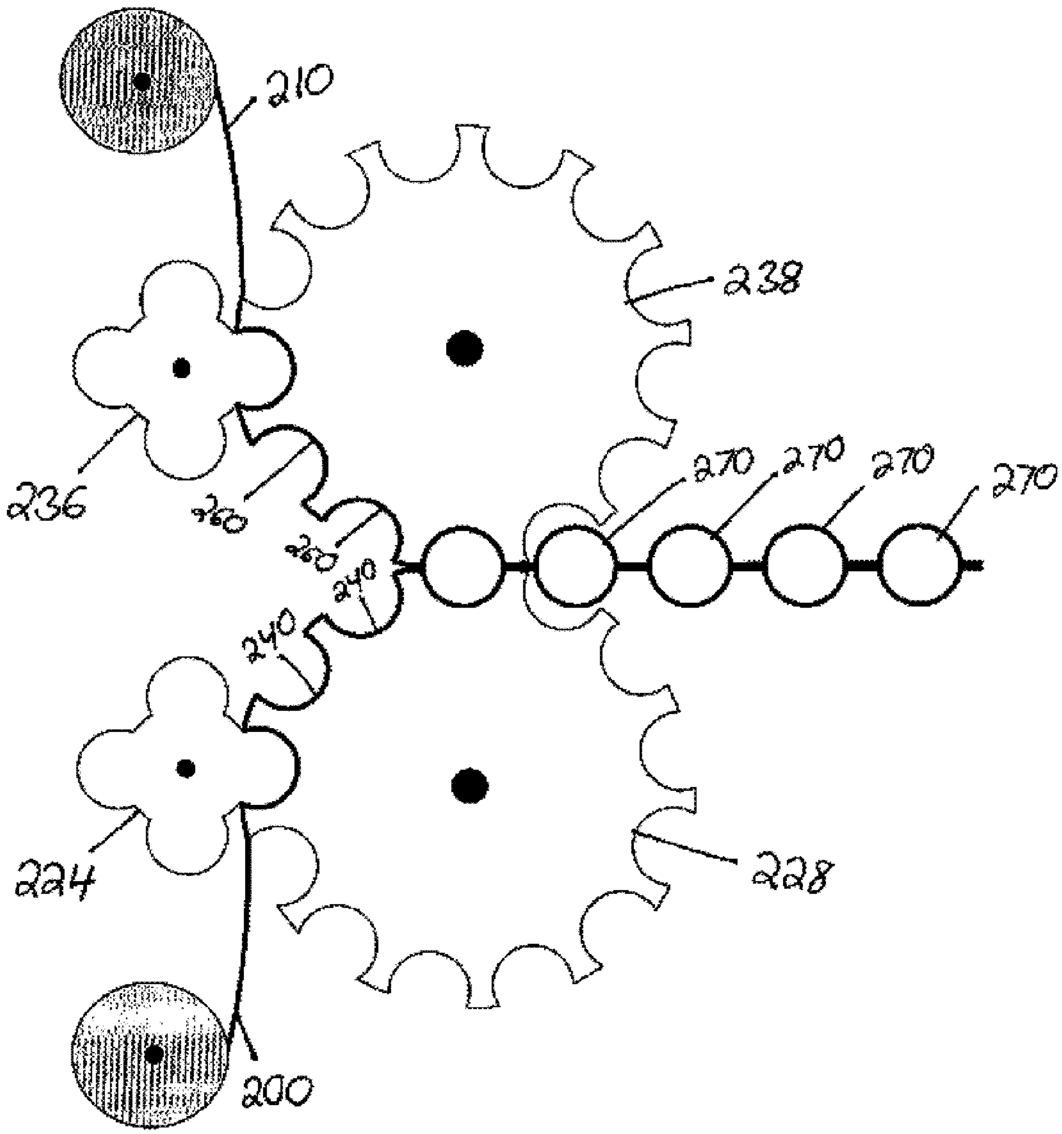


Fig. 6

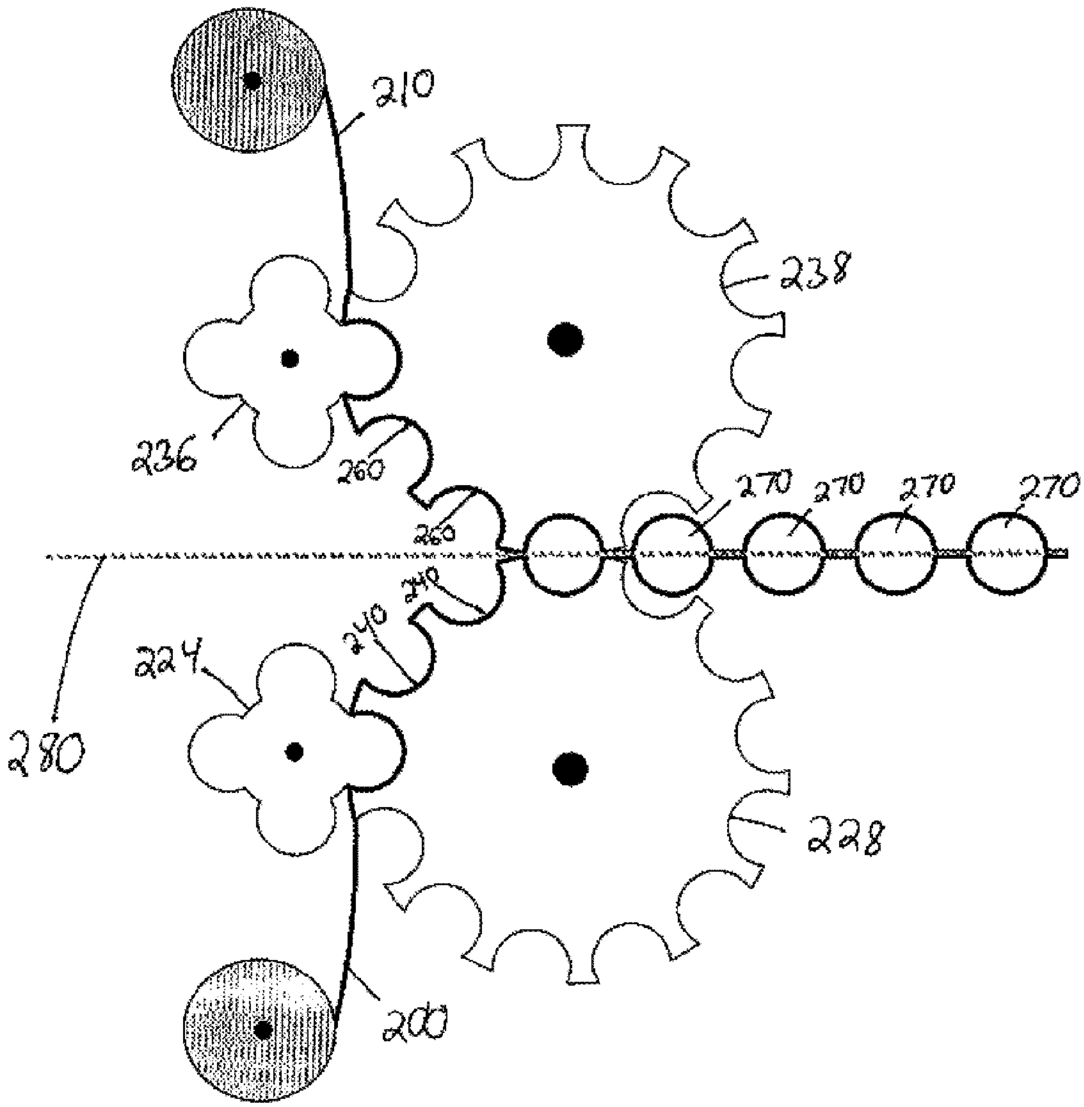


Fig. 7

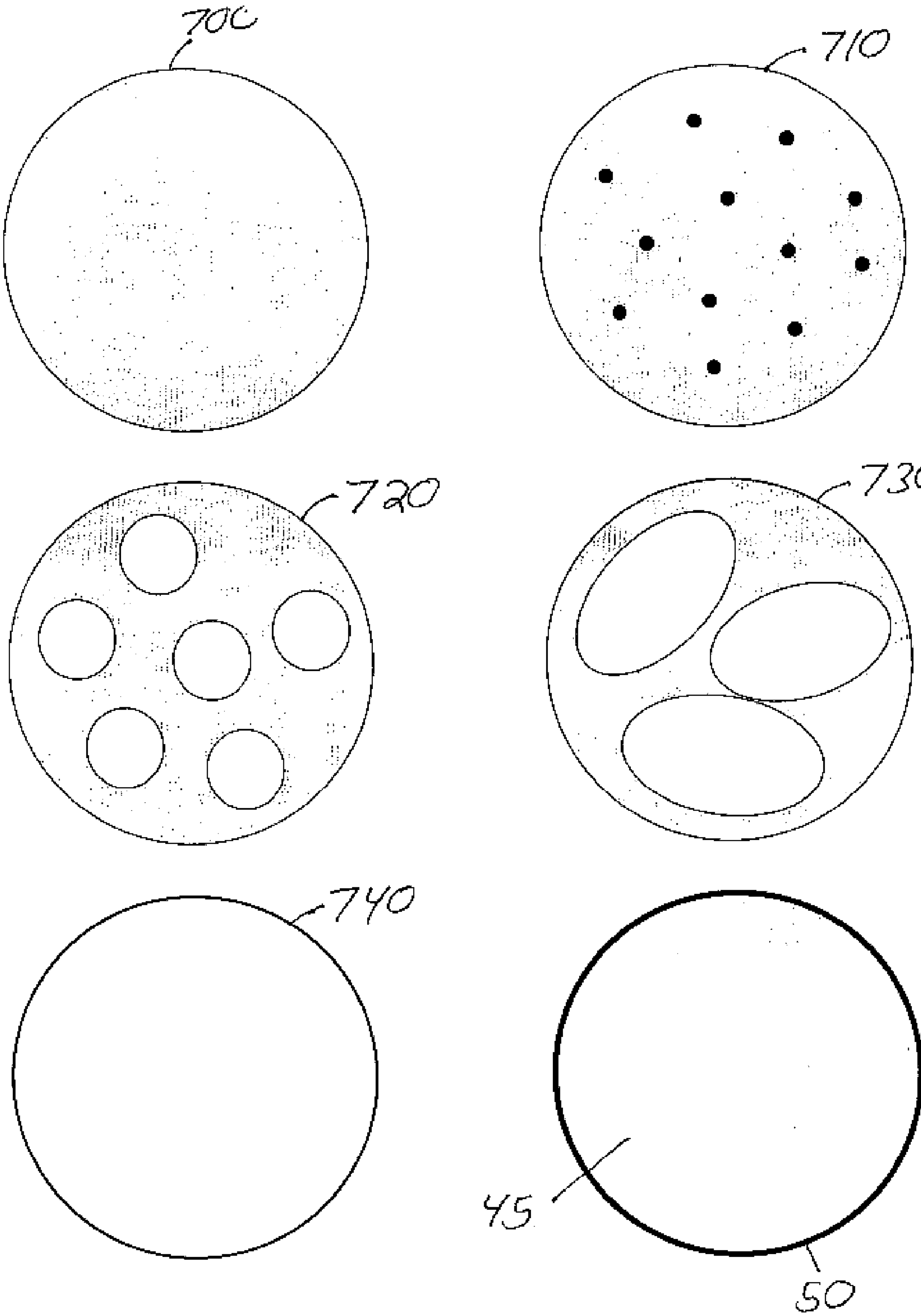


Fig. 8

# MICRO-COMPONENT FOR USE IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method for Making filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,346 entitled A Socket For Use in a Light-Emitting Panel filed Oct. 27, 2000."

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a micro-component for use in a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.



The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel.

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In one embodiment of the present invention, the micro-component is configured to emit ultra-violet (UV) light, which may be converted to visible light by at least partially coating each micro-component with phosphor. To obtain an increase in luminosity and radiation transport efficiency, each micro-component may be at least partially coated with a secondary emission enhancement material.

In another embodiment, each micro-component is coated with a reflective material. An index matching material is disposed so as to be in contact with at least a portion of the reflective material. The combination of the index matching material and the reflective material permits a predetermined wavelength of light to be emitted from each micro-component at the point of contact between the index matching material and the reflective material.

Another object of the present invention is to provide a micro-component for use in a light-emitting panel. A shell at least partially filled with at least one plasma-forming gas provides the basic micro-component structure. The shell may be doped or ion implanted with a conductive material, a material that provides secondary emission enhancement, and/or a material that converts UV light to visible light.

Another preferred embodiment of the present invention is to provide a method of making a micro-component. In one embodiment, the method is part of a continuous process, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the plasma-forming gas or gas mixture.

In another embodiment, the micro-component is made by affixing a first substrate to a second substrate in the presence of at least one plasma-forming gas. In this method, either the first and/or the second substrate contains a plurality of cavities so that when the first substrate is affixed to the second substrate the plurality of cavities are filled with the plasma-forming gas or gas mixture. In a preferred embodiment, a first substrate is advanced through a first roller assembly, which includes a roller with a plurality of nodules and a roller with a plurality of depressions. Both the plurality of nodules and the plurality of depressions are in registration with each other so that when the first substrate passes through the first roller assembly, the first substrate has a plurality of cavities formed therein. A second substrate is advanced through a second roller assembly and then affixed to the first substrate in the presence of at least one gas so that when the two substrates are affixed the cavities are filled with the gas or gas mixture. In an alternate preferred embodiment, the second roller assembly includes a roller with a plurality of nodules and a roller with a plurality of depressions so that when the second substrate passes through the second roller assembly, the second substrate also has a plurality of cavities formed therein. In either of these embodiments, at least one electrode may be sandwiched between the first and second substrates prior to the substrates being affixed.

In another embodiment, at least one substrate is thermally treated in the presence of a least one plasma-forming gas so as to form shells filled with the plasma-forming gas or gas-mixture.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing a plurality of micro-components disposed in sockets.

FIG. **2** shows a socket with a micro-component disposed therein.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components.

FIG. **5** shows an apparatus used in an embodiment of the present invention as part of another process for forming micro-components.

FIG. **6** shows an variation of the apparatus shown in FIG. **5**, which is used as part of another process for forming micro-components.

FIG. **7** illustrates, according to an embodiment, one way in which an electrode may be disposed between two substrates as part of a process for forming micro-components.

FIG. **8** depicts the steps of another method for forming micro-components.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a micro-component capable of being used in the light-emitting panel and at least partially disposed in at least one socket.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3**A–**3**J, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. In FIG. **2**, a two electrode configuration is shown including a first sustain electrode **520** and an address electrode **530**. In FIG. **1**, a three electrode configuration is shown, wherein a first sustain electrode **520**, an address electrode **530** and a second sustain electrode **540** are disposed within a plurality of material layers **60** that form the first substrate **10**. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may also work. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

Several methods are proposed, in various embodiments, for making a micro-component for use in a light-emitting panel. It has been contemplated that each of the coatings and dopants that may be added to a micro-component **40**, as disclosed herein, may also be included in steps in forming a micro-component, as discussed herein.

In one embodiment of the present invention, a continuous inline process for making a micro-component is described, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the gas or gas mixture. In a preferred embodiment, the process takes place in a drop tower. According to FIG. **4**, and as an example of one of many possible ways to make a micro-component as part of a continuous inline process, a droplet generator **600** including a pressure transducer port **605**, a liquid inlet port **610**, a piezoelectric transducer **615**, a transducer drive signal electrode **620**, and an orifice plate **625**, produces uniform water droplets of a predetermined size. The droplets pass through an encapsulation region **630** where each water droplet is encased in a gel outer membrane formed of an aqueous solution of glass forming oxides (or any other suitable material that may be used for a micro-component shell), which is then passed through a dehydration region **640** leaving a hollow dry gel shell. This dry gel shell then travels through a transition region **650** where it is heated into a glass shell (or other type of shell depending on what aqueous solution was chosen) and then finally through a refining region **660**. While it is possible to introduce a plasma-forming gas or gas mixture into the process during any one of the steps, it is preferred in an embodiment of the present invention to perform the whole process in the presence of the plasma-forming gas or gas mixture. Thus, when the shell leaves the refining region **660**, the plasma-forming gas or gas mixture is sealed inside the shell thereby forming a micro-component.

In an embodiment of the present invention, the above process is modified so that the shell can be doped with either a secondary emission enhancement material and/or a conductive material, although other dopants may also be used. While it is contemplated that the dopants may be added to the shell by ion implantation at later stages in the process, in a preferred embodiment, the dopant is added directly in the aqueous solution so that the shell is initial formed with the dopant already present in the shell.

The above process steps may be modified or additional process steps may be added to the above process for forming a micro-component to provide a means for adding at least one coating to the micro-component. For coatings that may be disposed on the inside of the shell including, but not limited to a secondary emission enhancement material and a conductive material, it is contemplated in an embodiment of the present invention that those coating materials are added to the initial droplet solution so that when the outer membrane is formed around the initial droplet and then passed through the dehydration region **640** the coating material is left on the inside of the hollow dry gel shell. For coatings that may be disposed on the outside of the shell including, but not limited to, coatings used to convert UV light to visible light, coatings used as reflective filters and coatings used as band-gap filters, it is contemplated that after the micro-component leaves the refining region **660**, the micro-component will travel through at least one coating region. The coatings may be applied by any number of processes known to those skilled in the art as a means of applying a coating to a surface.

In another embodiment of the present invention, two substrates are provided, wherein at least one of two substrates contain a plurality of cavities. The two substrates are affixed together in the presence of at least one plasma-forming gas so that when affixed, the cavities are filled with the gas or gas mixture. In an embodiment of the present invention at least one electrode is disposed between the two substrates. In another embodiment, the inside, the outside, or both the inside and the outside of the cavities are coated with at least one coating. It is contemplated that any coating that may be applied to a micro-component as disclosed herein may be used. As illustrated in FIG. **5**, one method of making a micro-component in accordance with this embodiment of the present invention is to take a first substrate **200** and a second substrate **210** and then pass the first substrate **200** and the second substrate **210** through a first roller assembly and a second roller assembly, respectively. The first roller assembly includes a first roller with nodules **224** and a first roller with depressions **228**. The first roller with nodules **224** is in register with the first roller with depressions **228** so that as the first substrate **200** passes between the first roller with nodules **224** and the first roller with depressions **228**, a plurality of cavities **240** are formed in the first substrate **200**. The second roller assembly, according to a preferred embodiment, includes two second rollers, **232** and **234**. The first substrate **200**, with a plurality of cavities **240** formed therein, is brought together with the second substrate **210** in the presence of a plasma-forming gas or gas mixture and then affixed, thereby forming a plurality of micro-components **250** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **210** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller **234**.

The nodules on the first roller with nodules **224** may be disposed in any pattern, having even or non-even spacing between adjacent nodules. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the distance between adjacent nodules is approximately equal. The nodules may also be disposed in groups such that the distance between one group of nodules and another group of nodules is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each nodule in a group of nodules may be used to form a micro-component that is configured for red, green, and blue, respectively.

While it is preferred that the second roller assembly simply include two second rollers, **232** and **234**, in an embodiment of the present invention as illustrated in FIG. **6**, the second roller assembly may also include a second roller with nodules **236** and a second roller with depressions **238** that are in registration so that when the second substrate **210** passes between the second roller with nodules **236** and the second roller with depressions **238**, a plurality of cavities **260** are also formed in the second substrate **210**. The first substrate **200** and the second substrate **210** are then brought together in the presence of at least one gas so that the plurality of cavities **240** in the first substrate **200** and the plurality of cavities **260** in the second substrate **210** are in register. The two substrates are then affixed, thereby forming a plurality of micro-components **270** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **240** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller with depressions **238**.

In an embodiment of the present invention that is applicable to the two methods discussed above, and illustrated in FIG. **7**, at least one electrode **280** is disposed on or within the first substrate **200**, the second substrate **210** or both the first substrate and the second substrate. Depending on how the electrode or electrodes are disposed, the electrode or electrodes will provide the proper structure for either an AC or DC (FIG. **7**) light-emitting panel. That is to say, if the at least one electrode **280** is at least partially disposed in a cavity **240** or **260** then there will be a direct conductive path between the at least one electrode and the plasma-forming gas or gas mixture and the panel will be configured for D.C. If, on the other hand, the at least one electrode is disposed so as not to be in direct contact with the plasma-forming gas or gas mixture, the panel will be configured for A.C.

In another embodiment of the present invention, at least one substrate is thermally treated in the presence of at least one plasma-forming gas, to form a plurality of shells **50** filled with the plasma-forming gas or gas mixture. In a preferred embodiment of the present invention, as shown in FIG. **8**, the process for making a micro-component would entail starting with a material or material mixture **700**, introducing inclusions into the material **710**, thermally treating the material so that the inclusions start forming bubbles within the material **720** and those bubbles coalesce **730** forming a porous shell **740**, and cooling the shell. The process is performed in the presence of a plasma-forming gas so that when the shell cools the plasma-forming gas **45** is sealed inside the shell **50**. This process can also be used to create a micro-component with a shell doped with a conductive material and/or a secondary emission enhancement material by combining the appropriate dopant with the initial starting material or by introducing the appropriate dopant while the shell is still porous.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, wherein one or more micro-components are at least partially coated with phosphor, and wherein at least one coating in addition to the phosphor is at least partially disposed on one or more micro-components;

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**2**. The light-emitting panel of claim **1**, wherein the at least one coating is a secondary emission enhancement material.

**3**. The light-emitting panel of claim **1**, wherein each micro-component of the plurality of micro-components is coated with a reflective material and wherein an index matching material is disposed on at least a portion of the reflective material, such that a predetermined wavelength range of radiation is emitted from each micro-component at the interface of the reflective material and the index-matching material.

**4**. The light-emitting panel of claim **3**, wherein the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

**5**. The light-emitting panel of claim **1**, wherein the at least one coating is an adhesive or bonding agent.

**6**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, and wherein at least one coating is at least partially disposed on one or more micro-components;

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**7**. The light-emitting panel of claim **6**, wherein the at least one coating is a secondary emission enhancement material.

**8**. The light-emitting panel of claim **6**, wherein the at least one coating is phosphor.

**9**. The light-emitting panel of claim **6**, wherein each micro-component of the plurality of micro-components is coated with a reflective material and wherein an index matching material is disposed on at least a portion of the reflective material, such that a predetermined wavelength range of radiation is emitted from each micro-component at the interface of the reflective material and the index-matching material.

**10**. The light-emitting panel of claim **9**, wherein the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

**11**. A light-emitting panel comprising: a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, and wherein at least one coating is at least partially disposed on one or more micro-components;

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing the at least two electrodes.

**12**. The light-emitting panel of claim **11**, wherein the at least one coating is a secondary emission enhancement material.

**13**. The light-emitting panel of claim **11**, wherein the at least one coating is phosphor.

**14**. The light-emitting panel of claim **11**, wherein each micro-component of the plurality of micro-components is coated with a reflective material and wherein an index matching material is disposed on at least a portion of the reflective material, such that a predetermined wavelength range of radiation is emitted from each micro-component at the interface of the reflective material and the index-matching material.

**15**. The light-emitting panel of claim **14**, wherein the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

**16**. The light-emitting panel of claim **11**, wherein the at least one coating is an adhesive or bonding agent.

**17**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, and wherein at least one shell comprises at least one dopant;

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**18**. The light-emitting panel of claim **17**, wherein the at least one dopant is a secondary-emission enhancement material.

**19**. The light-emitting panel of claim **17**, wherein the at least one dopant is a conductive material.

**20**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, and wherein an electrostatic charge is applied to one or more micro-components; and

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**21**. The light-emitting panel of claim **20**, wherein at least one electrode is energized such that an electrostatic field is created that assists in the placement or holding of one or more micro-components in at least one socket of the plurality of sockets.

**22**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, and wherein one or more micro-components are at least partially coated with a secondary emission enhancement material; and a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**23**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets;

a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas, wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket, wherein one or more micro-components are coated with a reflective material and wherein at least one index matching material is disposed on the reflective material; and

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**24**. The light-emitting panel of claim **17**, wherein the at least one dopant is phosphor.

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US006764367B2

(12) **United States Patent**
**Green et al.**

(10) **Patent No.: US 6,764,367 B2**
(45) **Date of Patent: Jul. 20, 2004**

(54) **LIQUID MANUFACTURING PROCESSES FOR PANEL LAYER FABRICATION**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 81 days.

(21) Appl. No.: **10/214,740**

(22) Filed: **Aug. 9, 2002**

(65) **Prior Publication Data**

US 2003/0207644 A1 Nov. 6, 2003

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**[7] .................................................. **H01J 9/24**
(52) **U.S. Cl.** .......................................... **445/24**; 445/58
(58) **Field of Search** .................................... 445/24, 58

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 A | 1/1971 | Bitzer et al. | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | * 11/1974 | MacIntyre, Jr. | 345/60 |
| 3,969,651 A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | * 7/1977 | Roeber | 345/41 |
| 4,303,433 A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | 8/1985 | D'Onofrio et al. | 445/24 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

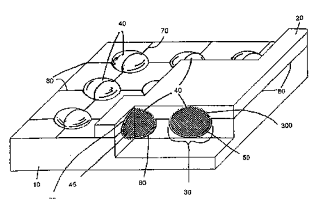
(List continued on next page.)

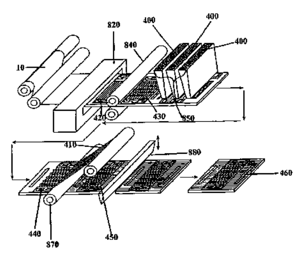
*Primary Examiner*—Kenneth J. Ramsey
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

A method for manufacturing a light-emitting panel sandwiches a plurality of micro-components between two flexible substrates in a web configuration. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. The micro-components are disposed in sockets formed at predetermined locations in a first dielectric substrate so that they are adjacent to electrodes imprinted in the first substrate. Dielectric layers and the conductors for acting as electrodes are formed using liquid processes or combined liquid and sheet processes, where liquid materials are applied to the surface of the underlying layer, then cured to complete the formation of layers. The assembled layers are coated with a protective coating and may include an RF shield. In one embodiment, patterning of the conductors is achieved by applying conductive ink using an ink jet process. In another embodiment, the conductors may be patterned photolithographically using a leaky optical waveguide as a contact mask.

**35 Claims, 15 Drawing Sheets**





U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 4,554,537 | A | | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | * | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | * | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | * | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | * | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | * | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | | 11/2001 | Sasaki et al. | 239/568 |
| 6,545,422 | B1 | * | 4/2003 | George et al. | 315/169.3 |
| 6,570,335 | B1 | * | 5/2003 | George et al. | 315/169.3 |
| 6,612,889 | B1 | * | 9/2003 | Green et al. | 445/24 |
| 2001/0008825 | A1 | | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | | 2/2002 | Miyashita et al. | 313/495 |
| 2003/0094891 | A1 | * | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1 | * | 9/2003 | Green et al. | 313/582 |

## OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

Sheats, James, "Introduction to Organic Light–Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll–to–Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online]. [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www–star.stanford.edu/–vlf/plasma_display/index.htm.

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21–25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self–Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar., 2001, pp. 17–17–24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nScqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online]. LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online]. LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco Plasma Wall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco Plasma Wall PI–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco Plasma Wall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Alien Technology Corporation's Technology Overview; copyright© 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb., 1999, pp. 14–15.

Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell." *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Kurihara, M., Makabe, T., "Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct., 1999, pp. 1372–1378.

Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

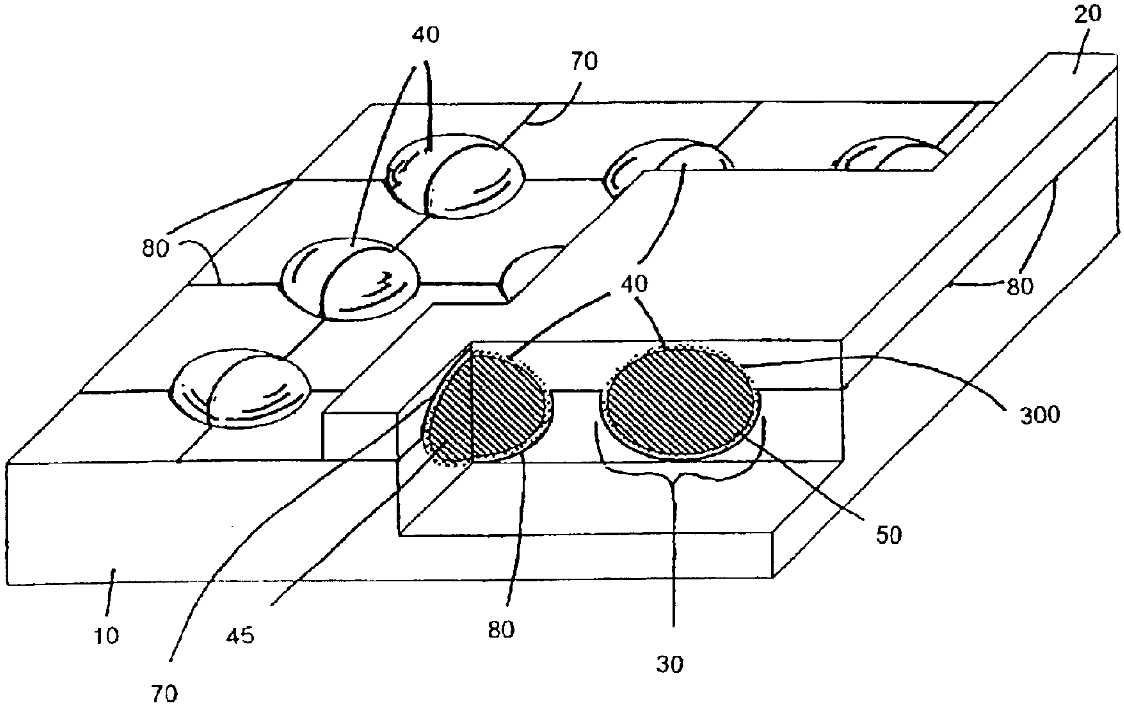
"Transparent Conductive Coatings," Copyright 1998, 4 pp.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep., 1997, pp. 1241–.

Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.
"Flat Panel Displays in Perspective," 44 pp., Sep., 1995.
Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.
International Search Report for application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

* cited by examiner

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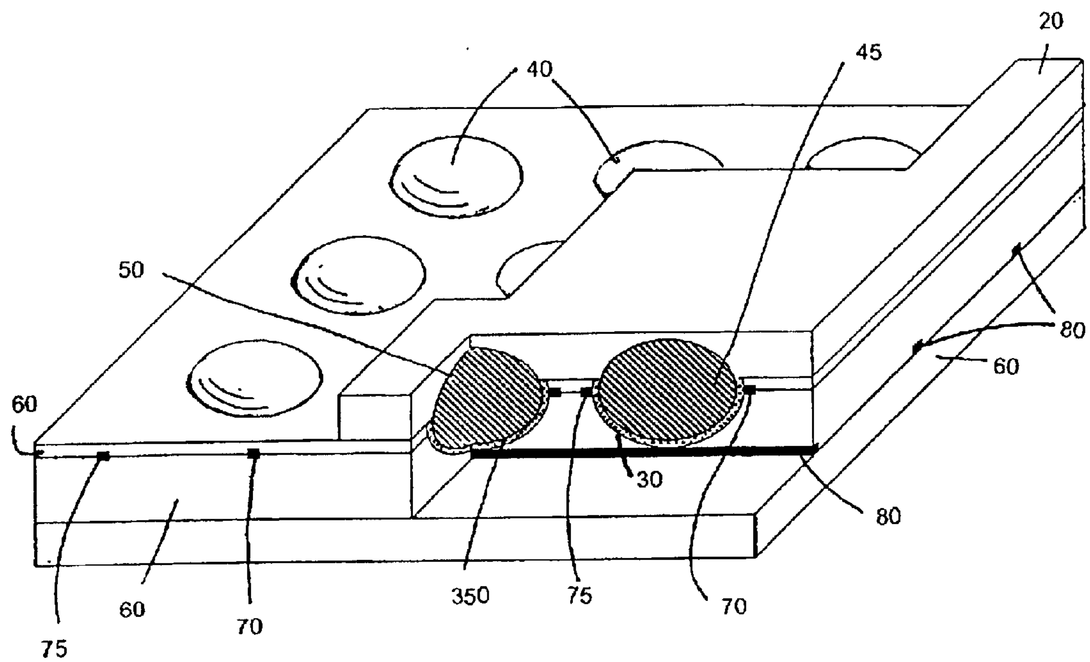



FIG. 2a

Fig. 2B

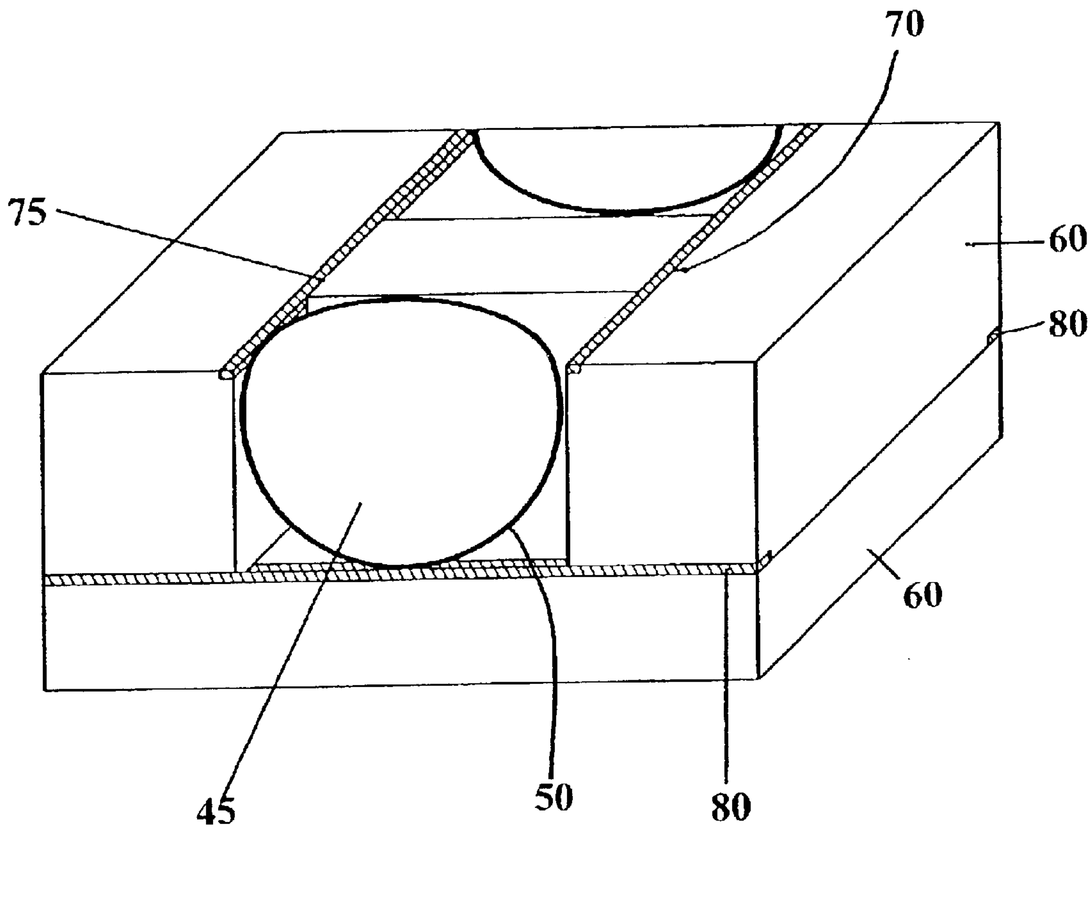


Fig. 3A

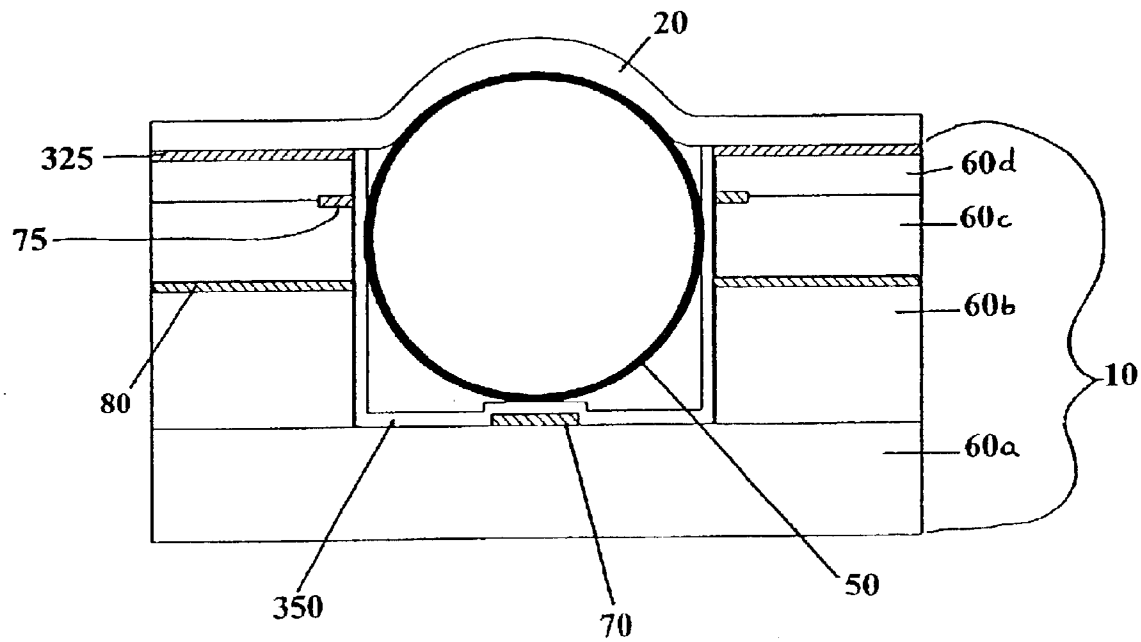


Fig. 3B

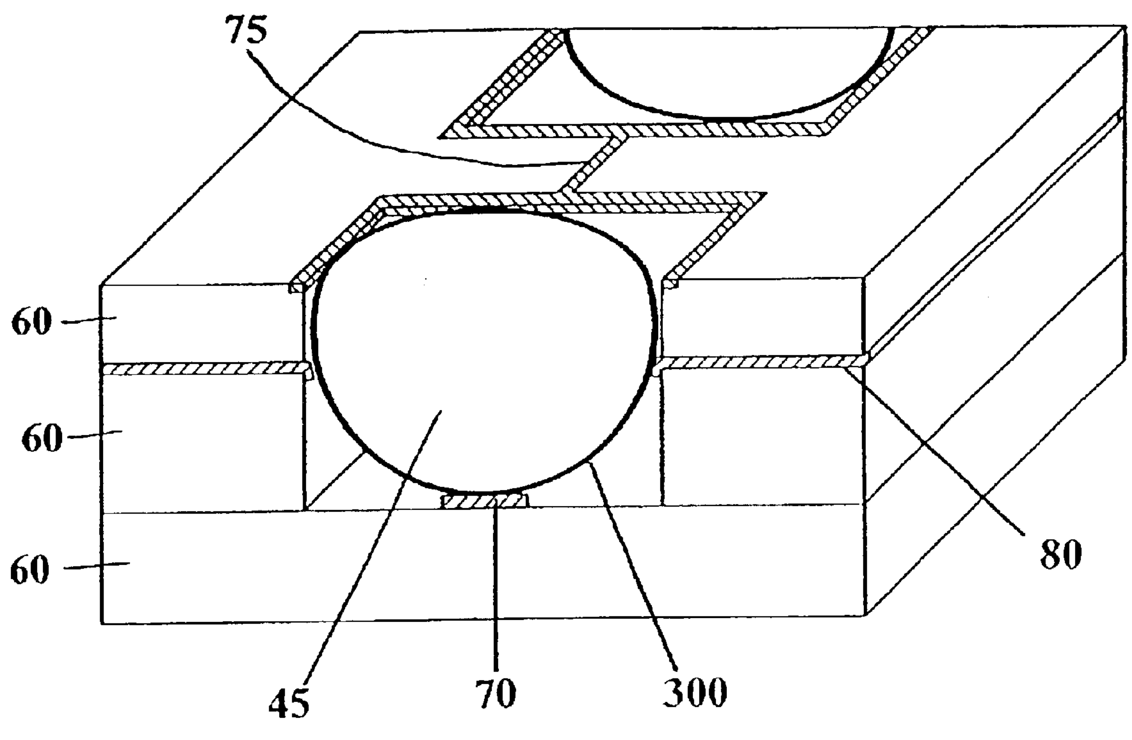


Fig. 4

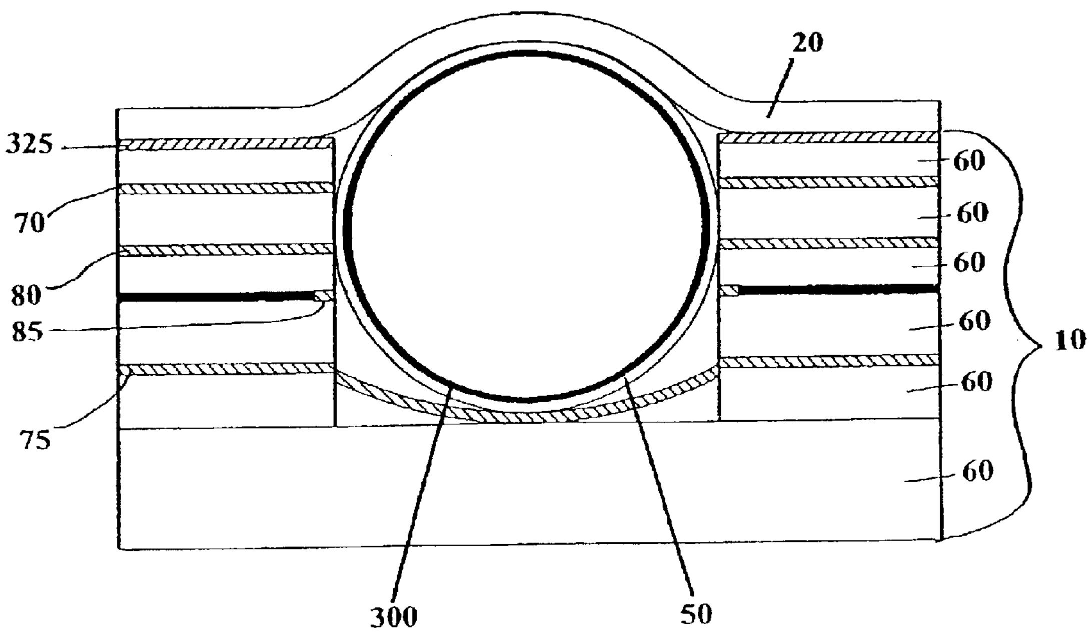


Fig. 5

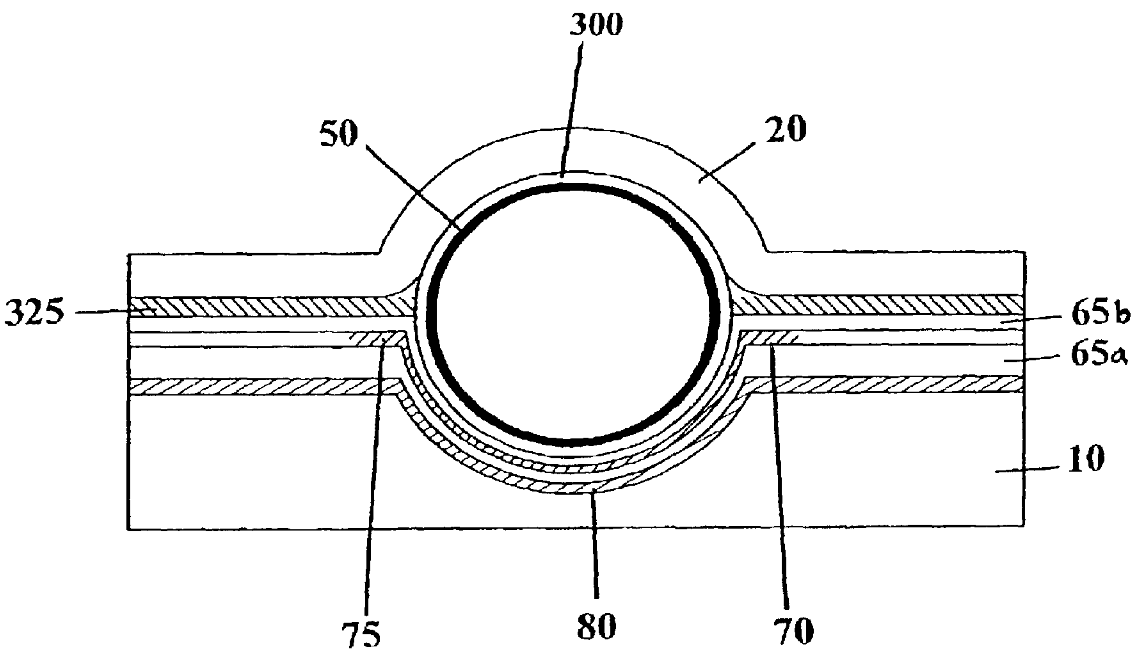


Fig. 6

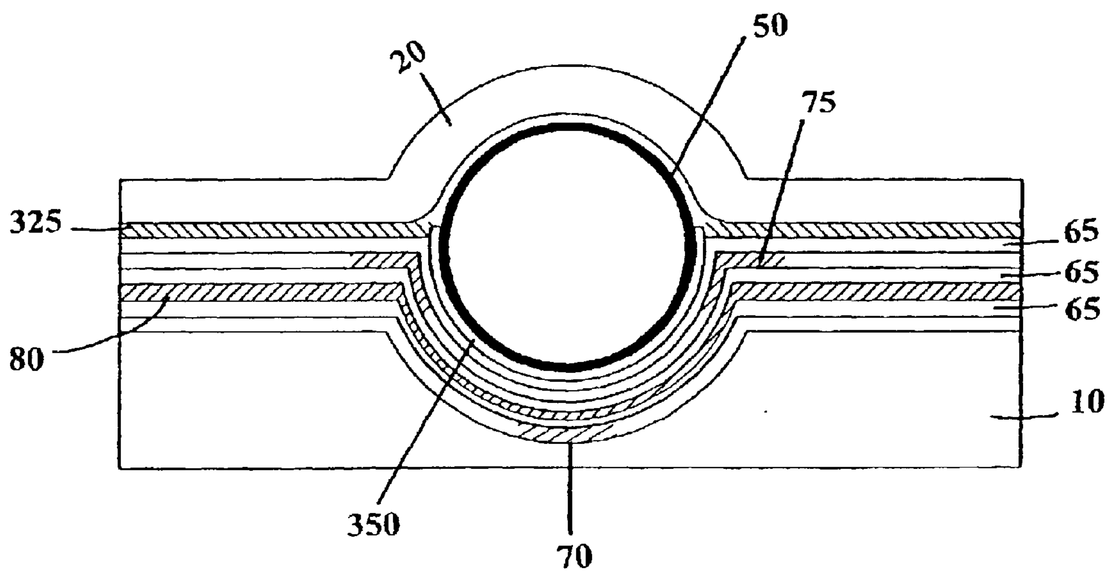
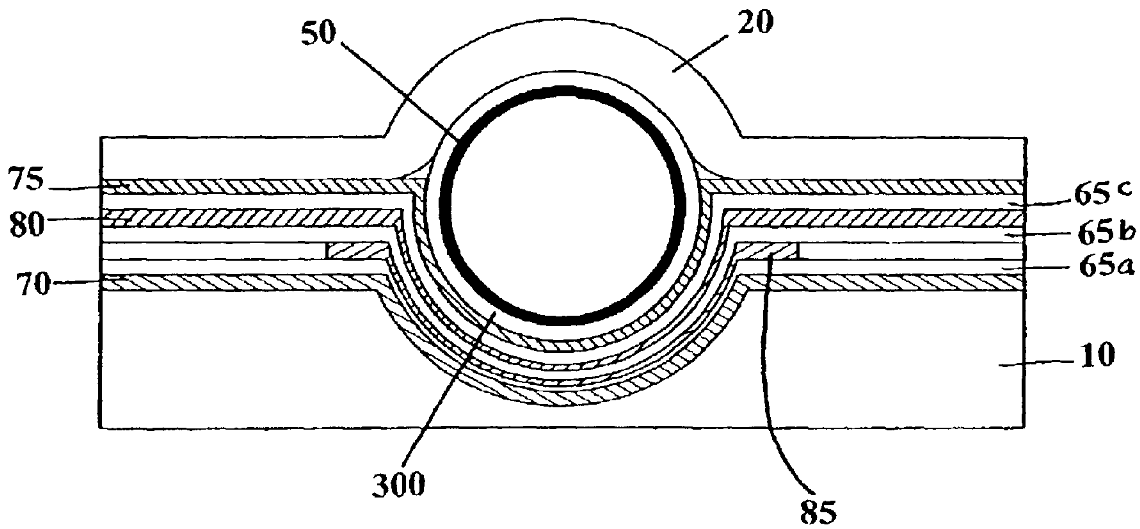


Fig. 7



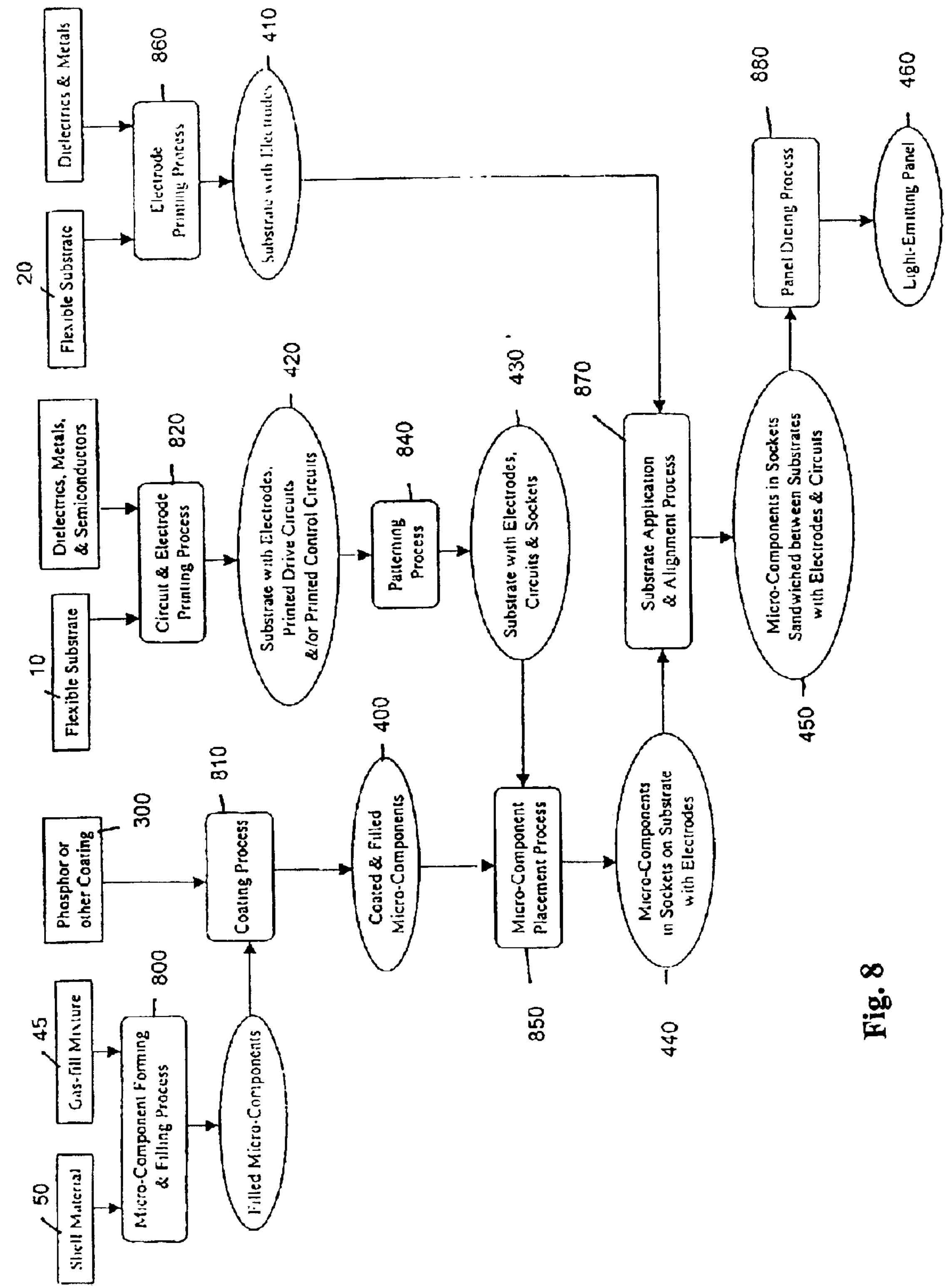
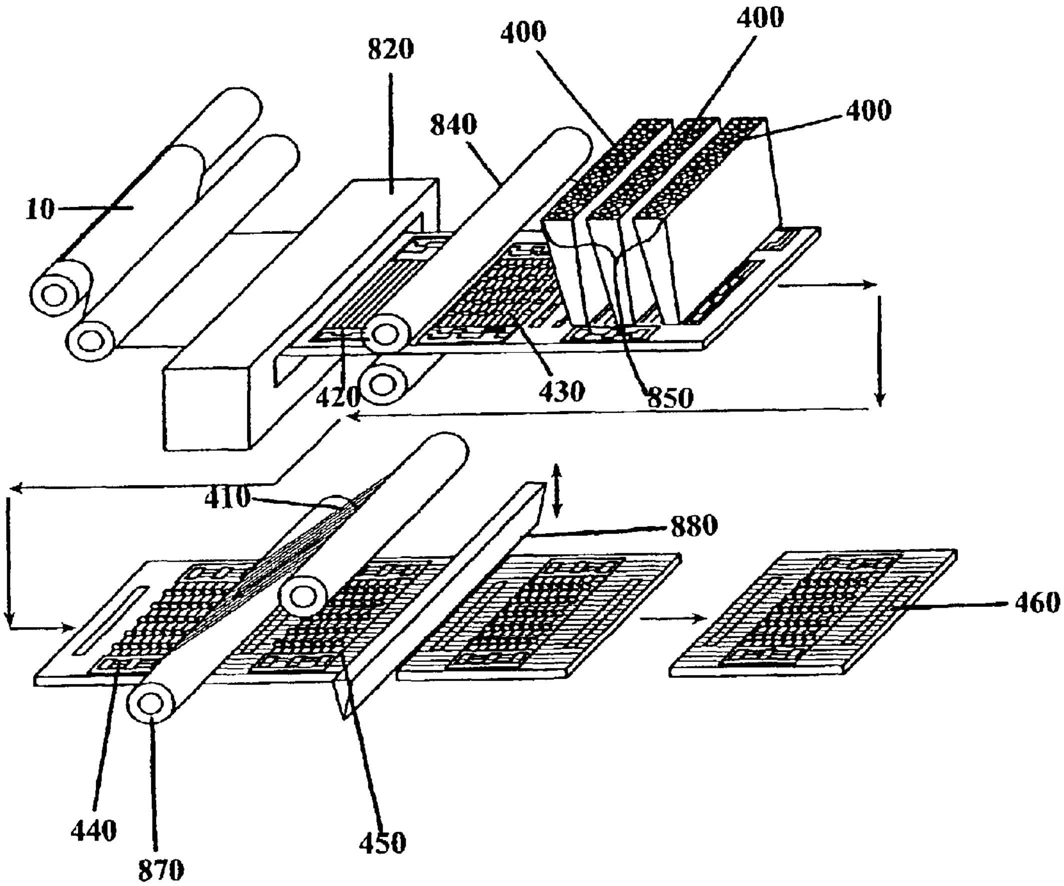
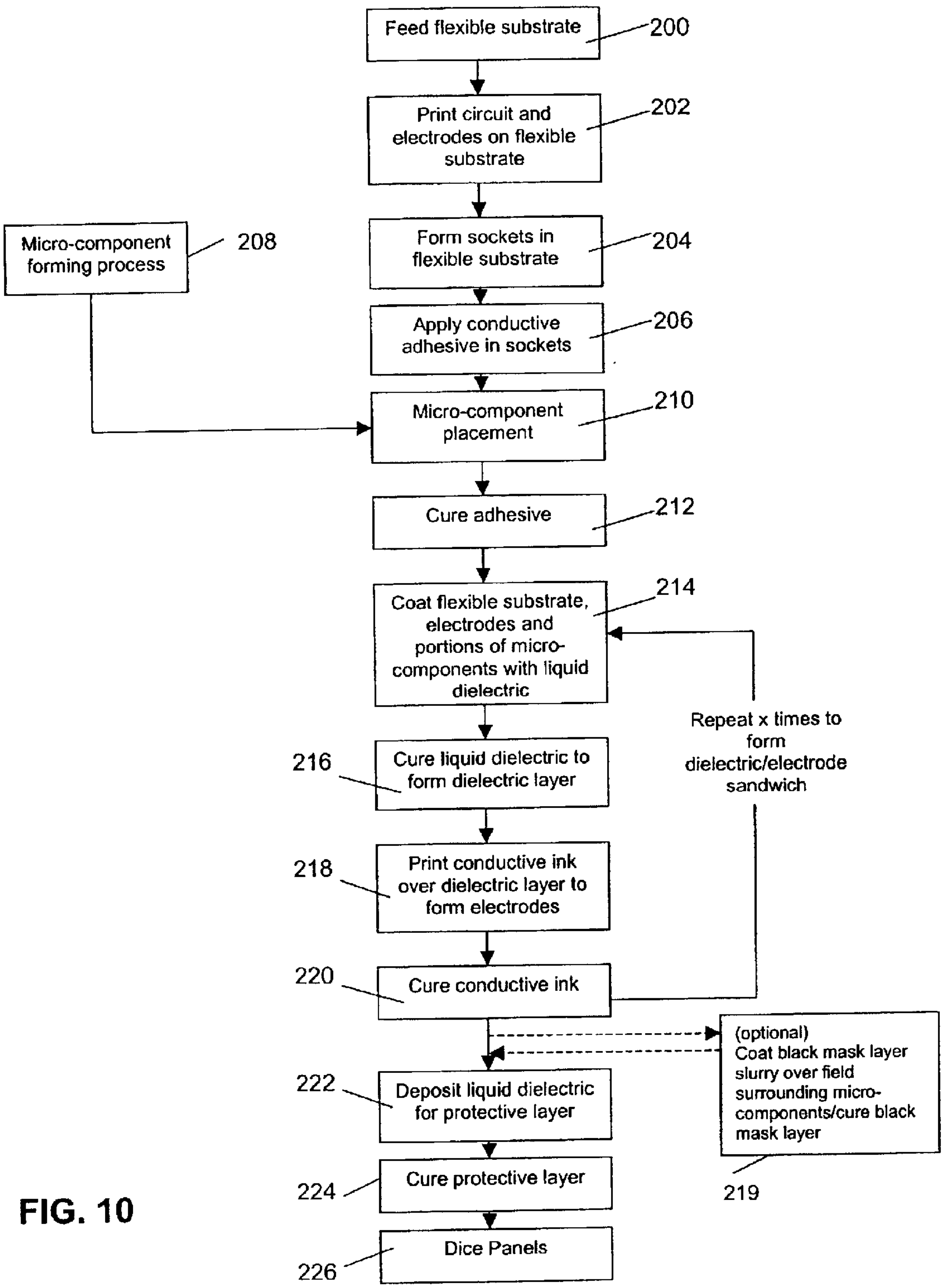

Shell Material
50
Gas-fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits &/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched between Substrates with Electrodes & Circuits
450
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Panel Dicing Process
880
Light-Emitting Panel
460

Fig. 8

Fig. 9





Feed flexible substrate
200
Print circuit and electrodes on flexible substrate
202
Micro-component forming process
208
Form sockets in flexible substrate
204
Apply conductive adhesive in sockets
206
Micro-component placement
210
Cure adhesive
212
Coat flexible substrate, electrodes and portions of micro-components with liquid dielectric
214
Repeat x times to form dielectric/electrode sandwich
216
Cure liquid dielectric to form dielectric layer
218
Print conductive ink over dielectric layer to form electrodes
220
Cure conductive ink
(optional) Coat black mask layer slurry over field surrounding micro-components/cure black mask layer
219
222
Deposit liquid dielectric for protective layer
224
Cure protective layer
226
Dice Panels


FIG. 10

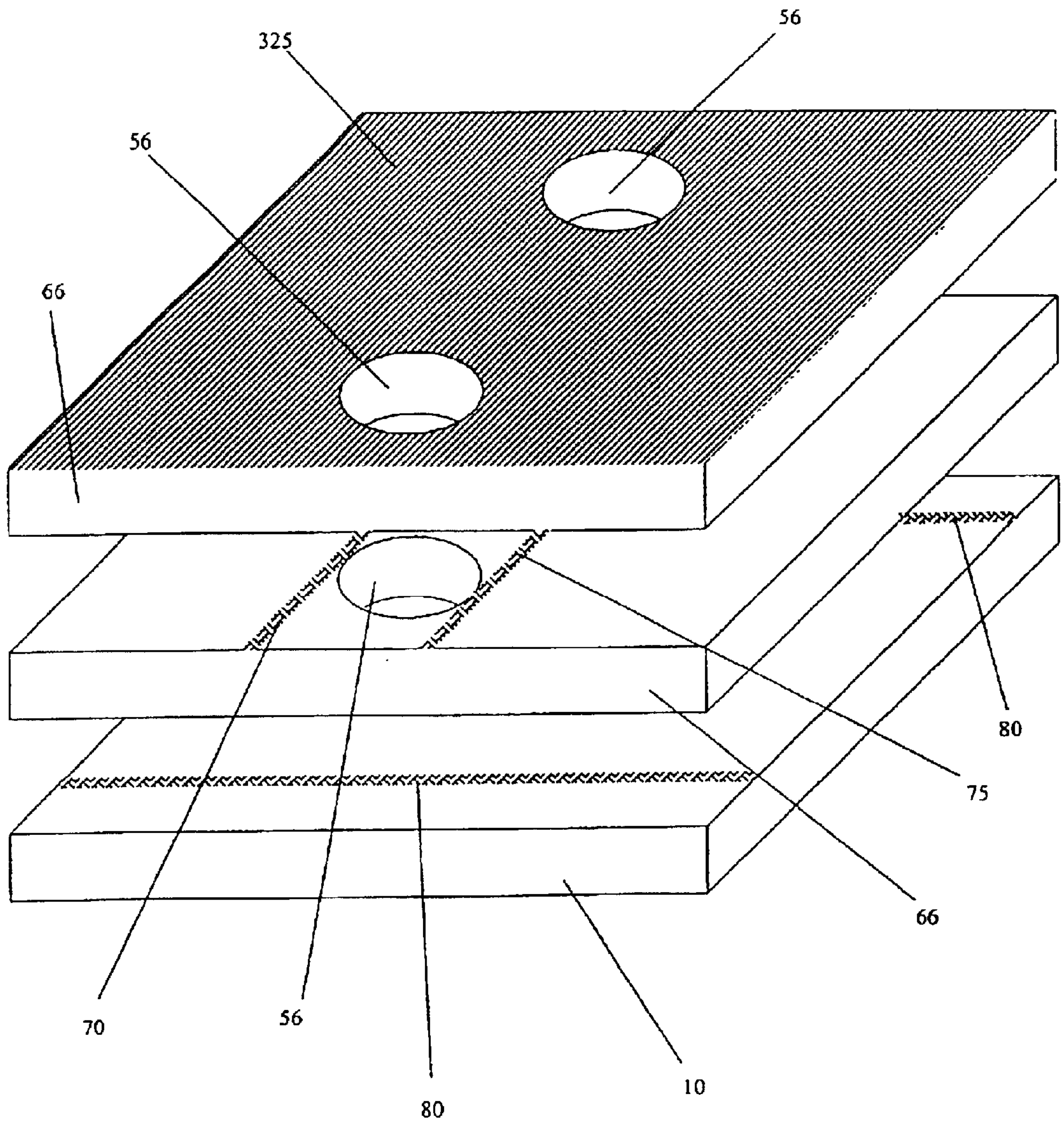



FIG. 11

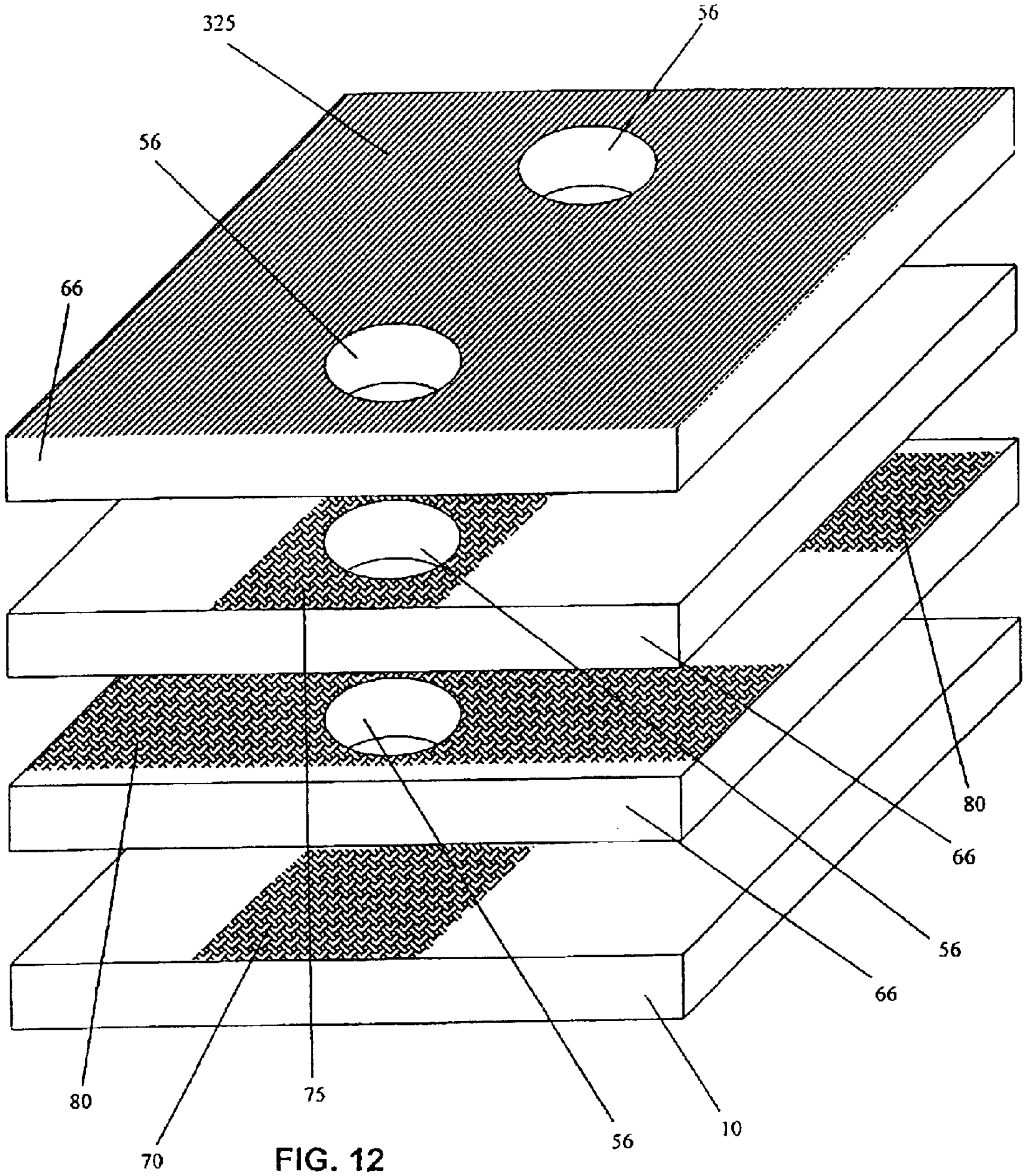



FIG. 12

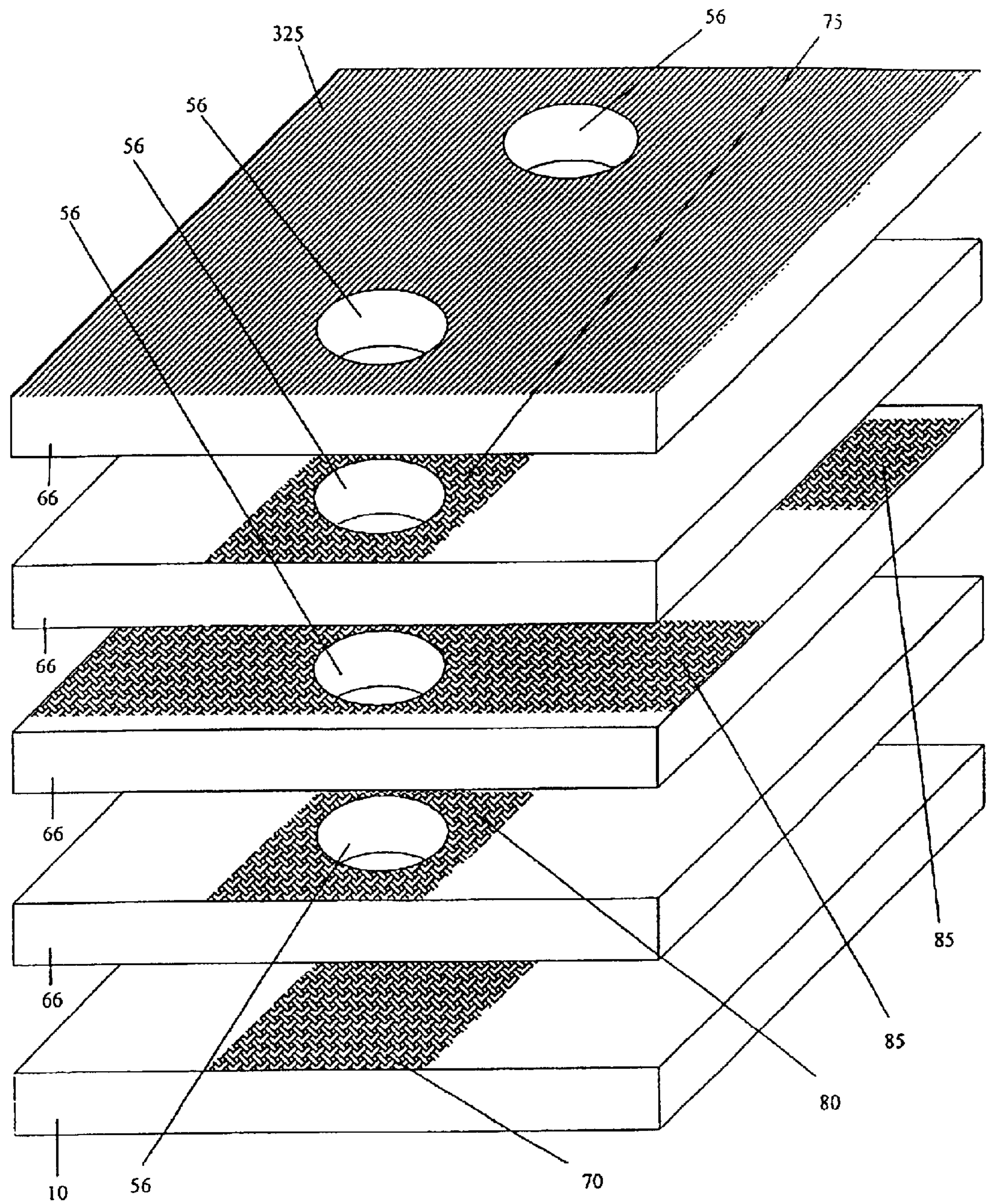



FIG.13

# LIQUID MANUFACTURING PROCESSES FOR PANEL LAYER FABRICATION

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 09/697,344, filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889, entitled Method for Making A Light-Emitting Panel, and is related to the following co-owned, applications: Ser. No. 09/697,346, filed Oct. 27, 2000, now U.S. Pat. No. 6,545,422 entitled: Socket for Use with a Micro-component in a Light-Emitting Panel; Ser. No. 09/697,358, filed Oct. 27, 2000, entitled: Micro-component for Use in a Light-Emitting Panel; Ser. No. 09/697,498, filed Oct. 27, 2000, now U.S. Pat. No. 6,620,012 entitled: Method for Testing a Light-Emitting Panel and the Components Therein; Ser. No. 09/697,345, filed Oct. 27, 2000, now U.S. Pat. No. 6,570,335 entitled: Method and System for Energizing a Micro-component in a Light-Emitting Panel; Ser. No. 10/214,769, entitled Use of Printing and Other Technology for Micro-component Placement filed herewith; Ser. No. 10/214,716, entitled Method of On-Line Testing of a Light-Emitting Panel filed herewith; Ser. No. 10/214,764, entitled Method and Apparatus for Addressing Micro-components in a Plasma Display Panel filed herewith; and Ser. No. 10/214,768, entitled Design, Fabrication, Conditioning, and Testing of Micro-Components for Use in a Light-Emitting Panel filed herewith. Each of the above-identified applications is incorporated herein by reference in its entirety.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a method for manufacturing a light-emitting panel and more particularly to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

A number of different methods have been used or proposed for construction of plasma panel display devices in which a plasma-forming gas is enclosed between sets of electrodes which are used to excite the plasma. In one type of plasma display panel, wire electrodes are placed on the surfaces of parallel plates of glass so that they are spaced uniformly apart. The plates are then sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure suffers from numerous disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates, which can result in gas leakage and a shortened product life. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates.



These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same: a batch fabrication process. It would be desirable to simplify and streamline the manufacturing process and to eliminate at least a portion of the steps which can have a negative impact on process yield and/or cost. The present invention is directed to such a method.

## BRIEF SUMMARY OF THE INVENTION

According to the present invention, a novel flexible plasma display panel and methods for making such a panel involve a web fabrication process. In this display panel, the plasma forming gas is sealed in transparent micro-components formed of a closed transparent shell. The micro-components, which may be spheres, capillaries or virtually any other three-dimensional shape, are then coated with phosphors to emit one of the primary colors: red, green or blue. In the web fabrication process, a nonconductive flexible first substrate has electrodes imprinted thereon using known printing techniques, such as lithography or screen printing. In one variation, dimples are embossed in the first substrate to define locations at which micro-components are to be placed relative to the electrodes. In another variation, the micro-components are electrostatically drawn to the correct locations relative to the electrodes. After affixing the micro-components in place, and possibly testing to ensure complete and proper placement of the micro-components, a second substrate, also in web form, is disposed over the first substrate so that the micro-components are sandwiched between the first and second substrates. Additional electrodes may be patterned on the second substrate, and the second substrate may be applied as more than one layer to create one or more dielectric/electrode sandwiches near the micro-component to provide additional sustain electrodes or addressing electrodes. Alternatively, the second substrate can be preformed with embedded electrodes which are then aligned with the micro-components when the second substrate is applied. A protective layer may be placed on top of the second substrate, then the layered assembly is diced to form individual light-emitting panels of the desired size.

In a second embodiment of the present invention, a light-emitting panel is formed on a first substrate comprising a flexible web material. A conductive film is patterned on the first substrate to define a plurality of electrodes and dimples are formed to define locations in which gas-filled micro-components, which emit light when excited, are to be located. An adhesive material may be deposited into the dimples. The micro-components are then applied to fill the dimples, where they are held in place by the adhesive. Application of the micro-components to the first substrate can be achieved by a number of different methods including use of a drop tower or an ink-jet type dispenser, or by running the first substrate through a shaker bath filled with an excess of micro-components. An electrostatic charge may be applied to the first substrate to draw the micro-components to the desired locations. After the micro-components are affixed to the first substrate, a liquid dielectric material is applied to the surface of the first substrate using known methods such a vacuum or atmospheric coating, which may include chemical vapor deposition (CVD), plasma sputtering, electron-beam deposition, injection of coating fluid under pressure, screen printing or similar processes. The conditions under which the liquid dielectric are applied, e.g., the surface energy and surface tension of the liquid, are selected to ensure good wetting of the micro-components, i.e., so that the dielectric material is in contact with the surfaces of the micro-components without bubbles or gaps. Further, the liquid dielectric should be applied with a uniform thickness across the first substrate so that the spacing between the excitation electrodes is uniform across the display. Depending on the deposition process that was used, the liquid dielectric is then cured to remove any solvents and other volatile agents that were included in the liquid to facilitate fluid delivery, leaving the micro-components embedded in the flexible, cured dielectric layer. In a preferred embodiment, the liquid dielectric is coated so as to form a dielectric layer with a thickness corresponding to about half the height of the micro-component, allowing a mid-plane conductor to be formed near the micro-components.

Electrodes are formed by applying a conductive liquid to the upper surface of the dielectric layer. The electrodes may be patterned using known lithographic methods, e.g., conductive film deposition, photoresist deposition, masked exposure and development of the photoresist followed by etching to remove the unprotected film, or by printing, e.g., ink-jet printing with a conductive ink. In an alternative embodiment, conductive liquids that are selectively drawn to the desired locations using one or more characteristics of the liquid including surface tension, viscosity, thickness and electrical conductivity in combination with surface characteristics of the dielectric layer. For example, where channels or depressions in the dielectric layer may act as guides for distribution of a liquid conductor to the desired locations near the micro-components, so that no alignment is required in the step for forming the electrodes.

A second application of liquid dielectric material coats the upper surface of the previous dielectric layer, mid-plane conductor and the surfaces of the micro-components above the mid-plane point. An additional sequence of depositing a liquid dielectric and a patterned conductive film may be added before "topping off" the layers with a final coating of liquid dielectric to form a layer that approaches, but not does not cover, the tops of the micro-components. A protective cover layer is then placed over top of the entire assembly, then the panels are diced into the desired dimensions. The cover layer is preferably a web material that may be applied according to known web manufacturing methods.

In an alternate method for patterning of electrodes using photolithographic methods, after formation of a conductive layer, a coating of photosensitive material, e.g., photoresist, is disposed on top of the conductive layer. A contact mask is formed using a flexible optical waveguide having a surface area which covers all or a significant portion of the light-emitting panel. During formation of the waveguide, the cladding material is patterned to allow light to escape from the waveguide at selective locations corresponding to locations of the electrodes to be defined. The photoresist is exposed at the desired locations by light "leaking" from the waveguide, then the waveguide mask is removed. After the photoresist is cured and the unexposed resist is removed, the conductive material is selectively etched to form the electrodes at the desired locations.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** is a perspective view of a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2***a* is a perspective view of a portion of a light-emitting panel, partially cut-away, to reveal micro-components and electrodes.

FIG. **2***b* is a detail view of the embodiment of FIG. **2***a* with upper dielectric layers cut away to reveal the co-planar sustaining electrodes.

FIG. **3***a* is a diagrammatic cross-sectional view of a portion of an embodiment of the light-emitting panel with the electrodes having a mid-plane configuration.

FIG. **3***b* is a perspective view of the embodiment of FIG. **3***a* with the upper dielectric layer cut away to reveal the uppermost sustain electrode.

FIG. **4** is a diagrammatic cross-sectional view of a portion of an embodiment of the light-emitting panel with the electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **5** is a diagrammatic cross-sectional view of a portion of an embodiment of the light-emitting panel with the electrodes having a co-planar configuration.

FIG. **6** is a diagrammatic cross-sectional view of a portion of an embodiment of the light-emitting panel with the electrodes having a mid-plane configuration.

FIG. **7** is a diagrammatic cross-sectional view of a portion of an embodiment of the light-emitting panel with the electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **8** is a flowchart of a first embodiment of a web fabrication method for manufacturing light-emitting displays according to the present invention.

FIG. **9** is a graphical representation of a web fabrication process for manufacturing light-emitting panels according to the first embodiment of the web fabrication method.

FIG. **10** is a flow diagram of a second embodiment of a web fabrication method according to the present invention.

FIG. **11** is an exploded perspective view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **12** shows an exploded perspective view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel method for making a light-emitting panel. In particular, preferred embodiments are directed to web fabrication processes for manufacturing light-emitting panels.

FIG. **1** illustrates an exemplary display panel in which a plurality of sphere-shaped micro-components **40** are embedded within a sandwich of dielectric layers consisting of first substrate **10** and second substrate **20**. The first substrate **10** is formed from a flexible sheet material that is appropriate for web fabrication, such as polyester (e.g., Mylar®), polyimide (e.g., Kapton®), polypropylene, polyethylene, propylene, nylon or any polymer-based material possessing dielectric properties appropriate for use as an insulator between electrodes as needed for operation of a plasma display panel. Such electrical requirements are known to those of skill in the art. Second substrate **20** may be made from the same or similar dielectric material.

The first substrate **10** includes a plurality of sockets **30** adapted for retaining at least one micro-component **40**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, a uniform array, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each group of sockets represents a combination of the primary colors: red, green and blue.

Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In one embodiment, the micro-components **40** are positioned in the sockets **30** of first substrate **10** by use of an ink-jet-type feeder which provides aligned placement of the micro-components **40**. A number of methods of placing the micro-components in the sockets are disclosed in co-pending application Ser. No. 10/214,769, which is incorporated herein by reference in its entirety.

An adhesive or bonding agent, discussed below, may be applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. This technique, known as "electrostatic sheet transfer" ("EST") is described in the aforementioned co-pending application Ser. No. 10/214,769. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun may be used to place an electrostatic charge on each micro-component, then one electrode disposed proximate to each socket **30** is energized to provide the opposing electrostatic field required to attract the electrostatically charged micro-component.

In order to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive, typically an electrically-conductive epoxy material which is filled with, for example, silver, copper, aluminum, or other conductor, may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or preferably, by deposition using ink jet technology. One skilled in the art will recognize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. Further, rare gas halide mixtures such as xenon chloride, xenon fluoride and the like are also suitable plasma-forming gases. Rare gas halides are efficient radiators having radiating wavelengths over the approximate range of 190 nm to 350 nm, i.e. longer than that of pure xenon (147 to 170 nm). Using compounds such as xenon chloride that radiates near 310 nm results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed above. This description is not intended to be limiting. One skilled in the art would recognize other gases or gas mixtures that could also be used. In a color display, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will produce a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of luminescing is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electrophoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40**, and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. Those skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic processes, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. In a preferred embodiment, the coating is applied by immersing the micro-components in a slurry of phosphor particles, similar to the procedures used in the manufacture of fluorescent lamps, so that the particles adhere to the outer surface of the micro-component. One skilled in the art will recognize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings may be coated on the inside of a socket **30**. These coatings include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the light emitting panel, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

Additional coatings may be applied or modifications made to the micro-component to enhance performance, for example, by increasing luminosity and radiation transport efficiency, and to permit construction of a DC light-emitting panel. Luminousity can be improved by at least partially coating the micro-component with a secondary emission enhancement material such as magnesium oxide and thulium oxide. Alternatively or in conjunction with the coating, the shell can be doped with a secondary emission enhancement material. The micro-component can also be coated with or have a doped shell to enhance emission and/or radiation transport with reflective or conductive materials. Doping the shell **50** with a conductive material such as silver, gold, platinum or aluminum provides a direct conductive path to the gas or gas mixture contained in the shell. Also, an index matching material may be used to select a pre-determined emission wavelength, i.e., providing a bandpass filter.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. For example, the size and shape may be chosen to provide a field of view with an angle that can be made wider or narrower as needed for a specific application. That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view may be set to a specific angle by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to correspond with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity is formed, or patterned, in a substrate **10** to create a basic socket **30**, such as illustrated in FIG. **1**. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket **30** may be a variety of enhancement materials **325**, as shown in FIG. **3***a*. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

Still referring to FIG. **3***a*, a socket **30** is formed by stacking a plurality of material layers **60***a–d* to form the first substrate, disposing at least one electrode either directly on the top of the first substrate, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60***a–d* to create a cavity. The material layers **60***a–d* include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**, as discussed above. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, xerographic-type processes, plasma deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The socket **30** may be formed in the combination of layers **60***a–d* using any of a variety of methods on the layers, either individually or combined, including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

Using FIG. **5** to illustrate, in an alternate method of forming a socket **30**, a cavity **55** is formed in a first substrate **10**, then a plurality of material layers **65***a,b* is disposed over the first substrate **10** so that the material layers **65***a,b* conform to the cavity **55**. At least one electrode is formed on the first substrate **10**, within the material layers **65**, or any combination thereof. In the example of FIG. **5**, electrode **80** is formed on the first substrate, while electrodes **70** and **75** are disposed within the layers. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **65***a,b* include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**, as described previously. The placement of the material layers **65***a,b* may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, xerographic-type processes, plasma deposition, coating with a liquid or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In yet another alternative method of forming a socket, at least one electrode is disposed on the first substrate, within the material layers, or any combination thereof. Each of the material layers includes a preformed aperture that extends through the entire material layer. The apertures may be of the same size or may be of different sizes, e.g., they may be graduated in size to create the socket with a tapered or curved profile. The plurality of material layers are sequentially disposed on top of the first substrate with the apertures in alignment thereby forming a cavity. The material layers include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials, as described previously. The placement of the material layers may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, xerographic-type processes, plasma deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above-described methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention, the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, xerographic-type processes, plasma deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the ionization potential of the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is activated or illuminated. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individually control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general configuration, the light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to either the first substrate or the second substrate, or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general configuration, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In the exemplary embodiment shown in FIG. **1**, a sustain electrode **70** is disposed on or within the second substrate **20** and an address electrode **80** is disposed on or within the first substrate **10**. As illustrated, address electrode **80** is positioned in the first substrate **10** so that it is at least partly disposed within the socket.

Methods for distributing the micro-components into the sockets include dispensing the micro-components using a placement tool, an ink jet-type printer, or a gravity-fed drop tower which is aligned with the sockets in the substrate. Alternatively, the substrate may be passed through one or more vibratory, e.g., ultrasonic, shaker baths containing an excess plurality of micro-components, i.e., a much larger number of micro-components than are needed to fill the available positions on the substrate. Such shakers are well known in the art and may include orbital shakers and other vibratory movements. The shaking causes the micro-components to be dispersed across the surface of the substrate so that a micro-component is disposed within each of the sockets. A further discussion of different methods for placement of the plurality of micro-components is provided in the aforementioned co-pending application Ser. No. 10/214,769.

In an embodiment of the light emitting panel where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **2***a*, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **2***b* is a cut-away of FIG. **2***a* showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **3***a*, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **3***b* is a cut-away of FIG. **3***a* showing the first sustain electrode **70**. As seen in FIG. **4**, in a preferred embodiment of the light emitting panel, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **5**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **6**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **7**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **11**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **12**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **13**, in a preferred embodiment of the light emitting panel, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be pre-formed so that the first substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As illustrated in FIGS. **8** and **9**, in an embodiment of the present invention, the web fabrication process includes the following process steps: First, a micro-component forming process **800** is performed to create the micro-component shells **50** and fill the micro-components with plasma-forming gas **45**. A micro-component coating process **810** follows in which the micro-components are coated with phosphor **300** or any other suitable coatings, producing a plurality of coated and filled micro-components **400**. In a preferred embodiment, coating of the micro-components is achieved by immersing the micro-components in a slurry of phosphor particles, allowing the phosphor particles to adhere to the outer surface. Afterwards, the micro-components are processed through a curing step to remove the solvents that were used to create the slurry. A circuit and electrode printing process **820** prints at least one electrode and any needed driving and control circuitry on a first substrate **420**. Patterning process **840** is performed to create a plurality of cavities on a first substrate to provide a plurality of sockets **430**. Generally, this step involves applying pressure and possibly heat to deform the substrate material and create a plurality of dimples in the substrate. Micro-component placement process **850** places at least one coated and filled micro-component **400** in each socket **430**, resulting in a first substrate assembly **440** comprising micro-components **400** in sockets **430** on the first substrate **10**. If required, an electrode printing process **860** prints at least one electrode on a second flexible substrate **20** to produce a second substrate with electrodes **410**. Second substrate application and alignment process **870** aligns the second substrate **410** over the first substrate assembly **440** so that the micro-components are sandwiched between the first substrate and the second substrate as assembly **450**. Panel dicing process **880** cuts through the assembly **450** to yield individual light-emitting panels **460**.

The process flow for an alternate embodiment of the web fabrication method is illustrated in FIG. **10**. As in the previously-described embodiment, the first substrate is a flexible dielectric material, which in step **200** is fed from a payout reel, to which a plurality of micro-components is applied, either by aligned placement with sockets (dimples) and/or adhesive spots formed in/on the first substrate, or by passing the first substrate with adhesive spots through a shaker bath filled with micro-components, as discussed above.

According to the exemplary process flow, electrodes and other circuitry are printed on the flexible substrate (step **202**), typically using an ink-jet process, then sockets are formed (**204**). It should be noted that these steps may be performed in reverse order, i.e., the sockets may be formed prior to patterning the electrodes. Conductive adhesive is applied to the sockets (**206**) using an ink jet-type printer. Alternatively, if may be possible to combine steps **204** and **206** by injecting adhesive through the tool used to create the dimple in the substrate material.

Micro-components, which were separately formed in step **208** are placed in the sockets using an appropriate method as described in the afore-mentioned co-pending application Ser. No. 10/214,769. As previously described, the micro-components are typically coated with a phosphor material for visible light emission. In an exemplary embodiment of micro-component forming process step **208**, the micro-components are coated with phosphor by immersing the micro-components in a bath containing a slurry of phosphor particles so that the particles adhere to the micro-component surface. The micro-components are then removed from the slurry and subjected to a curing process, e.g., a furnace, oven or other heat source, to remove any solvents that were used to form the slurry, leaving a solid phosphor coating on the micro-component surface.

In step **212**, the adhesive material that holds the micro-component in place is cured by applying heat for a predetermined time (based upon the manufacturer's recommendations), or at room temperature for a longer time (again, based on the manufacturer's specifications), introducing pressurized gas or other known adhesive curing method, then, the dielectric film is applied in liquid form by coating the substrate with a liquid dielectric material (step **214**). The liquid dielectric material may be a polyimide (e.g., Kapton®), or other polymeric materials.

Application of liquid dielectric uses known techniques of web coating using web coating systems such as those commercially available from Rolltronics (Menlo Park, Calif.), Sheldahl, Inc. (Northfield, Minn.), Frontier Industrial Technology, Inc. (Towanda, Pa.) and Applied Films Corp. (Longmont, Colo.), among others. An exemplary coating system comprises a web-handling machine mounted inside a large vacuum chamber. The machine unwinds a web from a payoff reel, wraps it over a drum, which may be temperature-controlled to assist in film formation, and winds it onto a take-up reel. Each reel is driven indirectly via chain drive and a DC motor, allowing better control of web speed while developing a higher tension than would be possible with a motor and gear reduction box. The signal from an optical encoder is delivered to a process controller for speed control of one motor, and a measurement of the length unwound. The other motor is operated in regenerative mode to develop holdback tension. An exemplary deposition process for a coating stack of films comprises positioning the drum over a first deposition device, e.g., sprayer or evaporator. A fixed length of web is unwound in the first pass to deposit the first film. Then the motor direction is reversed, and a second film is deposited in a second pass. Next the drum may be moved sideways to position it over a second deposition device, which may be, e.g., a sprayer, evaporator, or ink jet head. The web direction is reversed a third time and the third coating is deposited in a single pass. In each case, web speed is determined according to the desired coating thickness and deposition rate. An alternative configuration includes one or more accumulators disposed between the payoff and take-up reels which allows sections of the web to dwell in certain stations along the processing line, for example, for deposition or curing a film for an extended period of time, without requiring all other steps in the process to pause or interfering with the tension of the web.

The dielectric film may be applied as a thin film using chemical vapor deposition (CVD), plasma CVD, or other vapor deposition methods, sputtering, or may be applied as a liquid "paint" such as one of the roll coat methods used in the coating of magnetic recording media. See, e.g., U.S. Pat. No. 6,322,010, the disclosure of which is incorporated herein by reference in its entirety. In the preferred embodiment, a liquid process is used to create a film on the order of 100 microns with relatively tight tolerances across the film, e.g., ±1%. The viscosity of the dielectric material in its liquid form is selected to ensure complete wetting of the surfaces of the micro-components to the extent that the micro-components should be covered, and to ensure uniformity of the film thickness. The key parameter to be observed in formation of the dielectric film is the uniformity of the dielectric properties so that the surface flashover (voltage breakdown that occurs on or above the surface of an insulator) and bulk dielectric breakdown characteristics are tightly controlled to minimize the possibility of arcing or voltage breakdown across any dielectric discontinuities when voltage is applied to electrodes corresponding to a given micro-component. A typical good dielectric material has a breakdown voltage in the range of 500 to 5000 volts per mil (about 200 to 2000 kV/cm) in the bulk, with a preferred range of 1000 volts per mil (400 kV/cm) or higher. The surface flashover field strength should also be in the range of 1000 volts per mil (400 kV/cm). This will be achieved partially through material selection and principally with the application of a thin coating, such as a resin or epoxy, to the surfaces of the electrodes and micro-component. This coating inhibits electron flow over the surface between the electrodes thereby raising its flashover voltage. In addition, a good loss tangent for the dielectric material, typically in the range of 0.01 to 0.1, at 100 kHz to 1 MHz is preferred. An exemplary range for dielectric constant in this frequency range is 3.5 to 5.

Wetting can be enhanced by the inclusion of surfactants in the liquid dielectric material to manage the surface energy of the liquid. Alternatively, or in addition, surfactants may also be applied to the outer surface of the micro-components to facilitate complete wetting. Obtaining a uniform thickness of the dielectric film can be further facilitated by use of a scraper or knife edge which is precisely positioned over the drum to remove any excess thickness as the web material leaves the drum.

Viscosity and surface tension of the liquid dielectric may also be controlled to produce a positive, neutral, or negative meniscus around each micro-component. In one embodiment, a negative meniscus results in a surface depression abutting the micro-component

The dielectric material is then cured (step **216**) to form a uniform film at least partially covering the micro-components, embedding them in place within the combination of the first substrate and the dielectric layer formed using the liquid dielectric. Curing is typically achieved by passing the web material through a heated chamber set to a temperature appropriate for curing the dielectric film. As the liquid dielectric is typically a commercially-available product, the temperature and duration of the curing step will be based upon the manufacturer's recommendations for the selected liquid material. As will be apparent to those of skill in the art, some variation of the recommended curing conditions may be incorporated for compatibility with the particular web manufacturing equipment or process that is being used. The portion of web material to be cured may be paused or slowed by the use of an accumulator, or the heated chamber may have a length designed to provide a sufficient duration within the chamber while the web material moves at a predetermined speed, or a combination of the two.

In the preferred embodiment, a portion of the micro-component is left exposed after curing of the dielectric film. Considering the embodiment of FIG. **5** as an example, the first application of liquid dielectric resulted in a dielectric layer **65***a* that covers just under one-half the height of the micro-component **50**.

Electrodes are formed by applying a conductive liquid to the upper surface of the second substrate (step **218**). The electrodes may be patterned using known lithographic techniques, e.g., conductive film deposition over the entire area, photoresist deposition, masked exposure and development followed by etching, or by printing, e.g., ink-jet printing, or by using liquids that are selectively drawn to the desired locations using one or a combination of characteristics of the liquid including surface tension, viscosity, thickness and electrical conductivity. In the preferred embodiment, a conductive ink is applied using an ink-jet printing technique. The ink contains copper, indium oxide, silver, or other conductive material carried in an epoxy or epoxy-like material. Appropriate conductive inks are commercially available and will have electrical conductivity in the range of 1250 mhos/cm or higher. After printing, the conductive ink is cured based on the manufacturer's recommendations (step **220**).

In an alternate embodiment, the characteristics of the liquid dielectric material from which the dielectric layer is formed can be selected to create a shallow trough or depression connecting the micro-components in a line, e.g., a negative meniscus is formed upon deposition or a small amount of shrinkage can occur during curing to create the depression. The conductive liquid used to form the electrodes is selected with a viscosity and thickness such that it will be drawn into the depressions to fill them, thus creating a conductive line running between the micro-components. It is important, however, that the conductive film not stick to the micro-components themselves. Therefore, the liquid conductor should include a component to prevent wetting of the micro-component surface. An additional step in this alternate embodiment can be to scrape away any excess conductor from the surface of the dielectric layer except where it has filled the depressions. For example, a squeegee or other scraper can be used to level the outer surface of the assembly so that the conductor is flush with the outer surface of the dielectric layer. After deposition of the conductive film, an appropriate curing step is performed, generally according to specifications provided by the material manufacturer.

If an unpatterned conductive film has been deposited, i.e., a solid layer of conductive film is produced, the film can be patterned using conventional photolithographic methods in which a photoresist layer is formed on top of the conductive film, the photoresist is exposed through a mask bearing the desired electrode pattern, the photoresist is developed so that the desired electrode pattern remains, the conductor is selectively etched away using chemical or plasma etching, and the remaining photoresist is then stripped, leaving behind the patterned electrodes. Other forms of patterning are known to those of skill in the art, including e-beam writing or laser ablation.

In an alternate method for formation of electrodes using photolithographic methods, after formation of a conductive layer, a coating of photosensitive material, e.g., photoresist, is deposited on top of the conductive layer. A contact mask is provided which is formed from a flexible optical waveguide having a wide surface area which covers all or a significant area of a section of the web material. An exemplary waveguide device is described in U.S. Pat. No. 6,091,874, which is incorporated herein by reference in its entirety. The waveguide material is patterned so that the index of refraction of its cladding is selectively increased so that it "leaks" at positions corresponding to the desired locations of the electrodes to be defined. Light, typically from a laser light source or a high intensity lamp, of an appropriate wavelength for exposure of the photoresist is coupled into the waveguide using conventional coupling means. The flexible waveguide is aligned with the underlying pattern over the area of photoresist-coated conductive layer on which the pattern is to be formed. The photoresist is then exposed by the light emitted from the selective leaks in the waveguide. After the photoresist is cured and the unexposed resist is removed, the conductive material is selectively etched to form the electrodes at the desired locations.

In embodiments of the device in which multiple layers of conductors are required, see, e.g., the embodiments of FIGS. **5**–**7**, after curing and, if required, patterning, the conductive film to form the electrodes, another deposition of liquid dielectric is performed as described above by passing the web material through the liquid dielectric deposition process. After formation of a second dielectric layer, another step is performed to create additional electrodes. Referring to FIG. **7** to illustrate, dielectric layers **65***a*, **65***b* and **65***c* alternate with second address electrode **85**, first address electrode **80** and first sustain electrode **70**, respectively, such that the web manufacturing process includes three separate steps for depositing liquid dielectric to form the dielectric layers and three separate steps for depositing a conductive liquid to form the electrodes.

After formation of the final (uppermost) electrodes, a protective layer, e.g., layer **20** in FIG. **7**, is applied, either using a liquid dielectric uniformly coated over the assembly, or a flexible sheet material laminated over the top of the light-emitting panel assembly. If a liquid is used, the assembly must again be processed through the appropriate curing step (**224**). Then, the panels are cut to the desired size in the dicing step (**226**).

In one embodiment, prior to applying the top layer in step **222**, an optional contrast enhancement layer may be included in which the micro-components are surrounded by a dark, preferably black, background field. One method for applying this black mask layer includes coating the area surrounding the micro-components, i.e., the dielectric layer and conductive lines, with a slurry of carbon black particles (step **219**) or a similar black curable liquid. The coating can be applied by uniform application of the slurry to the upper surface of the assembly, then using a squeegee to remove the material from the micro-components. Alternatively, the slurry can be applied using an ink jet-type printer, with the printer target being aligned to selectively apply the slurry to create a ring or other pattern surrounding each micro-component. After deposition of the coating, a curing step is performed to dry the black mask layer by removing solvents used to make the slurry. In yet another alternative method for formation of the black mask layer, after curing of the carbon black slurry, a photolithographic process can be used to selectively etch the black film from the surface of the micro-components.

In another alternate embodiment of the web manufacturing process, a hybrid sheet/liquid process is used. As described with regard to the first embodiment of the web manufacturing process shown in FIG. **9**, a second substrate is applied as a sheet material, where openings are formed in the second substrate to correspond to the locations of the micro-components. However, in this embodiment, the openings are not as tightly toleranced to fit the micro-components, but are larger, thus requiring less precision in the alignment of the openings to the micro-components. Then, a liquid dielectric with dielectric characteristics close to or matching those of the second substrate material is applied by an ink-jet process, or may be coated over the entire surface. If coated over the entire surface, the use of a scraper or squeegee will assist in forcing the liquid into the spaces between the micro-components and the inside edges of the second substrate openings. The viscosity and surface energy of the liquid dielectric material are selected to wet the surfaces of the micro-components and file any gaps between the second substrate and the micro-components. After curing, a continuous dielectric film surrounds the micro-components as in the previous-described embodiments.

In yet another embodiment, after formation of the protective layer (step **224**) and before dicing, an RF screen is formed by depositing a conductive liquid over the entire top surface of the assembly, where the conductive liquid is clear or becomes clear when cured. For example, indium-tin-oxide (ITO) can be used, however, other transparent conductive coatings are known, including transparent gold (TPG) and transparent silver or aluminum-based coatings. It may be desirable to coat an additional protective dielectric layer over RF screen, which may be performed using a liquid dielectric material followed by curing, or by applying a sheet of dielectric materials over the assembly. In addition to use as a RF screen, transparent conductive materials can be used in the construction of the light-emitting displays so as to facilitate implementation as a heads-up display for use in motor vehicles for purposes of facilitating a driver's ability to read displays without diverting his or her eyes away from the road.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A method for manufacturing a light-emitting panel in a web configuration comprising:

(a) providing a first substrate in a web form, the first substrate having a plurality of first conductors formed thereon;

(b) disposing at least one micro-component of a plurality of micro-components at each of a plurality of first locations on the first substrate corresponding to the plurality of conductors, each micro-component adapted to emit radiation in response to electrical excitation;

(c) depositing a liquid dielectric material onto the first substrate to electrically isolate the plurality of micro-components from each other;

(d) curing the liquid dielectric material to form a dielectric layer;

(e) depositing a conductive liquid on top of the dielectric layer at a plurality of second locations adapted to interact with the first conductors to excite one or more selected micro-components;

(f) curing the conductive liquid to create a conductive film for providing second conductors;

(g) applying a top layer over the dielectric layer and the second conductors.

**2**. The method of claim **1**, wherein the micro-components are coated with a phosphor material.

**3**. The method of claim **2**, wherein the phosphor material is applied to the micro-components by immersing the micro-components in a slurry of phosphor particles, then curing a phosphor coating formed on the micro-components.

**4**. The method of claim **1**, further comprising, prior to step (g), the steps of depositing a liquid black mask layer onto the first substrate and the conductive layer; and

curing the liquid mask material to form a black mask layer.

**5**. The method of claim **1**, further comprising:

photolithographically patterning the conductive film to form the second conductors.

**6**. The method of claim **5**, wherein the step of photolithographically patterning comprises selectively exposing a photosensitive material by contacting the photosensitive material with a leaky optical waveguide.

**7**. The method of claim **1**, wherein the first substrate has a plurality of dimples formed therein, wherein one dimple is formed at each of the plurality of first locations.

**8**. The method of claim **7**, wherein an adhesive material is applied within each of the plurality of dimples for securing the micro-component in the dimple.

**9**. The method of claim **1**, wherein the step of depositing a conductive liquid comprises printing an electrode pattern with a conductive ink.

**10**. The method of claim **9**, wherein the printing comprises inkjet printing.

**11**. The method of claim **1**, wherein the liquid dielectric material has a surface tension adapted to provide a uniform thickness across the first substrate.

**12**. The method of claim **1**, wherein the liquid dielectric material includes a surfactant.

**13**. The method of claim **1**, further comprising disposing an RF screen over the top layer.

**14**. The method of claim **1**, further comprising, prior to step (g), repeating steps (c) through (f) at least one time to form additional conductors.

**15**. A method for forming a flexible light emitting panel comprising:

(a) feeding a first dielectric substrate material from a payout reel in a web coating machine;

(b) printing a first plurality of electrodes on the first dielectric material;

(c) before or after printing the first plurality of electrodes, forming a plurality of sockets at a plurality of location in the first dielectric material;

(d) disposing at least one micro-component in each socket of the plurality of sockets, wherein the at least one micro-component is adapted to emit light in response to electrical excitation;

(e) applying a liquid dielectric material over the first dielectric material, the first plurality of electrodes, and at least a portion of each micro-component of the plurality of micro-components;

(f) curing the liquid dielectric material to form a dielectric layer;

(g) printing a second plurality of electrodes over the dielectric layer using a conductive ink;

(h) curing the conductive ink;

(i) applying a top layer over the dielectric layer, the second plurality of electrodes and the micro-components.

**16**. The method of claim **15**, further comprising the step of applying an adhesive material within each of the plurality of sockets for securing the micro-component in the socket.

**17**. The method of claim **15**, wherein step (d) comprises using electrostatic sheet transfer to place each micro-component into an appropriate socket.

**18**. The method of claim **15**, wherein step (g) comprises inkjet printing.

**19**. The method of claim **15**, wherein the liquid dielectric material has a surface tension adapted to provide a uniform thickness across the first substrate.

**20**. The method of claim **15**, wherein the liquid dielectric material includes a surfactant.

**21**. The method of claim **15**, further comprising disposing an RF screen over the top layer.

**22**. The method of claim **15**, further comprising, prior to step (i), repeating steps (e) through (h) at least one time to form at least one additional plurality of electrodes.

**23**. The method of claim **15**, wherein the micro-components are coated with a phosphor material.

**24**. The method of claim **23**, wherein the phosphor material is applied to the micro-components by immersing the micro-components in a slurry of phosphor particles, then curing a phosphor coating formed on the micro-components.

**25**. The method of claim **15**, further comprising, prior to step (i), the steps of depositing a liquid black mask layer onto the first substrate and the conductive layer; and

curing the liquid mask material to form a black mask layer.

**26**. A method for forming a flexible light emitting panel comprising:

(a) feeding a first dielectric substrate material from a payout reel in a web coating machine;

(b) printing a first plurality of electrodes on the first dielectric material;

(c) before or after printing the first plurality of electrodes, forming a plurality of sockets at a plurality of location in the first dielectric material;

(d) disposing at least one micro-component in each socket of the plurality of sockets, wherein the at least one micro-component is adapted to emit light in response to electrical excitation;

(e) aligning a second sheet material having dielectric properties over the first dielectric substrate material and the first plurality of electrodes, wherein the second dielectric sheet material has a plurality of openings therethrough corresponding to the plurality of locations, the plurality of openings having diameters larger than an outer diameter of the micro-component; so that a gap is created between an inner diameter of each opening and the outer diameter of each micro-component;

(f) applying a liquid dielectric material over at least a portion of the second sheet material so that the gap corresponding to each micro-component is filled, the liquid dielectric material having dielectric properties adapted for control of electric field and breakdown characteristics of the micro-component;

(g) curing the liquid dielectric material;

(h) printing a second plurality of electrodes over the second sheet material using a conductive ink;

(i) curing the conductive ink;

(j) applying a top layer over the second sheet material, the second plurality of electrodes and the micro-components.

**27**. The method of claim **26**, further comprising the step of applying an adhesive material within each of the plurality of sockets for securing the micro-component in the socket.

**28**. The method of claim **26**, wherein step (d) comprises using electrostatic sheet transfer to place each micro-component into an appropriate socket.

**29**. The method of claim **26**, wherein step (h) comprises inkjet printing.

**30**. The method of claim **26**, wherein the liquid dielectric material includes a surfactant.

**31**. The method of claim **26**, further comprising disposing an RF screen over the top layer.

**32**. The method of claim **26**, further comprising, prior to step (j), repeating steps (e) through (i) at least one time to form at least one additional plurality of electrodes.

**33**. The method of claim **26**, wherein the micro-components are coated with a phosphor material.

**34**. The method of claim **33**, wherein the phosphor material is applied to the micro-components by immersing the micro-components in a slurry of phosphor particles, then curing a phosphor coating formed on the micro-components.

**35**. The method of claim **26**, further comprising, prior to step (j), the steps of depositing a liquid black mask layer onto the first substrate and the conductive layer; and

curing the liquid mask material to form a black mask layer.

* * * * *

US006791264B2

(12) **United States Patent**
**Green et al.**

(10) **Patent No.: US 6,791,264 B2**
(45) **Date of Patent: Sep. 14, 2004**

(54) **LIGHT-EMITTING PANEL AND A METHOD FOR MAKING**

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(73) Assignee: **Science Applications International Corporation**, San Diego, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/303,926**

(22) Filed: **Nov. 26, 2002**

(65) **Prior Publication Data**

US 2003/0094891 A1 May 22, 2003

**Related U.S. Application Data**

(62) Division of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**[7] .................................................. **H01J 17/49**

(52) **U.S. Cl.** ....................... **313/582**; 313/584; 313/495; 313/586

(58) **Field of Search** ................................ 313/582, 585, 313/586, 587, 495

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,704,386 A * 11/1972 Cola .......................... 313/585
4,563,617 A * 1/1986 Davidson .................... 315/312
5,808,403 A 9/1998 Clerc ........................ 313/336
5,939,826 A * 8/1999 Ohsawa et al. ............. 313/582
6,577,056 B1 * 6/2003 Chang ........................ 313/582

FOREIGN PATENT DOCUMENTS

WO WO 00/36465 6/2000 ........... G02F/1/167

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.
International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).
International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42805, dated Apr. 2, 2004 (mailing date).

* cited by examiner

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*Assistant Examiner*—Mariceli Santiago
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous inline process.

**29 Claims, 22 Drawing Sheets**

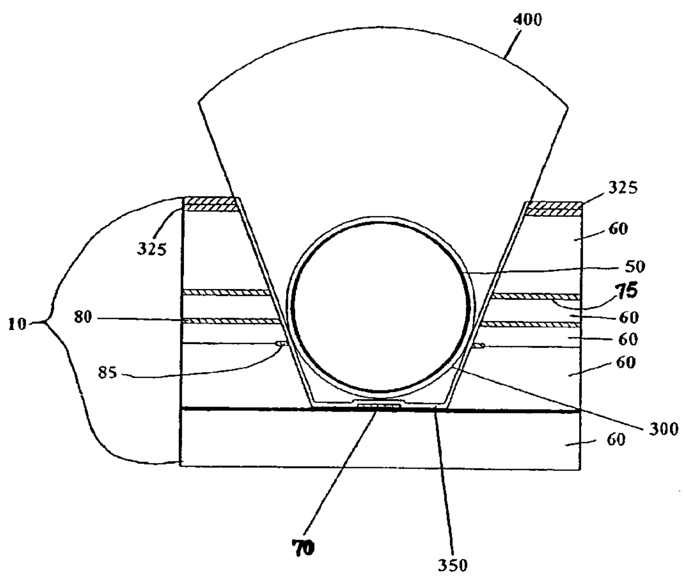


Fig. 1

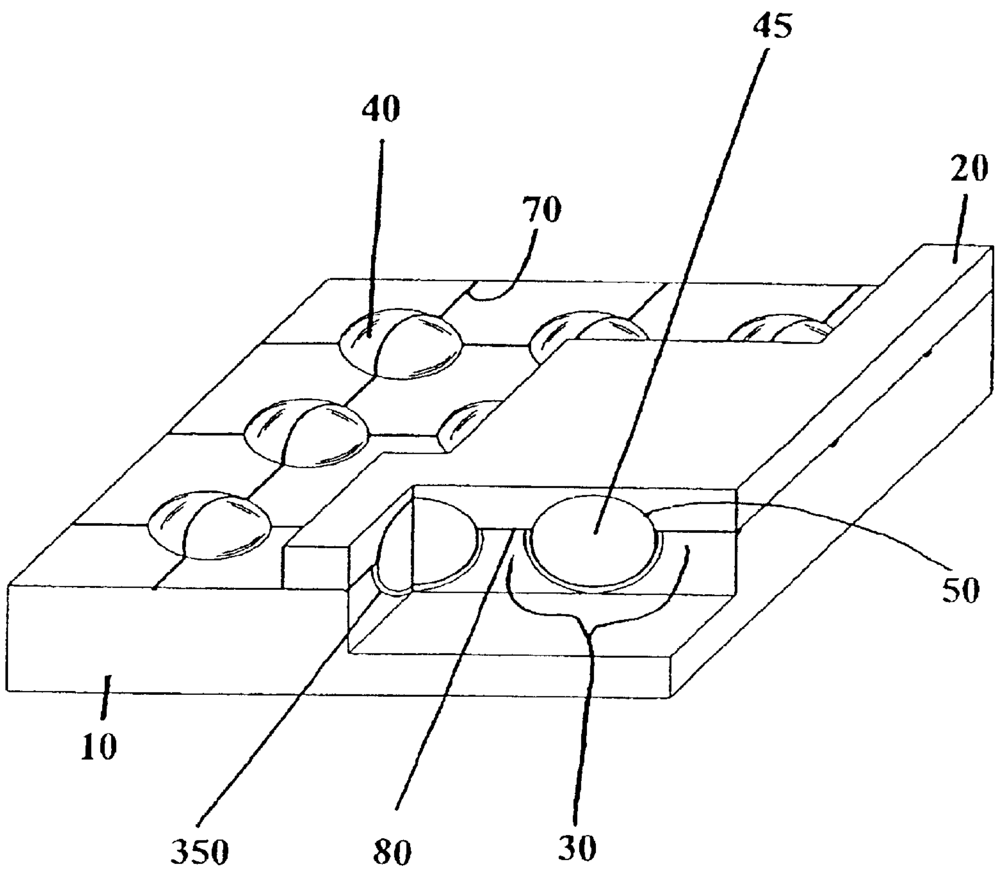
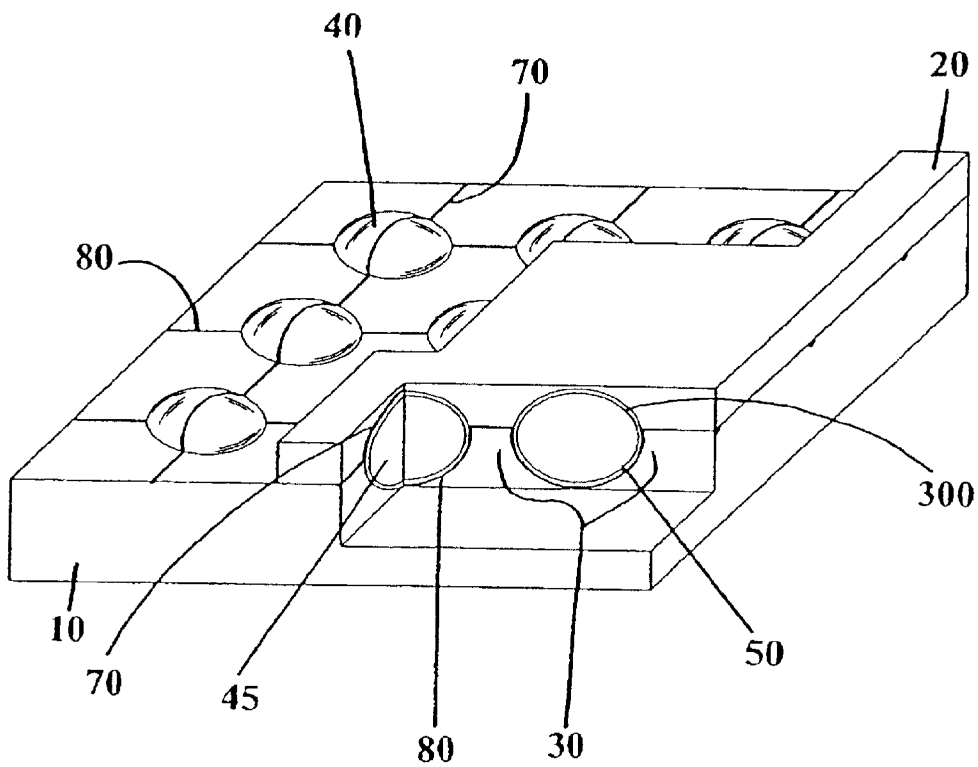


Fig. 2



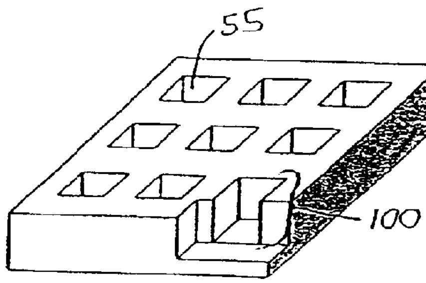



Fig. 3A

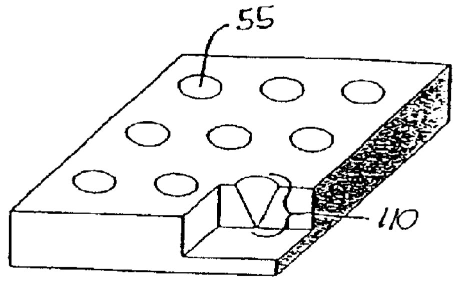



Fig. 3B

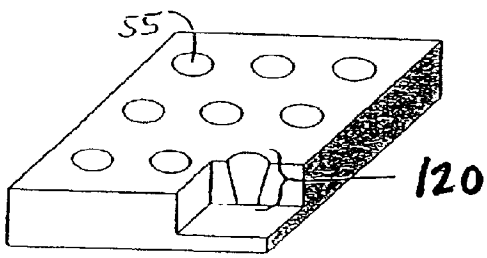



Fig. 3C

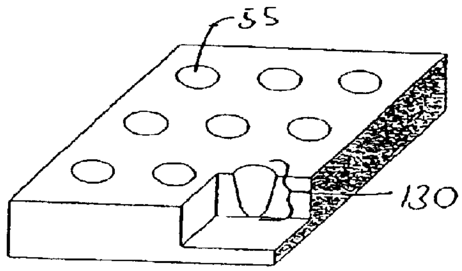



Fig. 3D

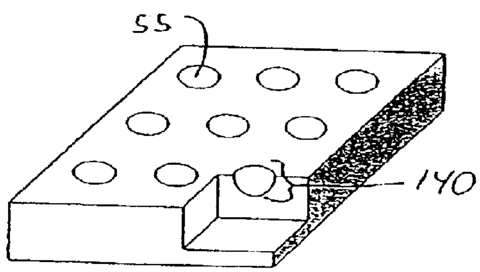



Fig. 3E

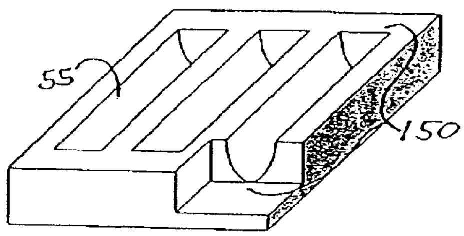



Fig. 3F

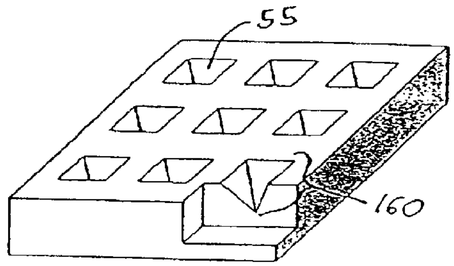



Fig. 3G

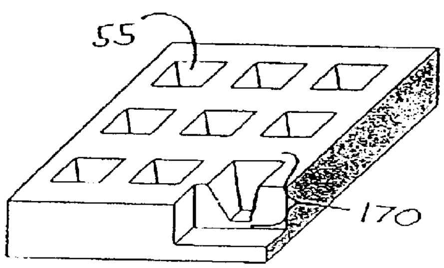



Fig. 3H

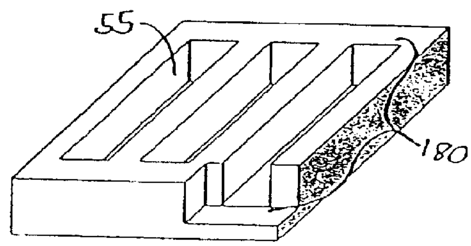



Fig. 3I

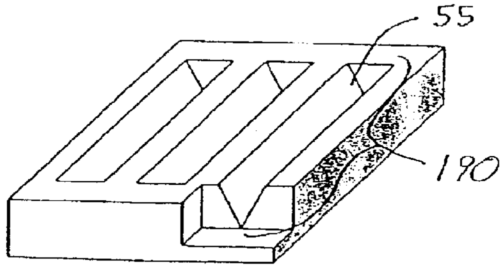



Fig. 3J

Fig. 4

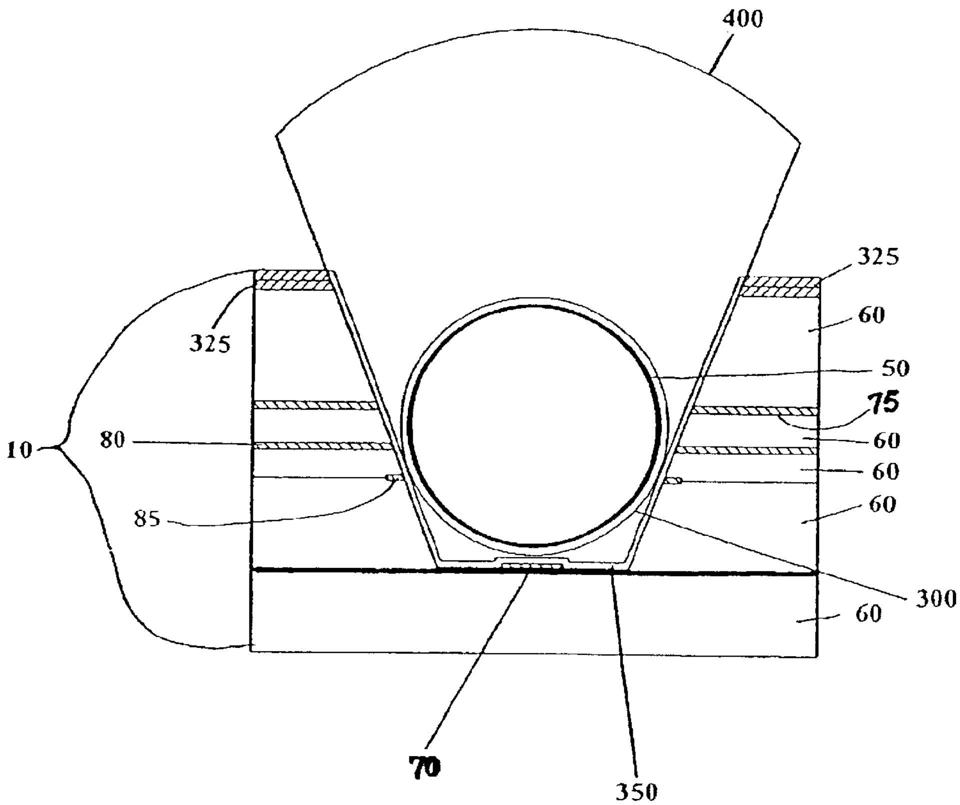


Fig. 5

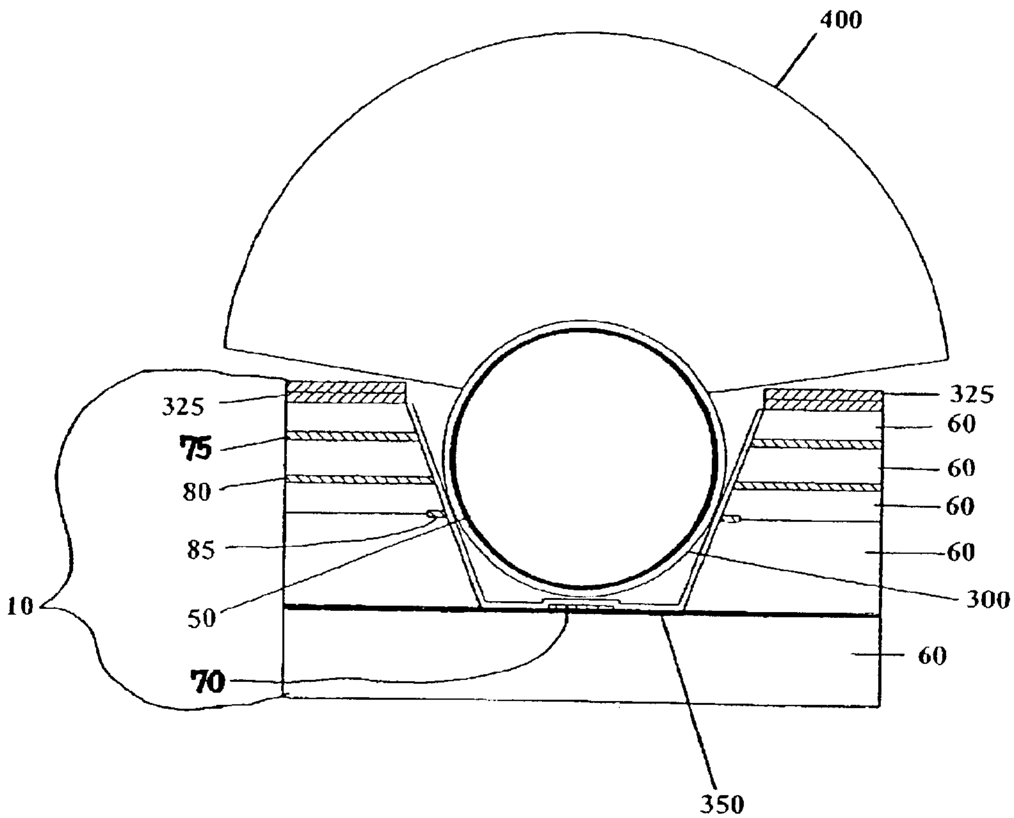


Fig. 6A

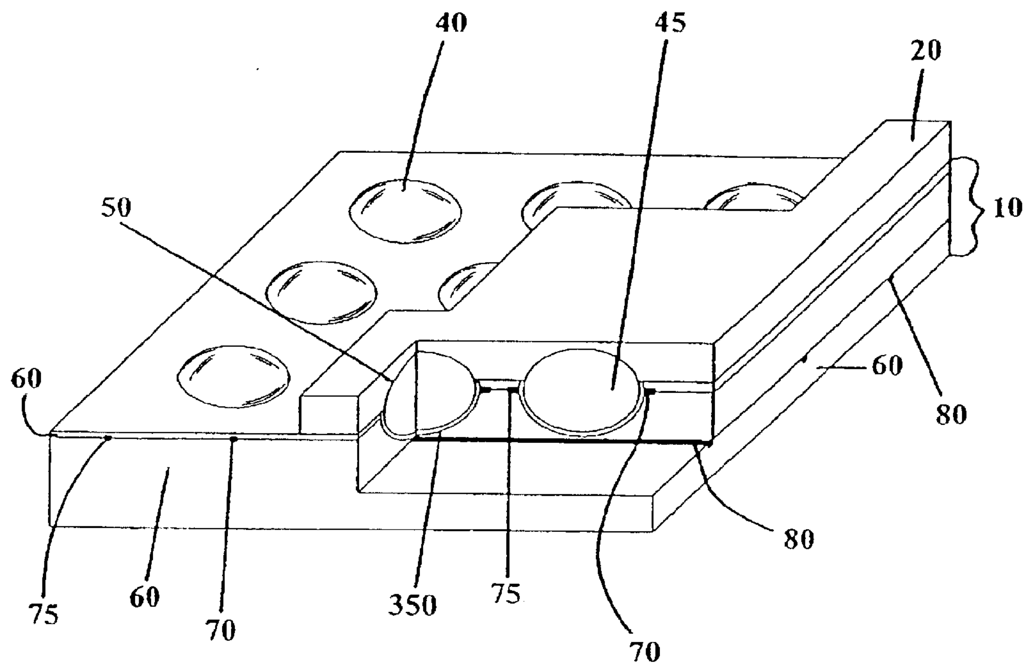


Fig. 6B

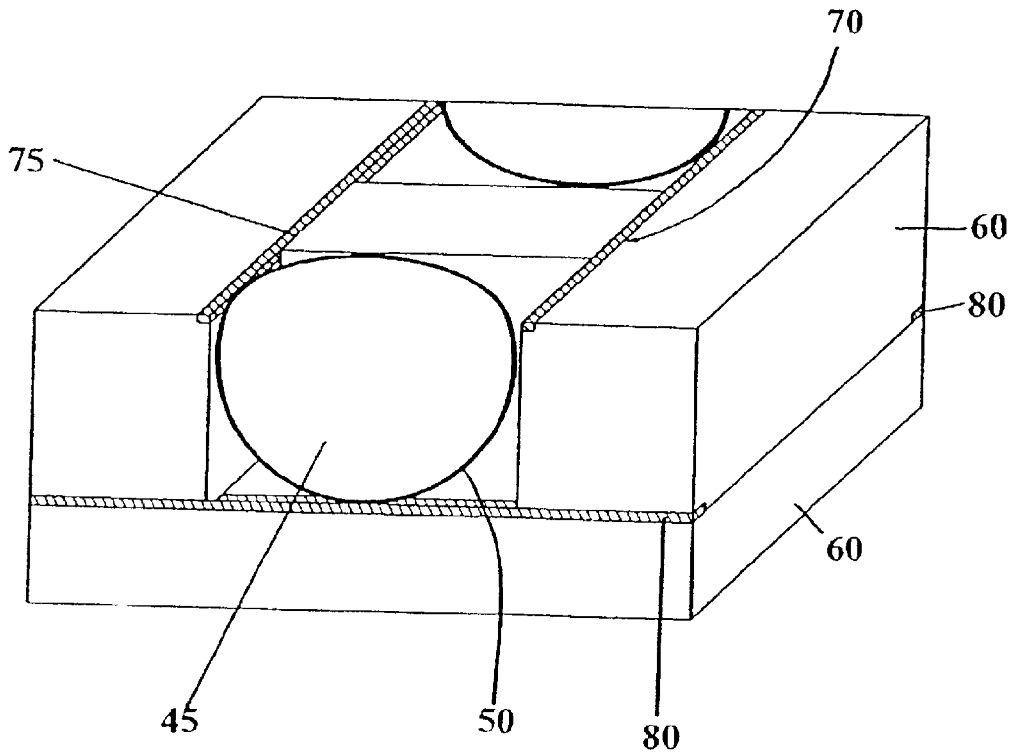


Fig. 7A

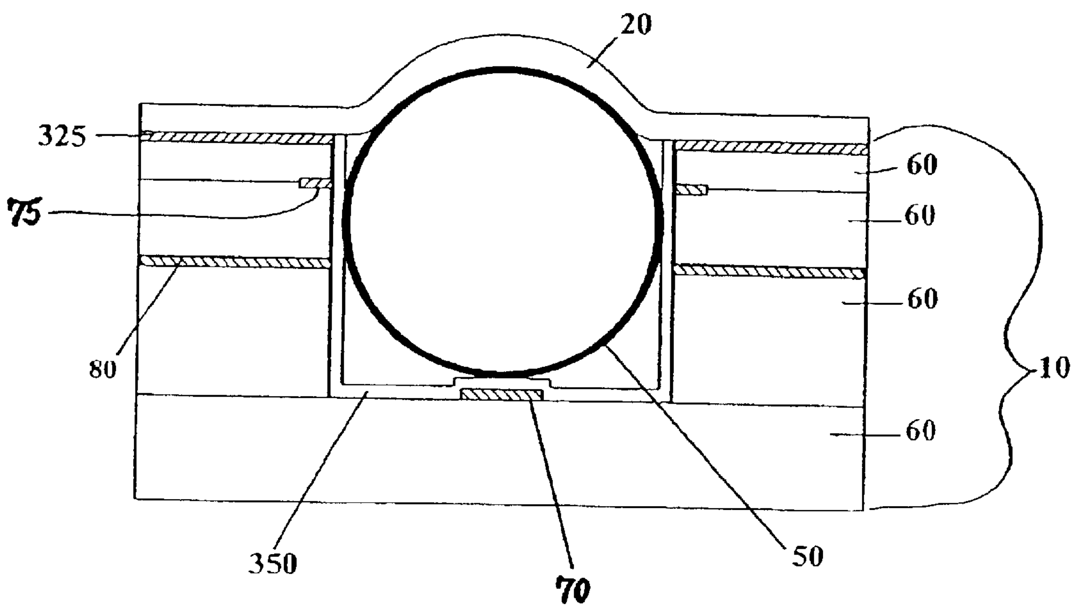


Fig. 7B

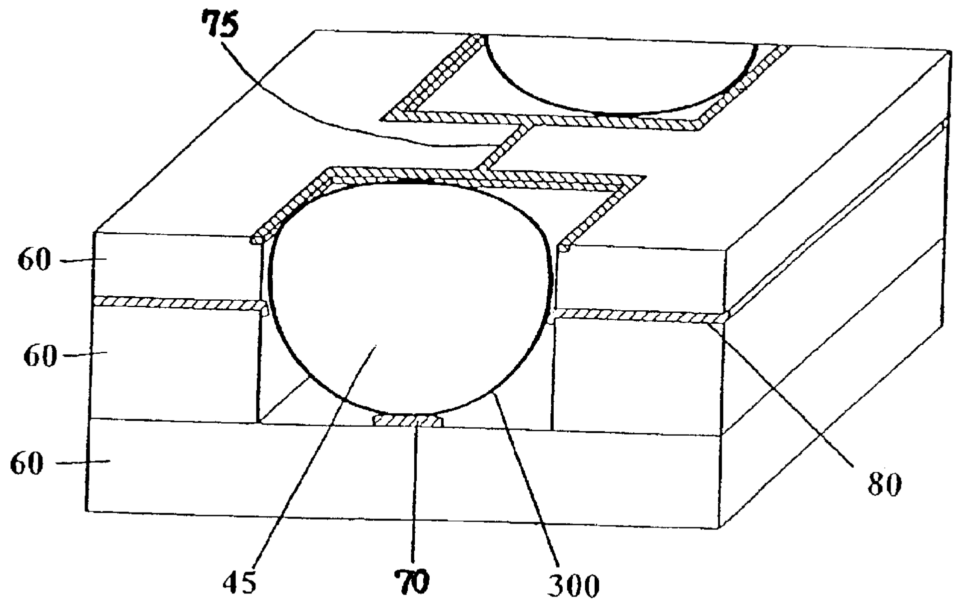


Fig. 8

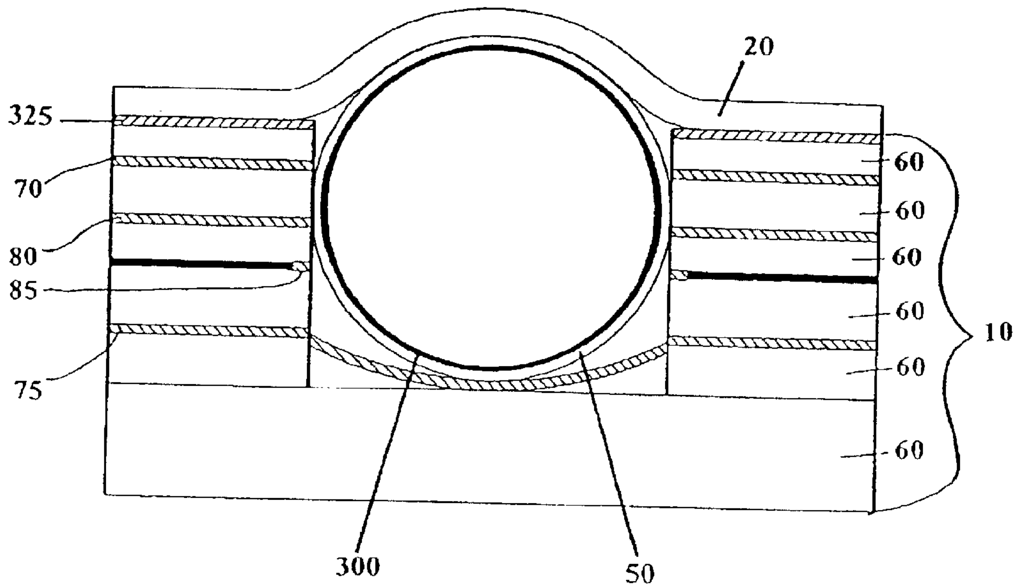


Fig. 9

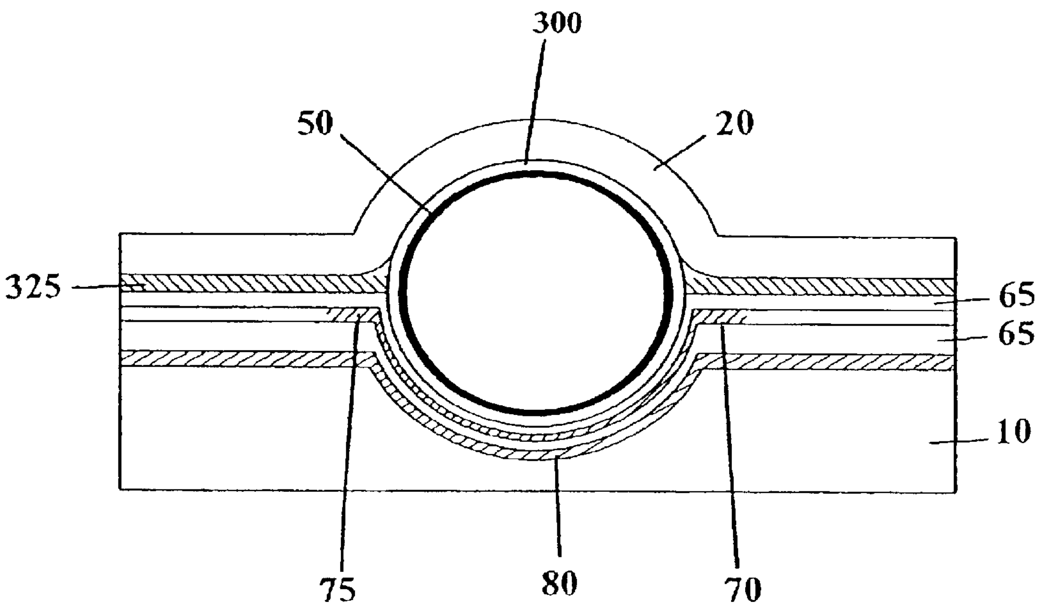


Fig. 10

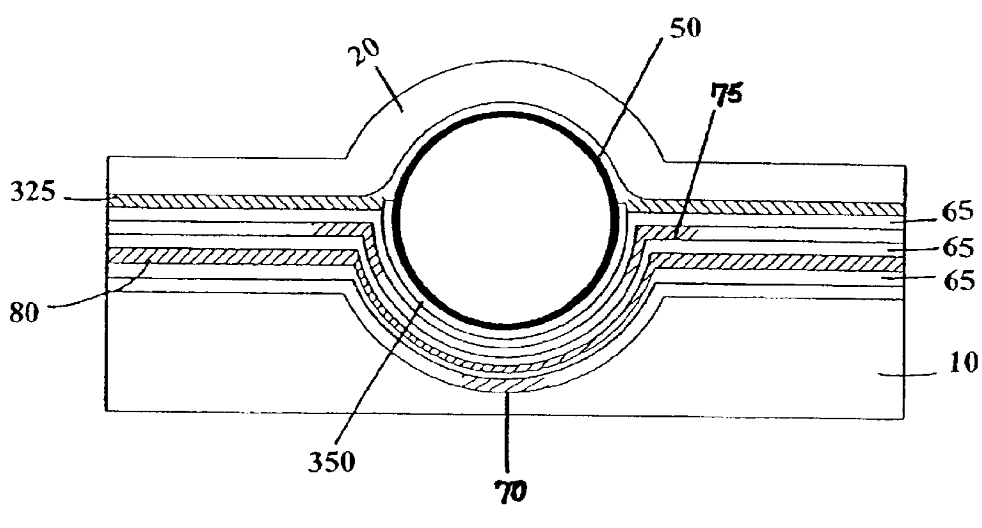
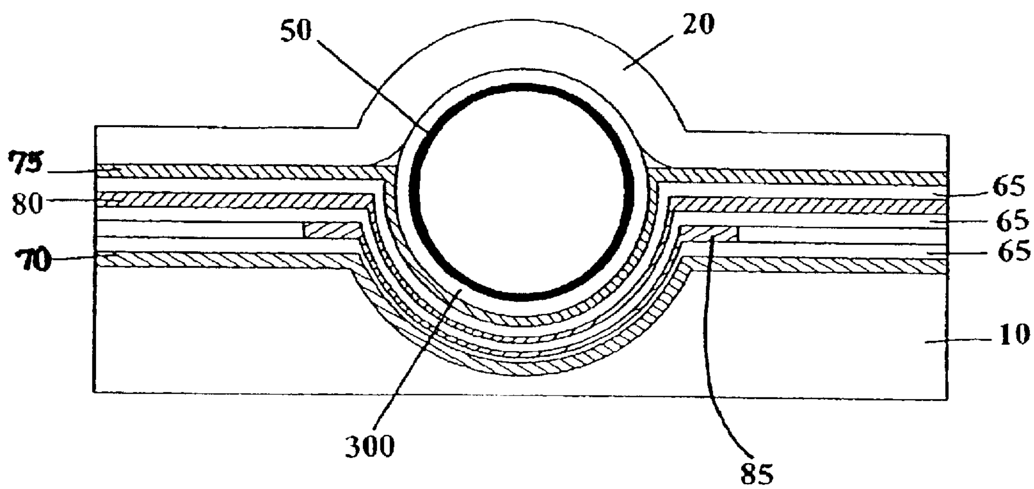


Fig. 11



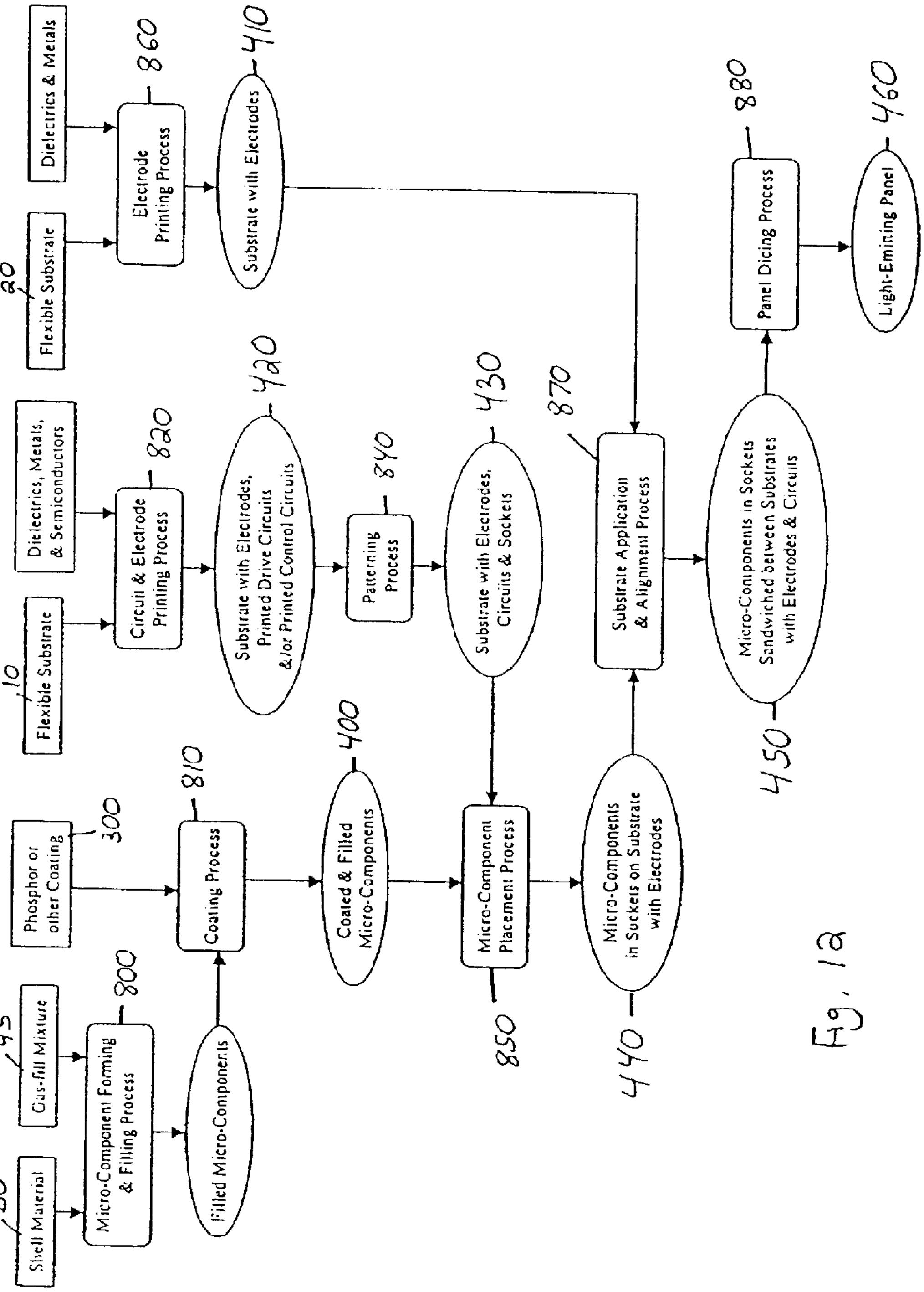
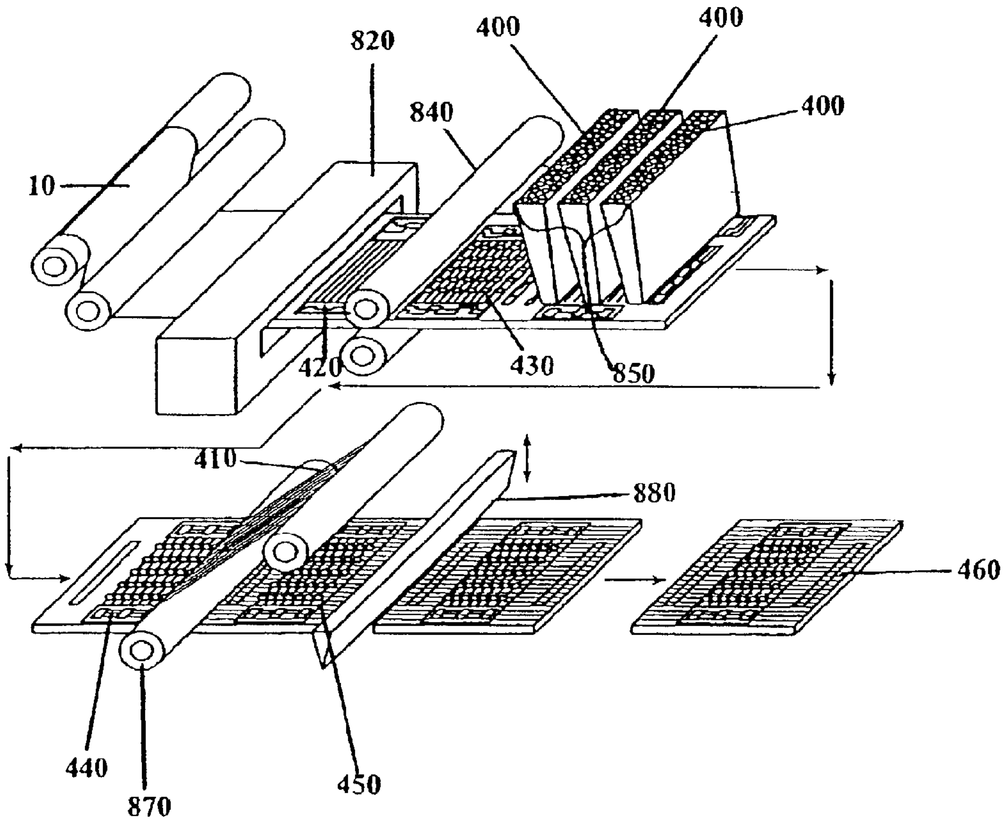

Shell Material
50
Gas-fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits &/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched between Substrates with Electrodes & Circuits
450
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Panel Dicing Process
880
Light-Emitting Panel
460

Fig. 1a

Fig. 13



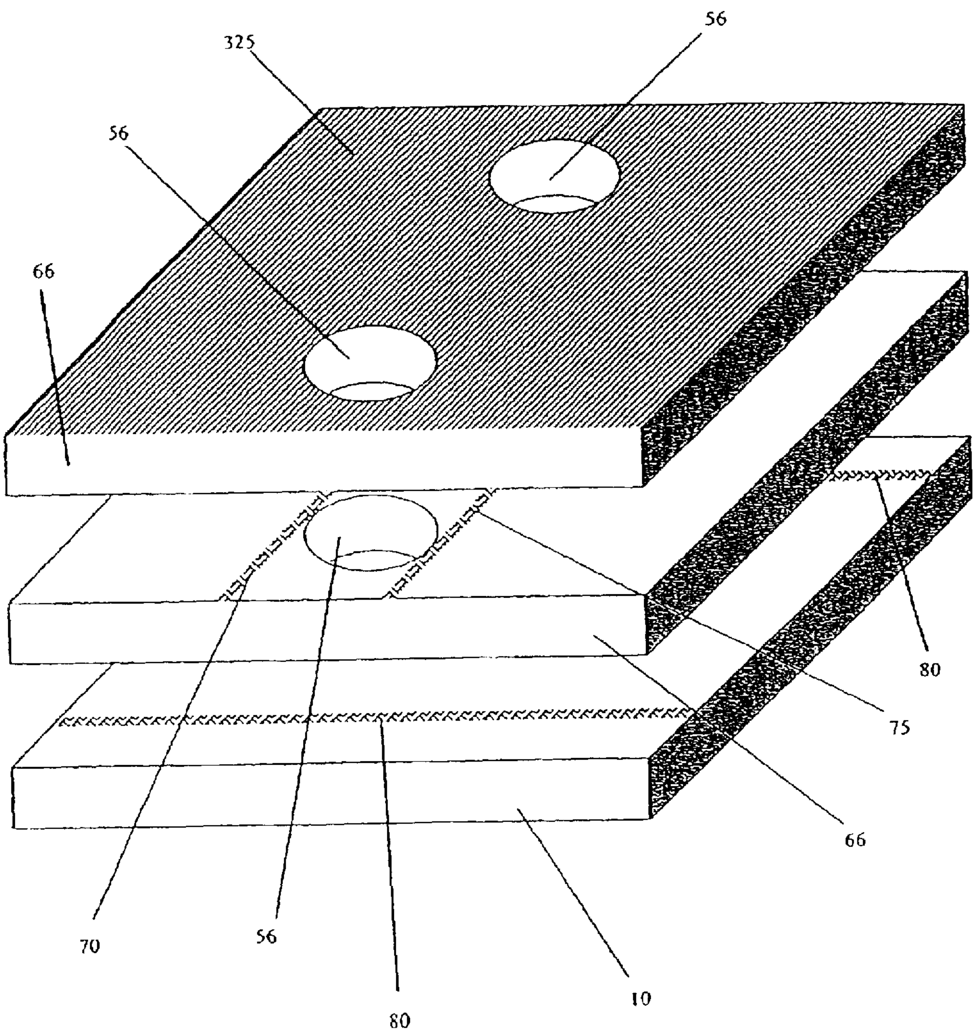



Fig. 14

Fig. 15

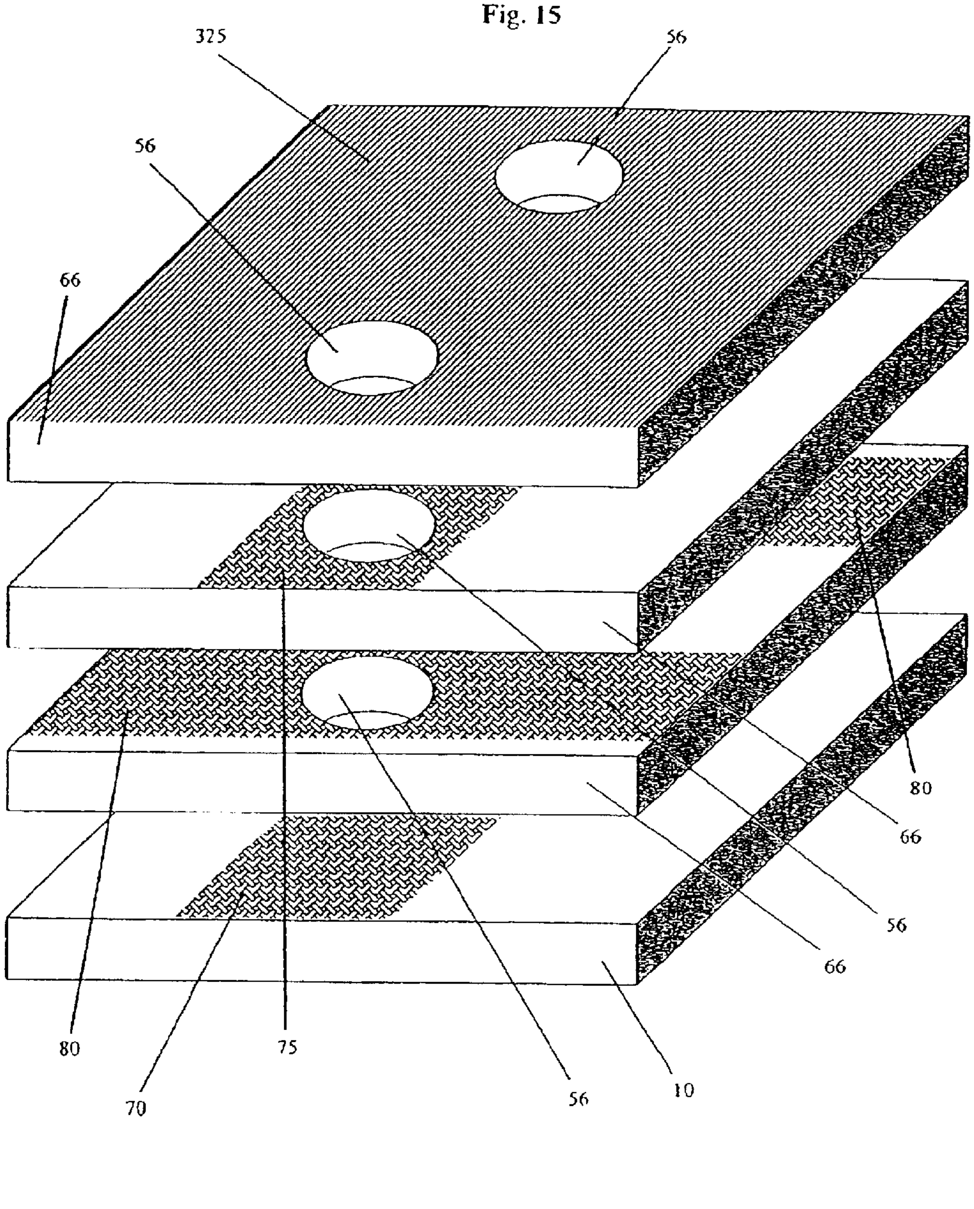


Fig. 16

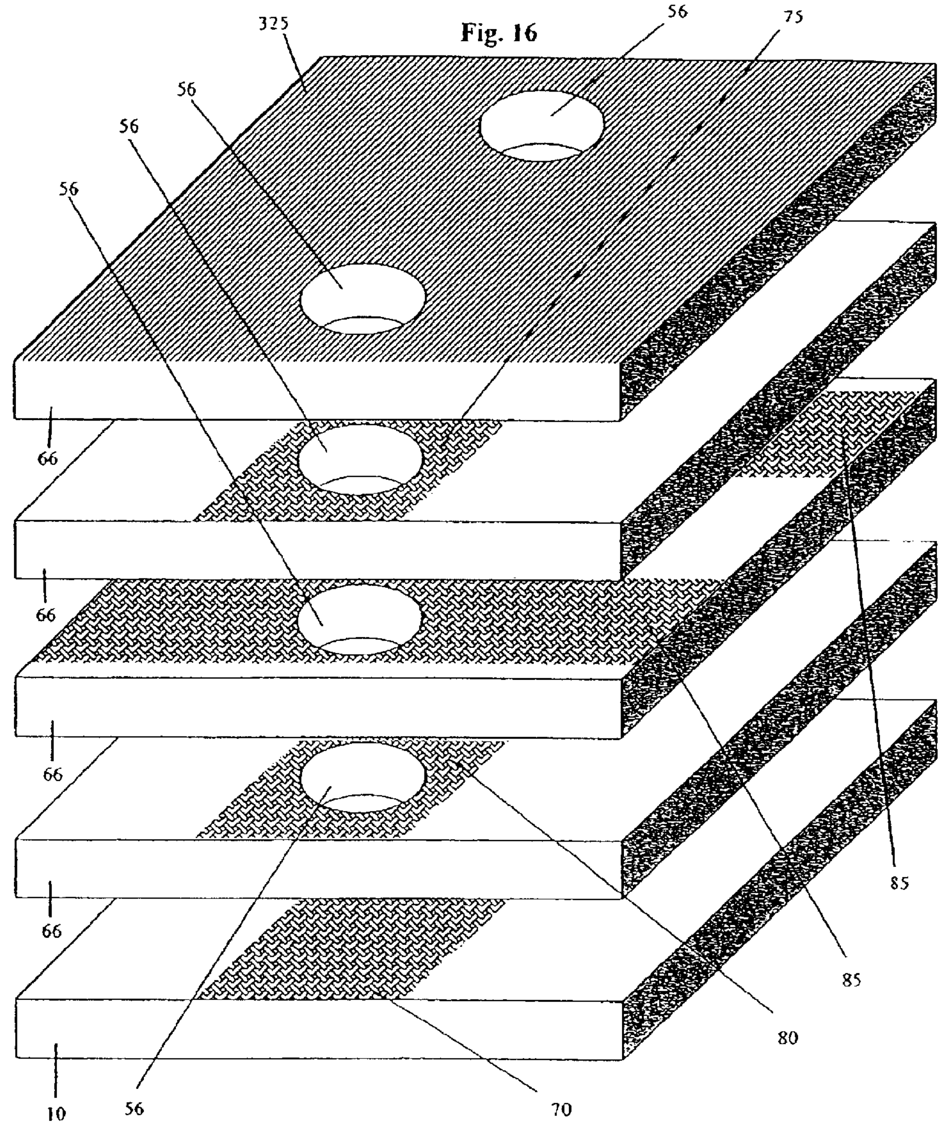


Fig. 17

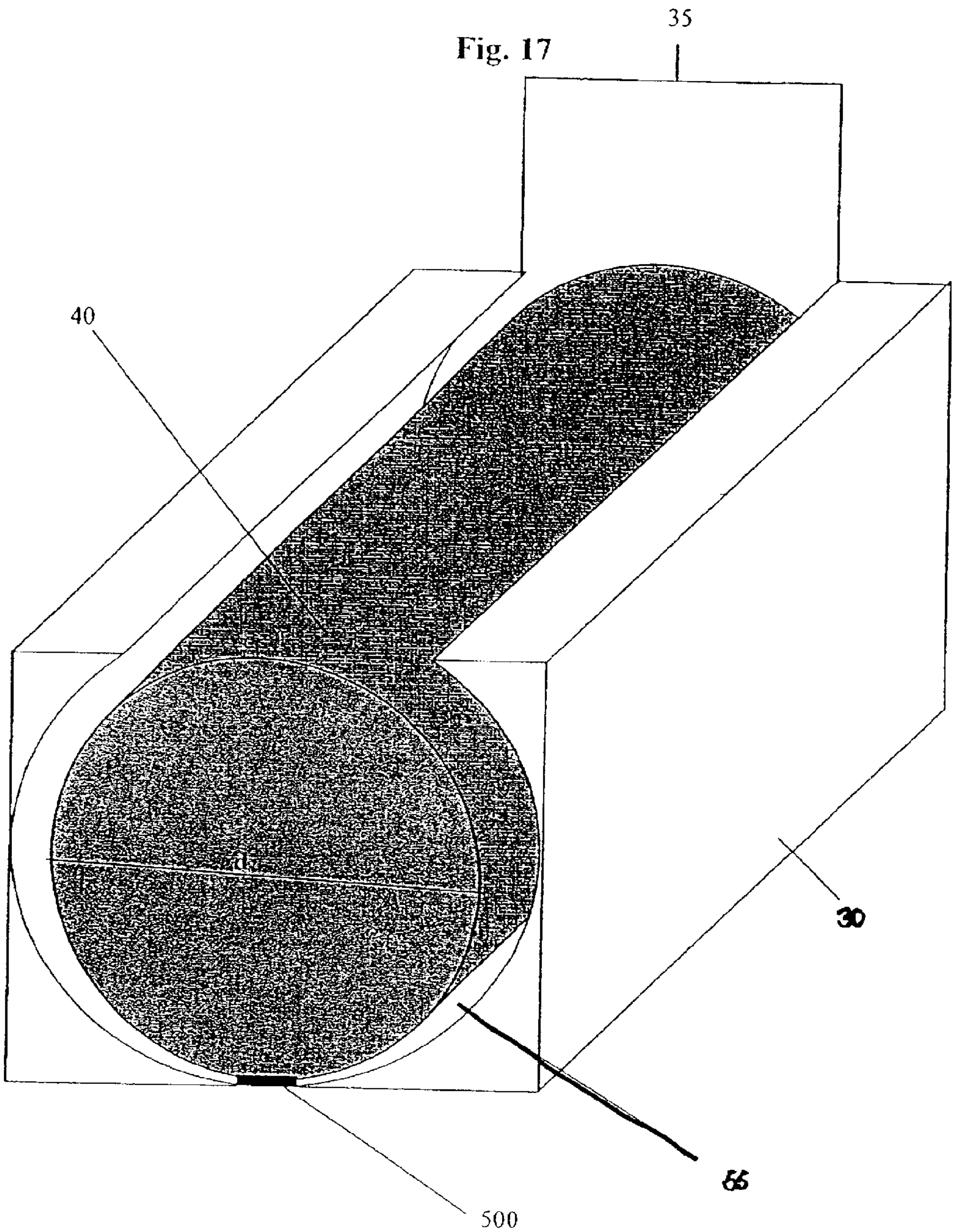


Fig. 18

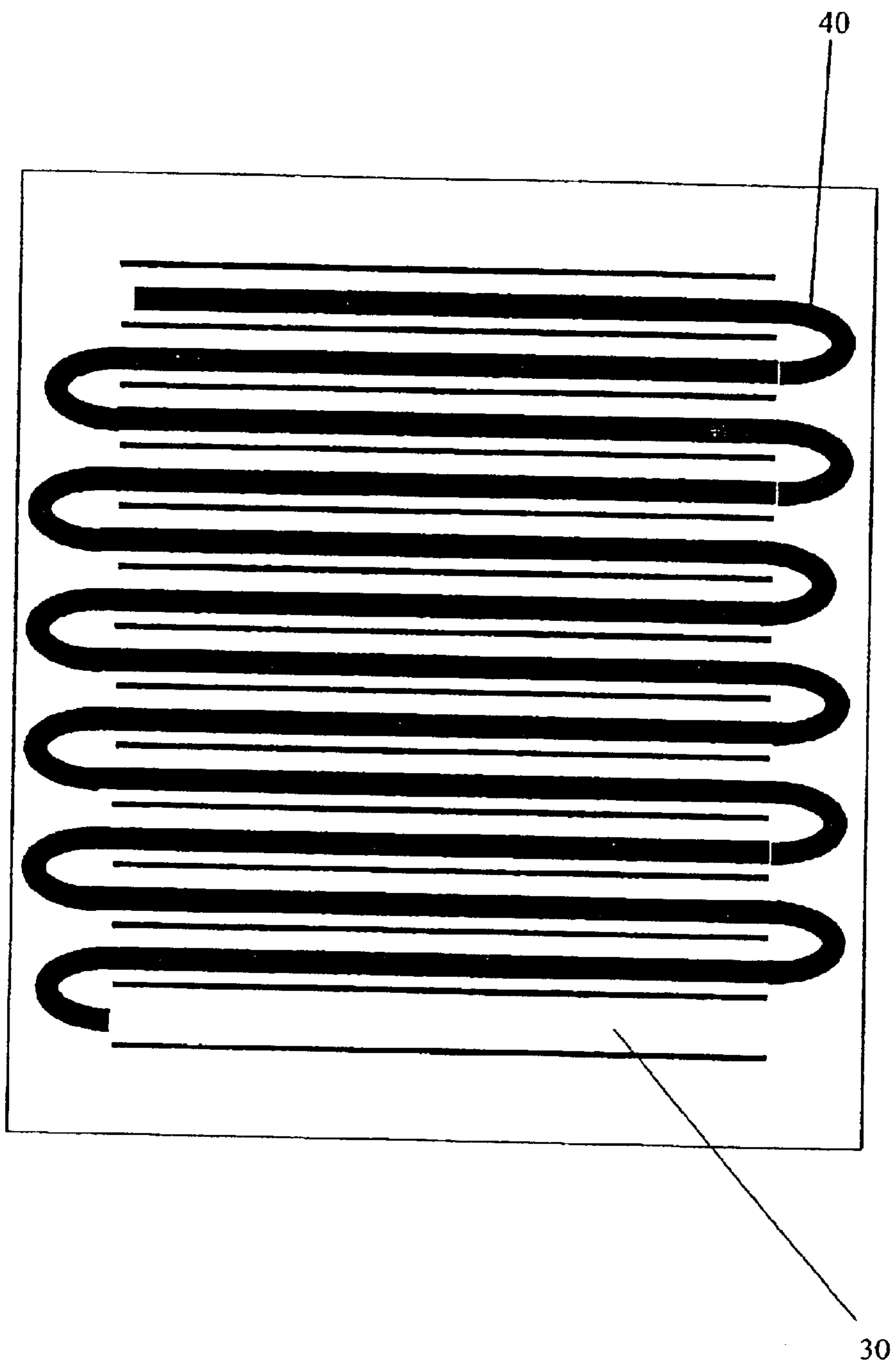
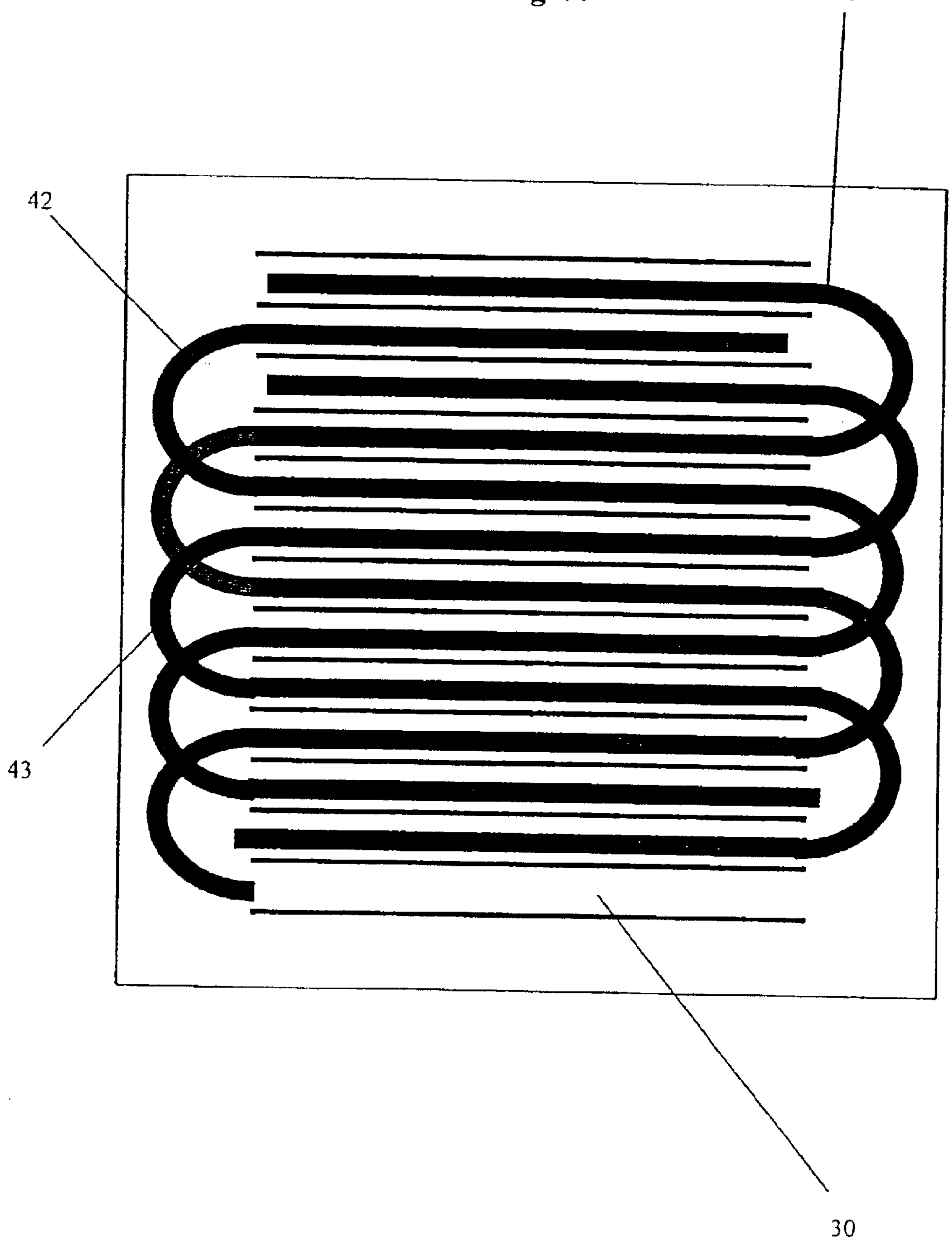


Fig. 19



# LIGHT-EMITTING PANEL AND A METHOD FOR MAKING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of and claims priority to and incorporates by reference in its entirety, application Ser. No. 09/697,344 now U.S. Pat. No. 6,612, 889, entitled, "A Light-Emitting Panel and a Method for Making," filed Oct. 27, 2000. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties: U.S. patent application Ser. No. 09/697,358 entitled *A Micro-Component for Use in a Light-Emitting Panel* filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled *A Method for Testing a Light-Emitting Panel and the Components Therein* filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled *A Method and System for Energizing a Micro-Component in a Light-Emitting Panel* filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,346 entitled *A Socket for Use in a Light-Emitting Panel* filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.



Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is

particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In another embodiment of the present invention, at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, at least two electrodes are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In yet another embodiment, disposed in, or proximate to, each socket is at least one enhancement material.

Another preferred embodiment of the present invention is drawn to a web fabrication method for manufacturing light-emitting panels. In an embodiment, the web fabrication process includes providing a first substrate, disposing a plurality of micro-components on the first substrate, disposing a second substrate on the first substrate so the at the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrates to form individual light-emitting panels. In another embodiment, the web fabrication method includes the following process steps: a micro-component forming process; a micro-component coating process; a circuit and electrode printing process; a patterning process; a micro-component placement process; an electrode printing process; a second substrate application and alignment process; and a panel dicing process.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.



In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 microns to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in

FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the fist substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17**, and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A light-emitting panel comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets; a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas and wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket;

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate and further wherein the second substrate comprises a plurality of lenses configurable to adjust a field of view of the light-emitting panel wherein a ratio of lenses to sockets is 1:1; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the at least two electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation.

**2**. The light-emitting panel of claim **1**, wherein the second substrate comprises at least one filter.

**3**. The light-emitting panel of claim **2**, wherein the plurality of micro-components are configured to emit ultraviolet radiation, wherein each micro-component is coated with phosphor to convert the ultraviolet radiation to visible light, and wherein the at least one filter changes the visible light passing through the filter to visible light of a specific color.

**4**. The light-emitting panel of claim **1**, wherein the emitted radiation is ultraviolet radiation, and further wherein each of the plurality of sockets is at least partially coated with phosphor in order to convert the ultraviolet radiation into red, green, or blue visible light.

**5**. A light-emitting panel, comprising:

a first substrate, wherein the first substrate comprises a plurality of sockets; a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled with a plasma-forming gas and wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket;

a second substrate, wherein the second substrate is opposed to the first substrate such that the at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are arranged so that voltage supplied to the at least two electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing the at least two electrodes.

**6**. The light-emitting panel of claim **5**, wherein the first substrate dissipates heat from the light-emitting panel.

**7**. The light-emitting display of claim **5**, wherein each socket includes at least one enhancement material is disposed in or proximate to each socket and wherein the at least one enhancement material is selected from a group consisting of transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

**8**. The light-emitting display of claim **7**, wherein the at least one enhancement material self-aligns in each socket.

**9**. The light-emitting display of claim **7**, further comprising a controller, wherein the controller selectively controls the operation of the at least one enhancement material to adjust at least one characteristic of the micro-component.

**10**. The colored light-emitting panel of claim **5**, wherein the second substrate is formed of a heat dissipating material.

**11**. The colored light-emitting panel of claim **5**, wherein the plurality of sockets is disposed in uniformly spaced pattern on the first substrate.

**12**. The light-emitting panel of claim **5**, wherein the plasma-forming gas is selected from the group consisting of neon-argon, xenon-oxygen, and krypton-neon.

**13**. The light-emitting panel of claim **5**, further comprising colored filters applied over each of the plurality of sockets for converting the emitted radiation from each of the plurality of micro-components into red, green, or blue visible light.

**14**. The light-emitting panel of claim **5**, wherein the emitted radiation is ultraviolet radiation, and further wherein each of the plurality of micro-components is at at least partially coated with phosphor in order to convert the ultraviolet radiation into red, green, or blue visible light.

**15**. The light-emitting panel of claim **5**, wherein the emitted radiation is ultraviolet radiation, and further wherein each of the plurality of sockets is at least partially coated with phosphor in order to convert the ultraviolet radiation into red, green, or blue visible light.

**16**. The light-emitting panel of claim **5**, further comprising means for selecting a particular field of view for the emitted radiation from the light-emitting panel.

**17**. The light-emitting panel of claim **16**, wherein the means is a single lens.

**18**. The colored light-emitting panel of claim **16**, wherein the means is a plurality of lenses, wherein the ratio of lenses to sockets is 1:1.

**19**. A colored light-emitting panel comprising:

a first substrate comprising a plurality of sockets;

a plurality of micro-components, wherein each of the plurality of micro-components is at least partially filled with an ionizable gas and is configured to emit radiation resulting in visible light having one of the following colors red, green, and blue being emitted from the light-emitting panel, and further wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each of the plurality of sockets;

a second substrate, wherein the second substrate is opposed to the first substrate such that the plurality of micro-components are sandwiched between the first substrate and the second substrate; and

means for applying a voltage across each of the plurality of micro-components to ionize the ionizable gas and cause each of the plurality of micro-components to emit the radiation throughout a field of view of the light-emitting panel without crossing the means for applying a voltage across each of the plurality of micro-components.

**20**. The colored light-emitting panel of claim **19**, wherein at least one of the first and second substrates are formed of a heat dissipating material.

**21**. The colored light-emitting panel of claim **19**, wherein the plurality of sockets is disposed in uniformly spaced pattern on the first substrate.

**22**. The colored light-emitting panel of claim **19**, wherein the ionizable gas is selected from the group consisting of neon-argon, xenon-oxygen, and krypton-neon.

**23**. The colored light-emitting panel of claim **19**, further comprising colored filters applied over each of the plurality of sockets for converting the emitted radiation from each of the plurality of micro-components into red, green, or blue visible light.

**24**. The colored light-emitting panel of claim **19**, wherein the emitted radiation is ultraviolet radiation, and further wherein each of the plurality of micro-components is at least partially coated with phosphor in order to convert the ultraviolet radiation into red, green, or blue visible light.

**25**. The colored light-emitting panel of claim **19**, wherein the emitted radiation is ultraviolet radiation, and further wherein each of the plurality of sockets is at least partially coated with phosphor in order to convert the ultraviolet radiation into red, green, or blue visible light.

**26**. The colored light-emitting panel of claim **19**, further comprising means for selecting a particular field of view for the visible light emitted from the light-emitting panel.

**27**. The colored light-emitting panel of claim **26**, wherein the means for selecting a particular field of view is a single lens.

**28**. The colored light-emitting panel of claim **26**, wherein the means for selecting a particular field of view is a plurality of lenses, wherein the ratio of lenses to sockets is 1:1.

**29**. The colored light-emitting panel of claim **19**, wherein the means for applying a voltage comprises at least two electrodes.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,791,264 B2 
APPLICATION NO. : 10/303926
DATED : September 14, 2004
INVENTOR(S) : Albert Myron Green et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:
UNDER REFERENCES CITED (56) - U.S. Patent Documents -

Please add:

| | | | |
|---|---|---|---|
| 2002/0024295 Al | 2/28/02 | Miyashita, et al. | 313/495 |
| 2002/0022565 Al | 2/21/02 | Sreeram, et al. | 501/16 |
| 2002/0017864 Al | 2/14/02 | Watanabe, et al. | 313/586 |
| 2002/0016075 Al | 2/7/02 | Peng, et al. | 438/700 |
| 2002/0009536 Al | 1/24/02 | Iguchi, et al. | 427/10 |
| 2002/0008470 Al | 1/24/02 | Uegaki, et al. | 313/567 |
| 2001/0053570 Al | 12/20/01 | Kido | 438/149 |
| 6,322,010 | 11/27/01 | Sasaki, et al. | 239/568 |
| 6,319,325 | 11/20/01 | Hiratsuka, et al. | 118/718 |
| 6,312,971 | 11/6/01 | Amundson, et al. | 438/99 |
| 6,312,304 | 11/6/01 | Duthaler, et al. | 445/24 |
| 2001/0033256 Al | 10/25/01 | Moore | 345/60 |
| 6,307,319 | 10/23/01 | Lee | 313/590 |
| 6,304,238 | 10/16/01 | Tsuchida | 345/87 |
| 6,304,032 | 10/16/01 | Asano | 313/582 |
| 6,304,031 | 10/16/01 | Wani, et al. | 313/582 |
| 6,300,932 | 10/9/01 | Albert | 345/107 |
| 6,300,152 | 10/9/01 | Kim | 438/30 |
| 6,297,590 | 10/2/01 | Nanto, et al. | 313/586 |
| 6,296,539 | 10/2/01 | Awaji, et al. | 445/24 |
| 6,295,040 | 9/25/01 | Nhan, et al. | 345/60 |
| 6,292,160 | 9/18/01 | Mikoshiba, et al. | 345/60 |
| 6,292,159 | 9/18/01 | Someya, et al. | 345/60 |
| 6,291,925 | 9/18/01 | Jacobson | 310/319 |
| 6,288,693 | 9/11/01 | Song, et al. | 345/68 |
| 6,288,488 | 9/11/01 | Amemiya | 313/582 |
| 6,285,434 | 9/4/01 | Ma, et al. | 349/189 |
| 6,285,129 | 9/4/01 | Park, et al. | 313/586 |
| 6,281,863 | 8/28/01 | Sasaki, et al. | 345/60 |
| 6,265,826 | 7/24/01 | Miyazaki | 313/586 |
| 2001/0008825 Al | 7/19/01 | Toyoda, et al. | 445/24 |
| 6,262,706 | 7/17/01 | Albert, et al. | 345/107 |
| 6,255,777 | 7/3/01 | Kim, et al. | 313/582 |
| 6,201,518 | 3/13/01 | Kane, et al. | 345/60 |
| 6,137,553 | 10/24/00 | Izumi, et al. | 349/49 |

# UNITED STATES PATENT AND TRADEMARK OFFICE
# CERTIFICATE OF CORRECTION

PATENT NO. : 6,791,264 B2
APPLICATION NO. : 10/303926
DATED : September 14, 2004
INVENTOR(S) : Albert Myron Green et al.



It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

UNDER REFERENCES CITED (56) - U.S. Patent Documents (cont'd):

| | | | |
|---|---|---|---|
| 6,130,655 | 10/10/00 | Lammers | 345/72 |
| 6,097,147 | 8/1/2000 | Baldo et al. | 313/506 |
| 6,091,874 | 7/18/00 | Higashi, et al. | 384/130 |
| 6,091,380 | 7/18/00 | Hashimoto et al. | 345/60 |
| 6,091,195 | 7/18/00 | Forrest et al. | 313/504 |
| 8,087,196 | 7/11/00 | Sturm et al. | 438/29 |
| 6,080,606 | 6/27/00 | Gleskova et al. | 438/151 |
| 6,079,814 | 6/27/00 | Lean, et al. | 347/55 |
| 6,072,276 | 6/6/00 | Okajima | 313/581 |
| 6,069,443 | 5/30/00 | Jones et al. | 313/504 |
| 6,049,366 | 4/11/00 | Hakemi et al. | 349/86 |
| 6,048,630 | 4/11/00 | Burrows et al. | 428/690 |
| 6,048,469 | 4/11/00 | Xiang, et al. | 252/301.6 R |
| 6,046,543 | 4/4/00 | Bulovic et al. | 313/504 |
| 6,045,930 | 4/4/00 | Thompson et al. | 428/690 |
| 6,039,619 | 3/21/00 | Kang et al. | 445/24 |
| 6,038,002 | 3/14/00 | Song | 349/43 |
| 6,037,918 | 3/14/00 | Hansen et al. | 345/74 |
| 6,037,710 | 3/14/00 | Poole et al. | 313/422 |
| 6,033,547 | 3/7/00 | Trau et al. | 204/622 |
| 6,030,715 | 2/29/00 | Thompson et al. | 428/690 |
| 6,030,269 | 2/29/00 | Drumm | 445/52 |
| 6,025,097 | 2/15/00 | Drumm | 430/7 |
| 6,023,259 | 2/8/00 | Howard et al. | 345/76 |
| 6,022,652 | 2/8/00 | Haven et al. | 430/26 |
| 6,019,657 | 2/1/00 | Chakvorty et al. | 445/24 |
| 6,017,584 | 1/25/00 | Albert et al. | 427/213.3 |
| 6,013,538 | 1/11/00 | Burrows et al. | 438/22 |
| 6,002,198 | 12/14/99 | Spindt et al. | 313/292 |
| 5,990,620 | 11/23/99 | Lepselter | 313/585 |
| 5,990,614 | 11/23/99 | Spindt | 313/495 |
| 5,986,409 | 11/16/99 | Farnworth et al. | 315/169.4 |
| 5,985,460 | 11/16/99 | Wang et al. | 428/426 |
| 5,984,747 | 11/16/99 | Bhagavatula et al. | 445/24 |
| 5,975,683 | 11/2/99 | Smith, et al. | 347/55 |
| 5,969,472 | 10/19/99 | Kisner | 313/484 |
| 5,967,871 | 10/19/99 | Kaake, et al. | 445/24 |
| 5,965,109 | 10/12/99 | Lohrmann | 424/9.52 |

# UNITED STATES PATENT AND TRADEMARK OFFICE
# CERTIFICATE OF CORRECTION

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It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

UNDER REFERENCES CITED (56) - U.S. Patent Documents (cont'd):

| | | | |
|---|---|---|---|
| 5,964,630 | 10/12/99 | Slusarczuk et al. | 445/25 |
| 5,953,587 | 9/14/99 | Forrest et al. | 438/99 |
| 5,949,513 | 9/7/99 | Ma, et al. | 349/187 |
| 5,945,174 | 8/31/99 | Shaw et al. | 427/509 |
| 5,920,080 | 7/6/99 | Jones | 257/40 |
| 5,917,646 | 6/29/99 | Sheridon | 359/296 |
| 5,914,150 | 6/22/66 | Porter et al. | 427/77 |
| 5,913,704 | 6/22/99 | Spindt et al. | 445/24 |
| 5,898,266 | 4/27/99 | Spindt et al. | 313/495 |
| 5,897,414 | 4/27/99 | Bergeron et al. | 445/3 |
| 5,865,657 | 2/2/99 | Haven et al. | 445/24 |
| 5,862,054 | 1/19/99 | Li | 364/468.28 |
| 5,853,446 | 12/29/98 | Carre, et al. | 65/17.3 |
| 5,844,363 | 12/1/98 | Gu et al. | 313/506 |
| 5,837,221 | 11/17/98 | Bernstein, et al. | 424/9.52 |
| 5,825,451 | 10/20/98 | Ma, et al. | 349/187 |
| 5,815,306 | 9/29/98 | Sheridon et al. | 359/296 |
| 5,811,833 | 9/22/98 | Thompson | 257/40 |
| 5,798,604 | 8/25/98 | Duboc, Jr., et al. | 313/495 |
| 5,793,158 | 8/11/98 | Wedding, Sr. | 313/493 |
| 5,788,814 | 8/4/98 | Sun, et al. | 204/297R |
| 5,777,782 | 7/7/98 | Sheridon | 359/296 |
| 5,757,139 | 5/26/98 | Forrest et al. | 315/169.3 |
| 5,757,131 | 5/26/98 | Tsuchiya | 375/582 |
| 5,757,026 | 5/26/98 | Forrest et al. | 257/40 |
| 5,755,944 | 5/26/98 | Haven et al. | 204/486 |
| 5,747,931 | 5/5/98 | Riddle et al. | 313/581 |
| 5,746,635 | 5/5/98 | Spindt et al. | 445/24 |
| 5,725,787 | 3/10/98 | Curtin et al. | 216/25 |
| 5,721,160 | 2/24/98 | Forrest et al. | 438/28 |
| 5,707,745 | 1/13/98 | Forrest et al. | 428/432 |
| 5,703,436 | 12/30/97 | Forrest et al. | 313/506 |
| 5,686,790 | 11/11/790 | Curtin et al. | 313/493 |
| 5,675,212 | 10/7/97 | Schmid et al. | 313/422 |
| 5,674,351 | 10/7/97 | Lovoi | 156/629.1 |
| 5,514,934 | 5/7/96 | Matsumoto et al. | 313/607 |
| 5,510,678 | 4/23/96 | Sakai, et al. | 315/58 |
| 5,501,871 | 3/26/96 | Henderson | 427/160 |

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO. : 10/303926
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UNDER REFERENCES CITED (56) - U.S. Patent Documents (cont'd):

| | | | |
|---|---|---|---|
| 5,500,287 | 3/19/96 | Henderson | 428/403 |
| 5,396,149 | 3/7/95 | Kwon | 313/486 |
| 5,315,129 | 5/24/94 | Forrest et al. | 257/21 |
| 5,150,007 | 9/22/92 | Andreadakis | 313/586 |
| 5,126,632 | 6/30/92 | Parker | 313/634 |
| 5,075,597 | 12/24/91 | Deschamps, et al. | 315/169.4 |
| 5,068,916 | 11/26/91 | Harrison et al. | 455/39 |
| 5,062,916 | 11/5/91 | Aufderheide et al. | 156/269 |
| 5,030,888 | 7/9/91 | Salavin, et al. | 315/169.4 |
| 5,019,807 | 5/28/91 | Stapleton, et al. | 340/718 |
| 4,912,364 | 3/27/90 | Holló et al. | 313/623 |
| 4,887,003 | 12/12/89 | Parker | 313/634 |
| 4,843,281 | 6/27/89 | Mendelsohn | 313/587 |
| 4,833,463 | 5/23/89 | Dick, et al. | 340/775 |
| 4,728,864 | 3/1/98 | Dick | 315/169.3 |
| 4,697,123 | 9/29/87 | Shinoda, et al. | 315/169.4 |
| 4,658,269 | 4/14/87 | Rezanka | 346/75 |
| 4,654,561 | 3/31/87 | Shelton | 315/111.71 |
| 4,591,847 | 5/27/86 | Criscimagna, et al. | 340/776 |
| 4,563,617 | 1/7/86 | Davidson | 315/312 |
| 4,554,537 | 11/19/85 | Dick | 340/775 |
| 4,534,743 | 8/13/85 | D'Onofrio, et al. | 445/24 |
| 4,429,303 | 1/31/84 | Aboelfotoh | 340/701 |
| 4,393,326 | 7/12/83 | Kamegaya, et al. | 313/582 |
| 4,386,358 | 5/31/83 | Fischbeck | 346/1.1 |
| 4,379,301 | 4/5/83 | Fischbeck | 346/1.1 |
| 4,303,433 | 12/1/81 | Torobin | 65/21.4 |
| 4,035,690 | 7/12/77 | Roeber | 315/169 TV |
| 4,027,246 | 5/31/77 | Caccoma, et al. | 235/151.1 |
| 3,998,618 | 12/21/76 | Kreick et al. | 65/105 |
| 3,990,068 | 11/2/76 | Mayer, et al. | 340/324M |
| 3,969,651 | 7/13/76 | Greeson, Jr. | 315/169 TV |
| 3,848,248 | 11/12/74 | MacIntyre, Jr. | 340/324 M |
| 3,755,027 | 8/28/73 | Gilsing | 156/67 |
| 3,704,052 | 11/28/72 | Coleman | 316/17 |
| 3,646,384 | 2/29/72 | Lay | 313/109.5 |
| 3,559,190 | 1/26/71 | Blitzer et al. | 340/173 |

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,791,264 B2 
APPLICATION NO. : 10/303926
DATED : September 14, 2004
INVENTOR(S) : Albert Myron Green et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:
UNDER REFERENCES CITED (56) - Foreign Patent Documents -

Please add:

| | | | |
|---|---|---|---|
| JP 10-3869 | 1/6/98 | Canon, Inc. | H01J/31/12 |
| JP 4-287397 | 10/12/92 | NEC Corp. | H05K/9/00 |

On the Title Page:
UNDER REFERENCES CITED (56) - Other Publications -

Please add:

Written Opinion for Application No. PCT/US01/42782, dated December 31, 2002 (mailing date)

International Search Report for Application No. PCT/US01/42807, dated December 8, 2002 (mailing date)

International Search Report for Application No. PCT/US01/51439, dated September 23, 2002 (mailing date)

Written Opinion for Application No. PCT/US01/42807, dated September 17, 2002 (mailing date)

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date)

International Search Report for Application No. PCT/US01/42782, dated April 11, 2002 (mailing date)

Sheats, James, “Introduction to Organic Light-Emitting Diodes (OLEDs)” [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm

Sauvante, Michael, “Roll-to-Roll Manufacturing” [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm

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It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

UNDER REFERENCES CITED (56) - Other Publications - (cont'd):

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on March 13, 2002], 8 pp., Retrieved from the Internet: http://www-star.stanford.edu/~vlf/plasma_display/index.htm

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose, Washington, DC, 8 pp., April 21-25, 2001

Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," Journal of Microelectromechanical Systems, Vol. 10, No. 1, March, 2001, pp. 17-17-24

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," The American Physical Society, Vol. 62, No. 7, 5 pp., August 15, 2000

"Rolltronics" [online], February 20, 2000 [retrieved on March 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 1 p., Retrieved from the Internet: http://www.lge.com

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp

"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21

# UNITED STATES PATENT AND TRADEMARK OFFICE
# CERTIFICATE OF CORRECTION

PATENT NO. : 6,791,264 B2
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It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

UNDER REFERENCES CITED (56) - Other Publications - (cont'd):

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=

"LG Electronics – To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on 11/7/2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=l3&type=&word

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on 1/17/2002], 2 pp., Retrieved from the Internet: http://www.runco.com/ Products/Plasma/Default.htm

"Runco PlasmaWall PL-42cx" [online], Copyright 2001 [retrieved on 1/17/2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm

"Runco PlasmaWall P1-50c" [online], Copyright 2001 [retrieved on 1/17/2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm

"Runco PlasmaWall™ PL-61cx" [online], Copyright 2001 [retrieved on 1/17/2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm

Alien Technology Corporation's Technology Overview; copyright Ó 2000, Alien TechnologyÔ; http://www.alientechnology.com/d/technology/overview.html

Anonymous, Alien Technology Corporation White Paper – Fluidic Self Assembly, Alien Technology Corp., October 1999, pp. 1-7.

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,791,264 B2
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It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

UNDER REFERENCES CITED (56) - Other Publications - (cont'd):

Shin, Y. K., Lee, J. K., Shon, C. H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," IEEE Transactions on Plasma Science, Vol. 27, No. 1, February, 1999, pp. 14-15

Raulf, S., Kushner, M. J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell," IEEE Transactions on Plasma Science, Vol. 27, No. 1, February 1999, pp. 10-11

Kurihara, M., Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency," IEEE Transactions on Plasma Science, Vol. 27, No. 5, October, 1999, pp. 1372-1378

Peterson, "Rethinking Ink" [online], Science News, Vol. 153, No. 25, June 20, 1998 [retrieved on December 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm

"Transparent Conductive Coatings," Copyright 1998, 4 pp.

Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," IEEE Photonics Technology Letters, Vol. 9, No. 9, September, 1997, pp. 1241-

Jacobson, et al., "The Last Book" [online], IBM Systems Journal, Vol. 36, No. 3, 1997 [retrieved on December 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996

"Flat Panel Displays In Perspective," 44 pp., September, 1995

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,791,264 B2 
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It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

UNDER REFERENCES CITED (56) - Other Publications - (cont'd):

Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on December 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm

Signed and Sealed this

Thirtieth Day of October, 2007

Jon W. Dudas

JON W. DUDAS
*Director of the United States Patent and Trademark Office*

US006796867B2

# (12) United States Patent
George et al.

(10) Patent No.: US 6,796,867 B2
(45) Date of Patent: Sep. 28, 2004

(54) USE OF PRINTING AND OTHER TECHNOLOGY FOR MICRO-COMPONENT PLACEMENT

(75) Inventors: **E. Victor George**, Temecula, CA (US); **Albert M. Green**, Springfield, VA (US); **N. Convers Wyeth**, Oakton, VA (US)

(73) Assignee: **Science Applications International Corporation**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 78 days.

(21) Appl. No.: **10/214,769**

(22) Filed: **Aug. 9, 2002**

(65) **Prior Publication Data**

US 2003/0207645 A1 Nov. 6, 2003

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**[7] .................................................. **H01J 9/24**
(52) **U.S. Cl.** ........................................................ **445/24**
(58) **Field of Search** .............................. 445/24, 25, 22

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 A | | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | * | 11/1974 | MacIntyre, Jr. | 345/60 |
| 3,969,651 A | | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 A | | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | * | 7/1977 | Roeber | 345/41 |
| 4,303,433 A | | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 A | | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 A | | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | | 1/1984 | Aboelfotoh | 340/701 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

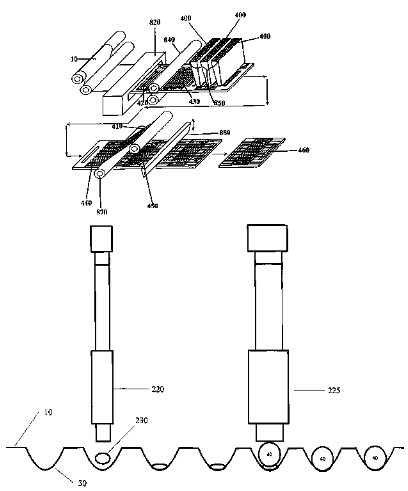
(List continued on next page.)

*Primary Examiner*—Kenneth J. Ramsey
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous inline process.

**13 Claims, 26 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 4,534,743 | A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | * | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | * | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/952 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | * | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/952 |
| 5,967,871 | A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | * | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | | 11/2001 | Sasaki et al. | 239/568 |
| 6,570,335 | B1 | * | 5/2003 | George et al. | 315/169.3 |
| 6,612,889 | B1 | * | 9/2003 | Green et al. | 445/24 |
| 6,620,012 | B1 | * | 9/2003 | Johnson et al. | 445/3 |
| 2001/0008825 | A1 | | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | | 2/2002 | Miyashita et al. | 313/495 |
| 2003/0094891 | A1 | * | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1 | * | 9/2003 | Green et al. | 313/582 |

## OTHER PUBLICATIONS

Sheats, James, "Introduction to Organic Light–Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll–to–Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp. Retrieved from the Internet: http://www.star.stanford.edu/~vlt/plasma_display/index.htm.

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21–25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self–Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar. 2001, pp. 17–17–24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], L.G Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.Igeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplaycom/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay com/eng/news/e_read.asp?n.SeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco PlasmaWall PL–42ex" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42ex.htm.

"Runco PlasmaWall PL–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco PlasmaWall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Alien Technology Corporation's Technology Overview: copyright ©2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Coproration White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb., 1999, pp. 14–15.

Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Kurihara, M., Makabe, T., "Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372–1378.

Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/$6_{13}$ 20_98/bob2.htm.

"Transparent Conductive Coatings," Copyright 1998. 4 pp.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep., 1997, p. 1241.

Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.

"Flat Panel Displays in Perspective," 44 pp., Sep., 1995.

Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

International Search Report for Application No. PCT US01/42805, dated Apr. 3, 2003 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.

* cited by examiner

Fig. 1

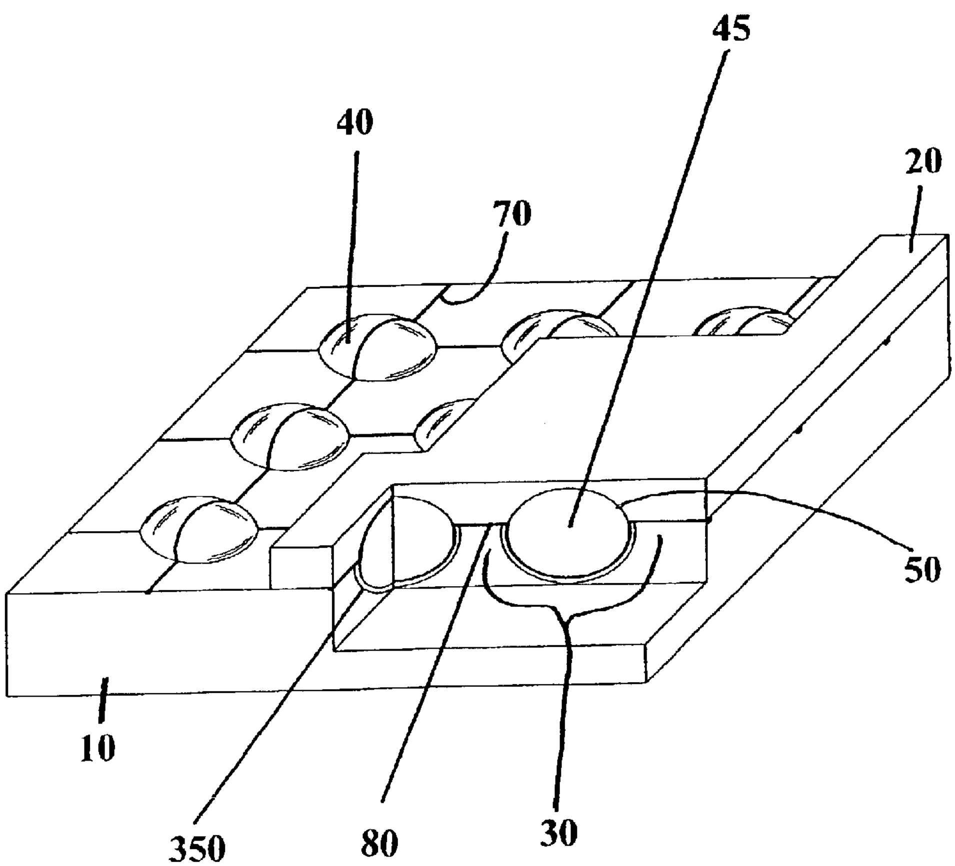
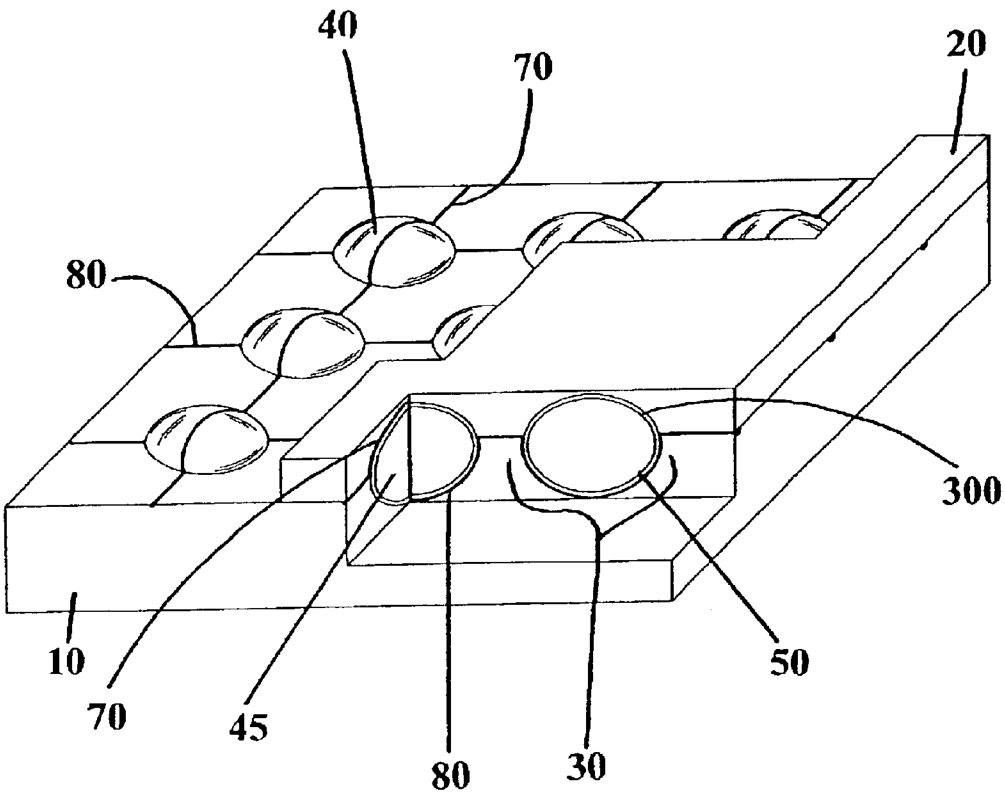


Fig. 2



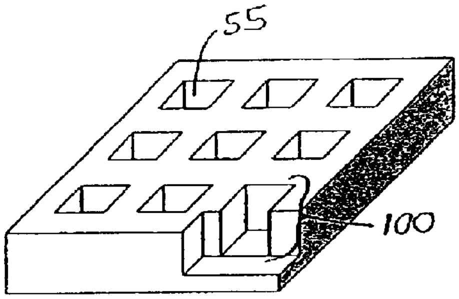



Fig. 3A

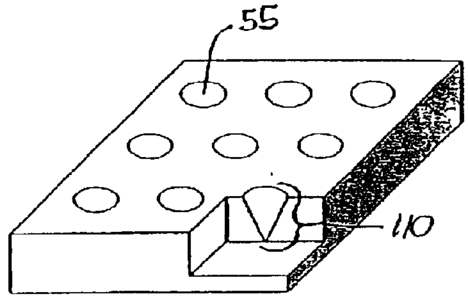



Fig. 3B

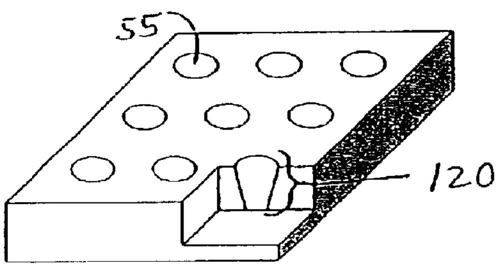



Fig. 3C

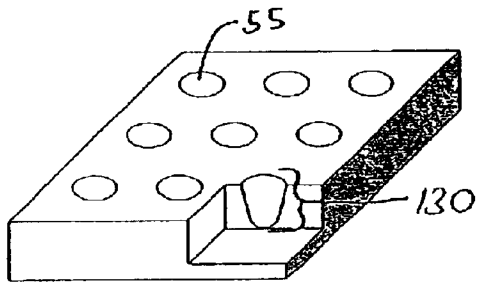



Fig 3D

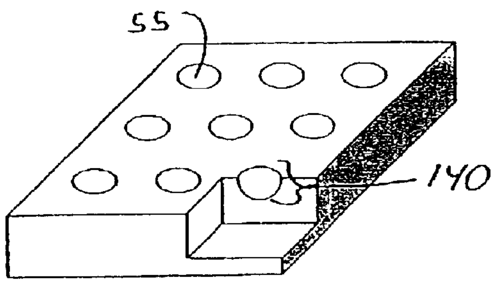



Fig 3E

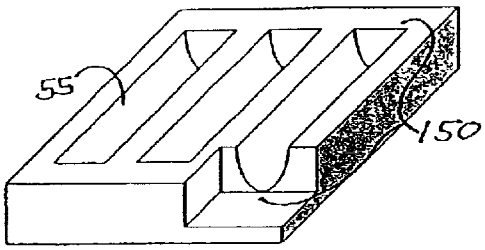



Fig. 3F

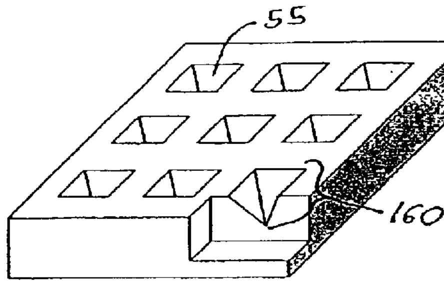



Fig. 3G

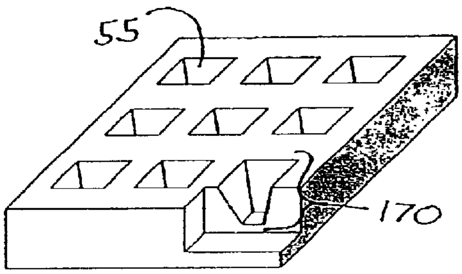



Fig. 3H

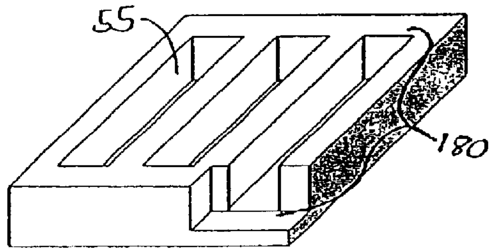



Fig. 3I

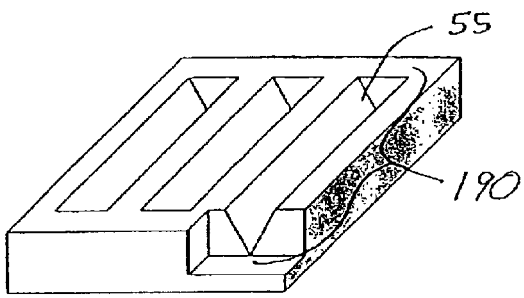



Fig. 3J

Fig. 4

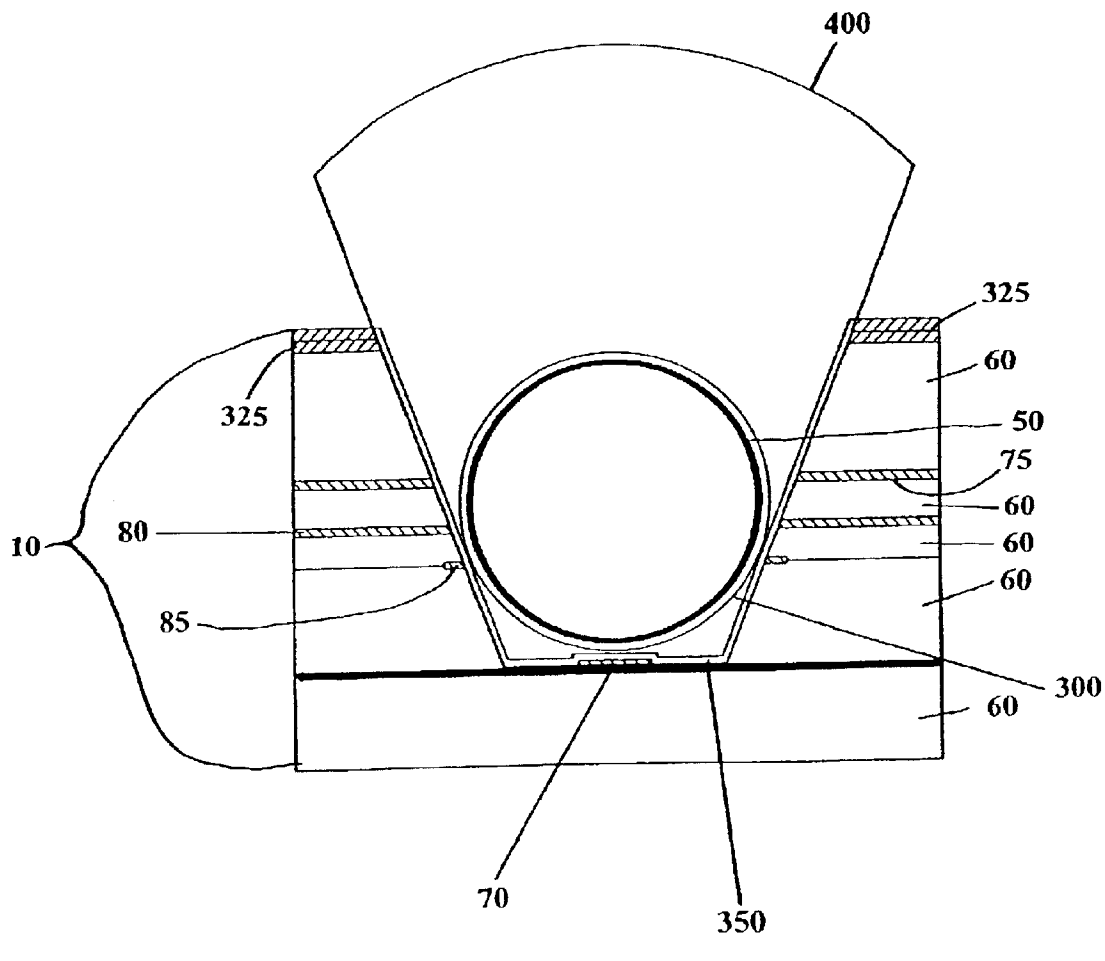


Fig. 5

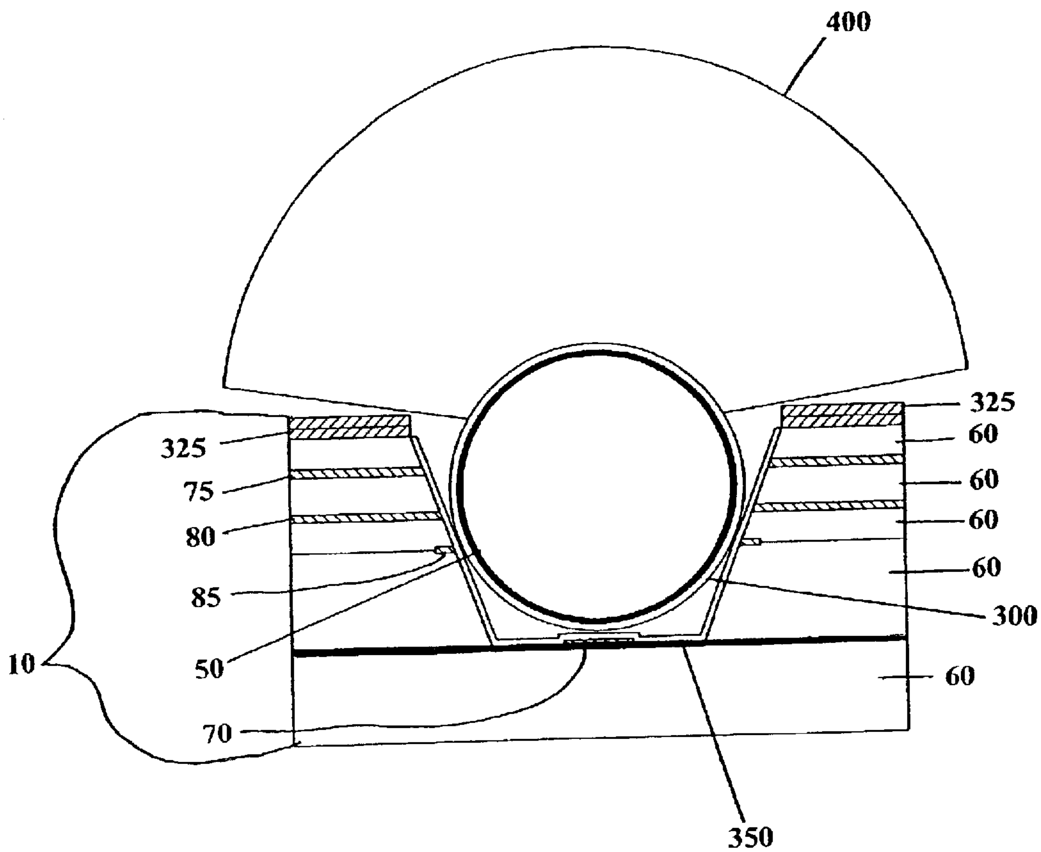


Fig. 6A

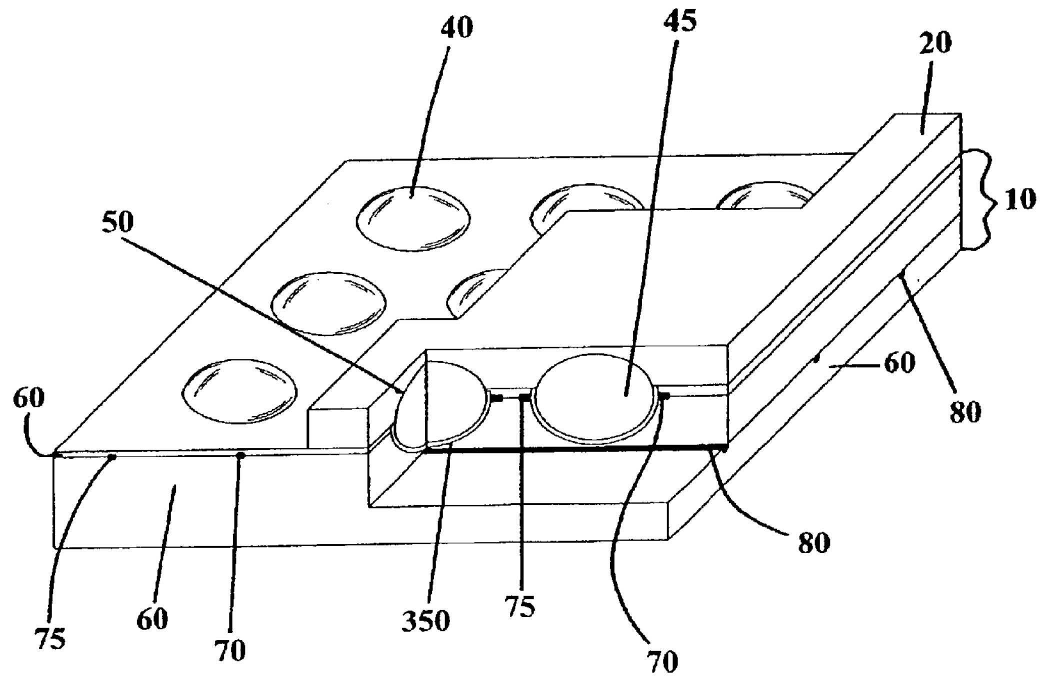


Fig. 6B

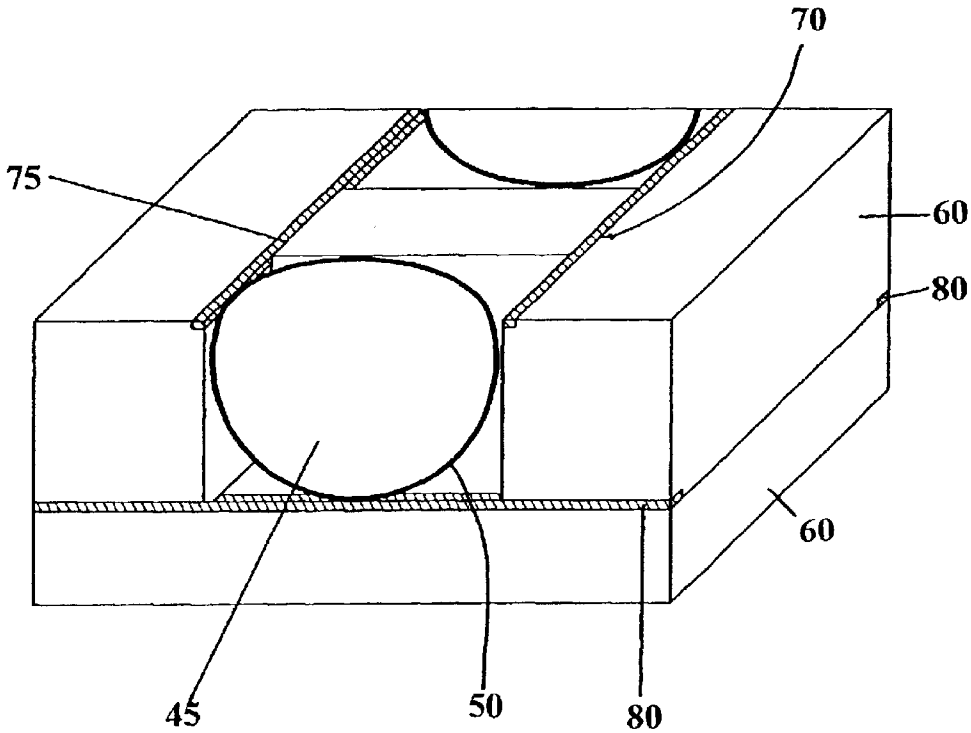


Fig. 7A

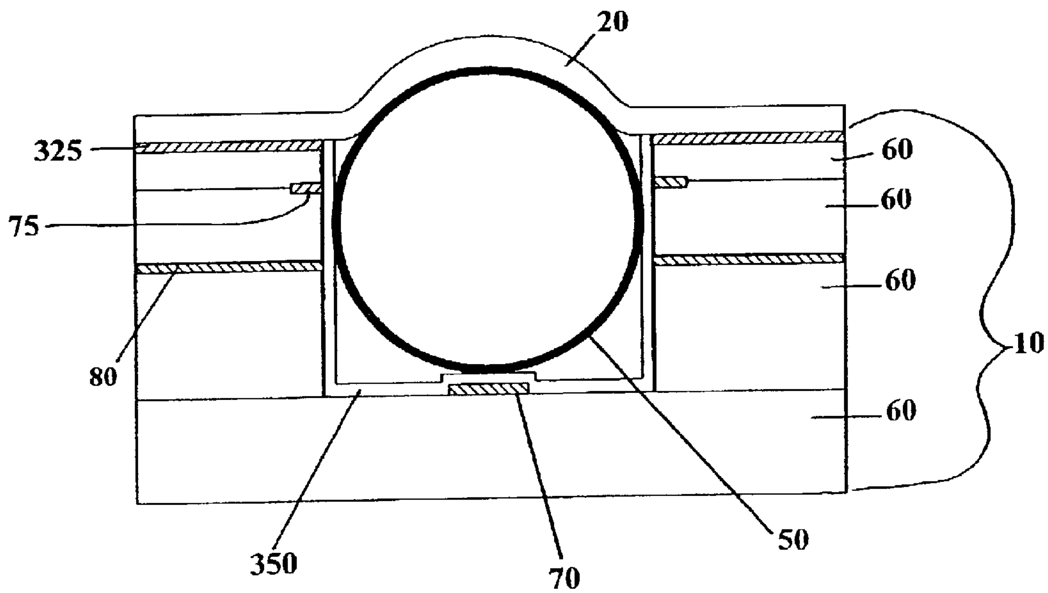


Fig. 7B

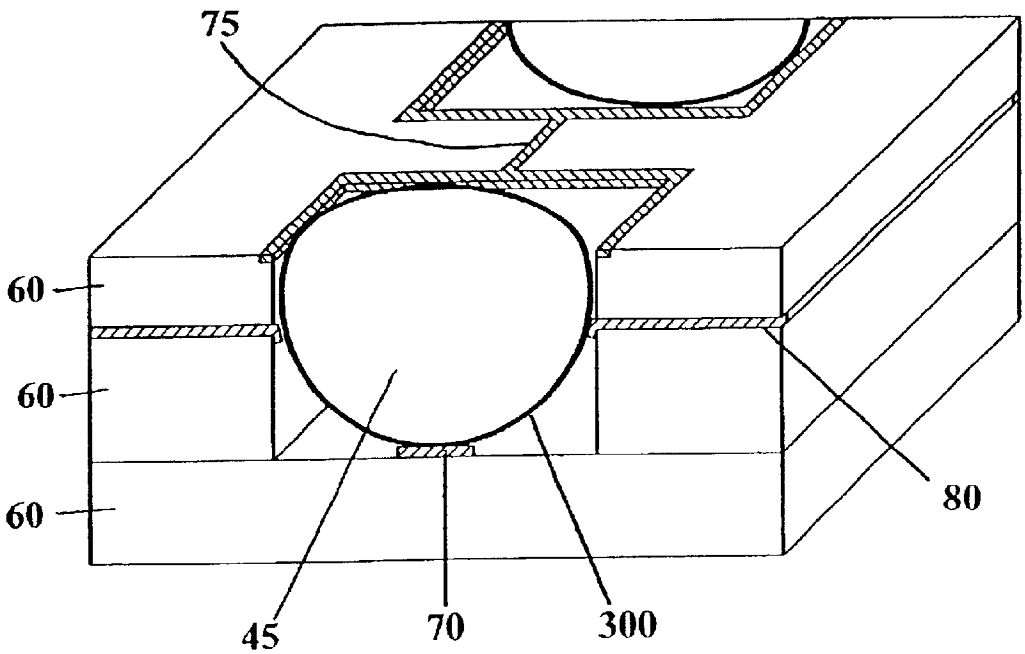


Fig. 8

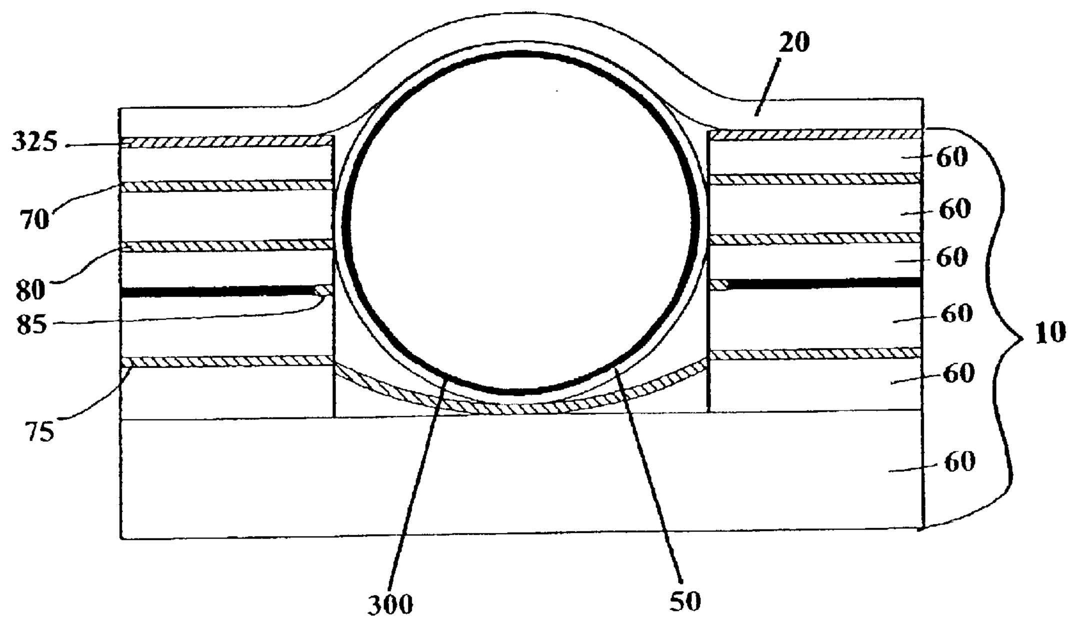


Fig. 9

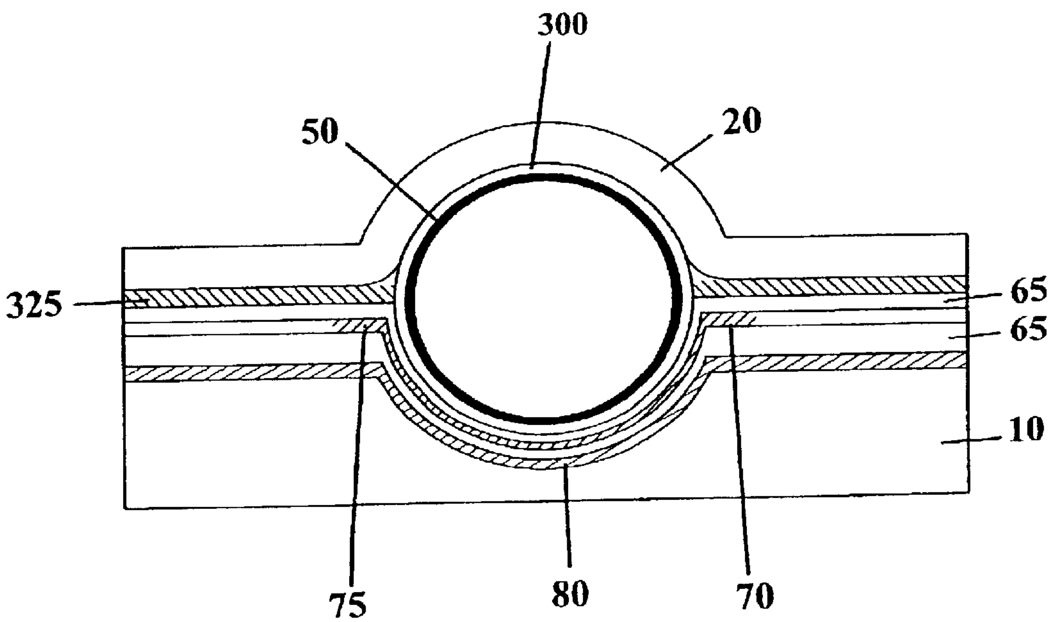


Fig. 10

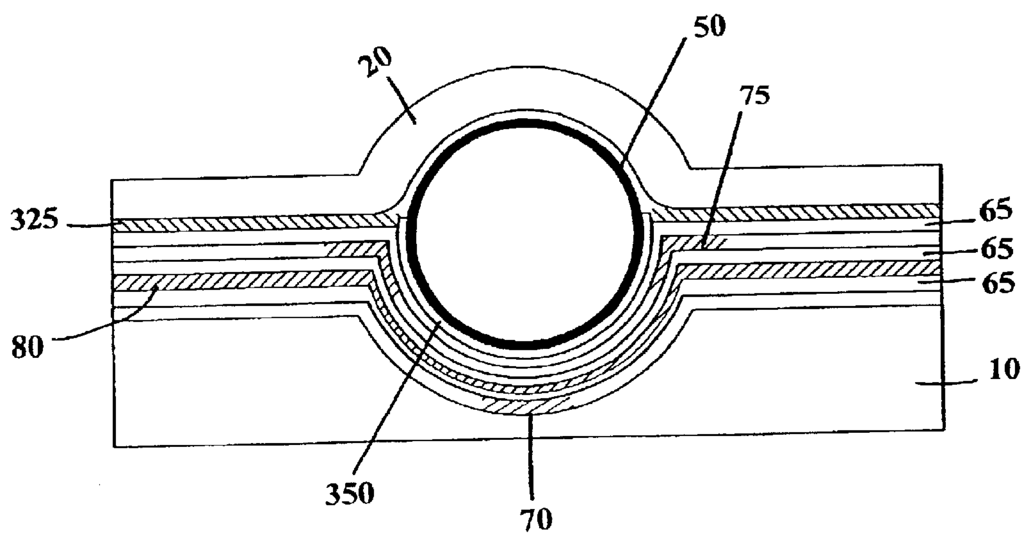
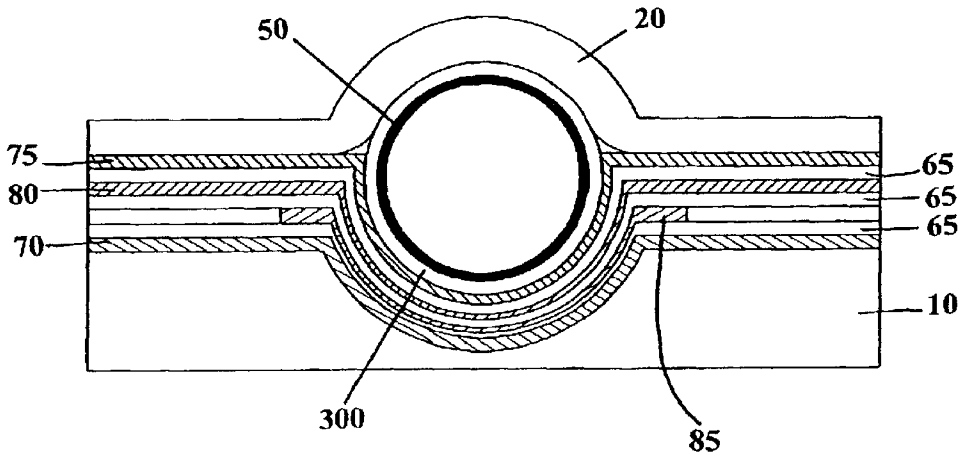


Fig. 11



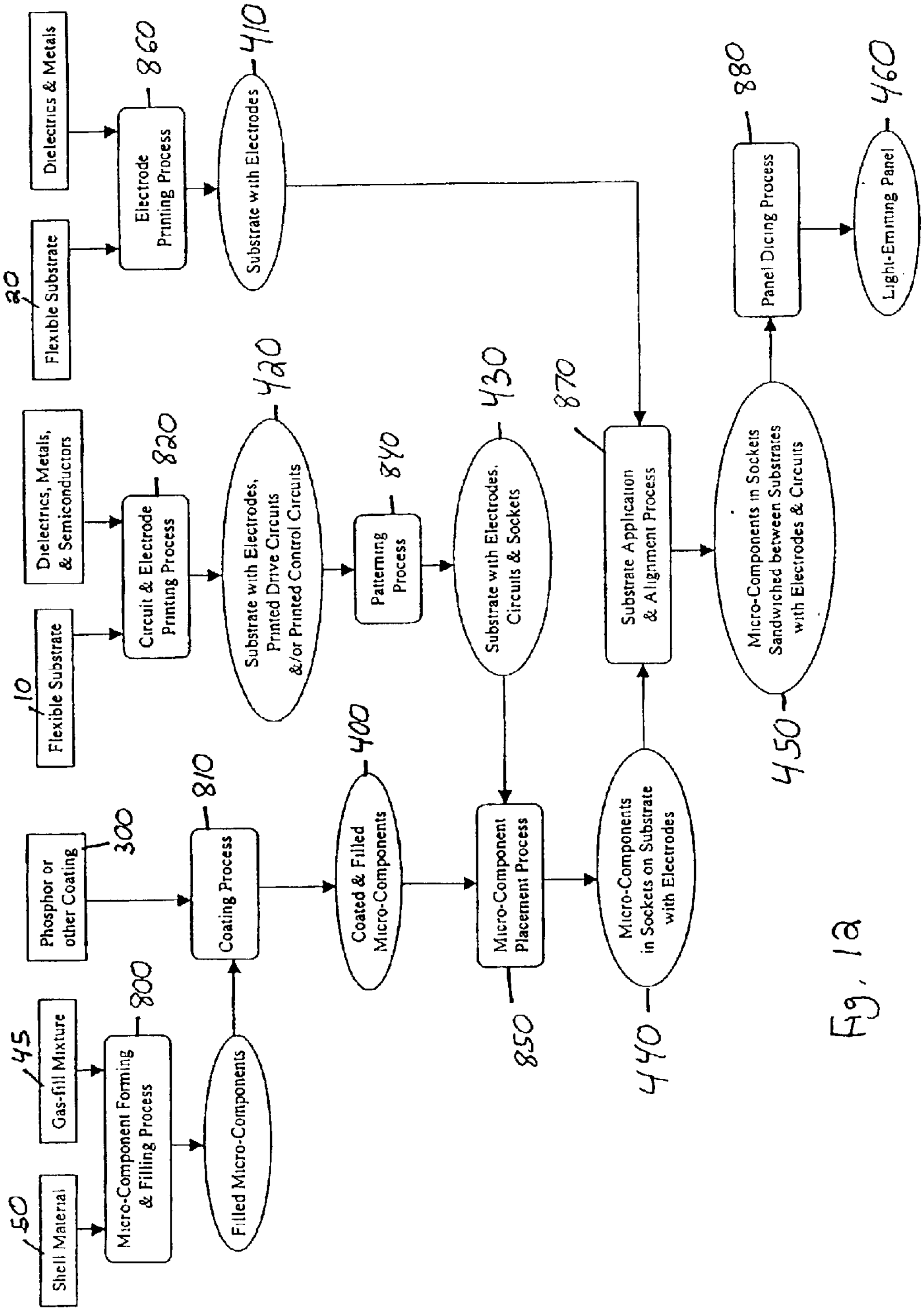
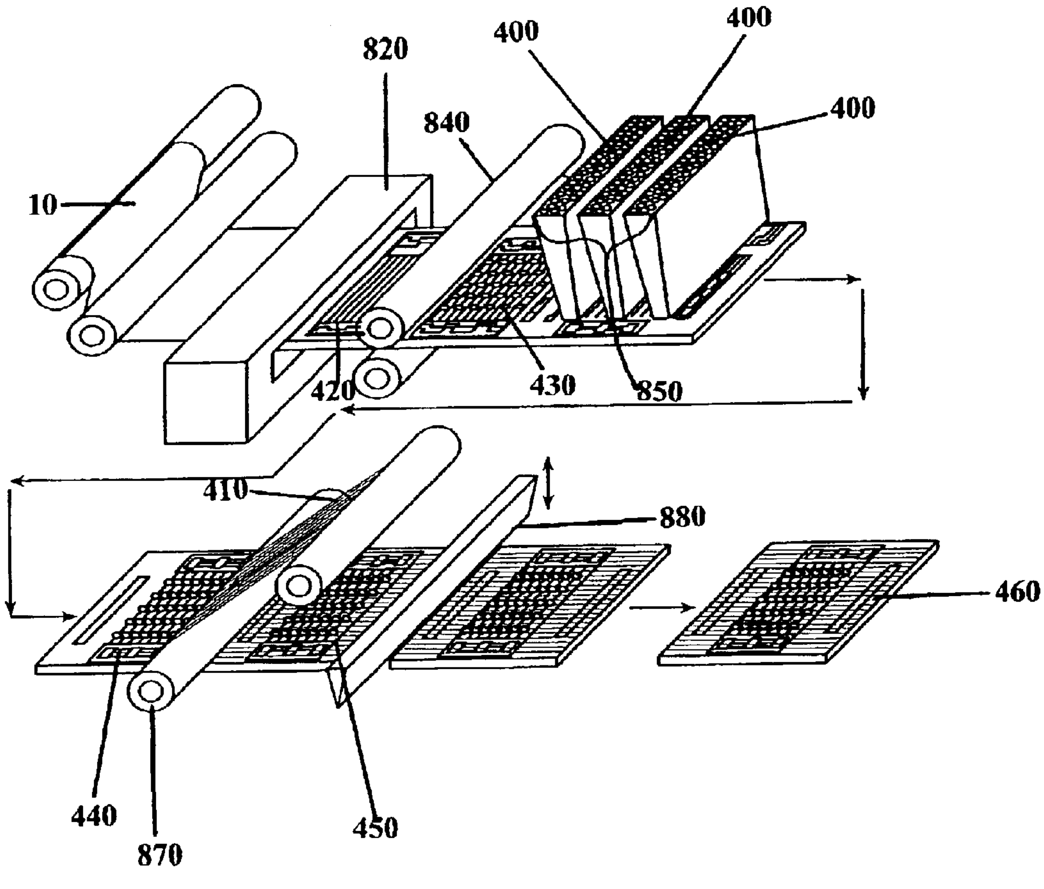

Shell Material
50
Gas-fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits &/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched between Substrates with Electrodes & Circuits
450
Panel Dicing Process
880
Light-Emitting Panel
460

Fig. 1a

Fig. 13



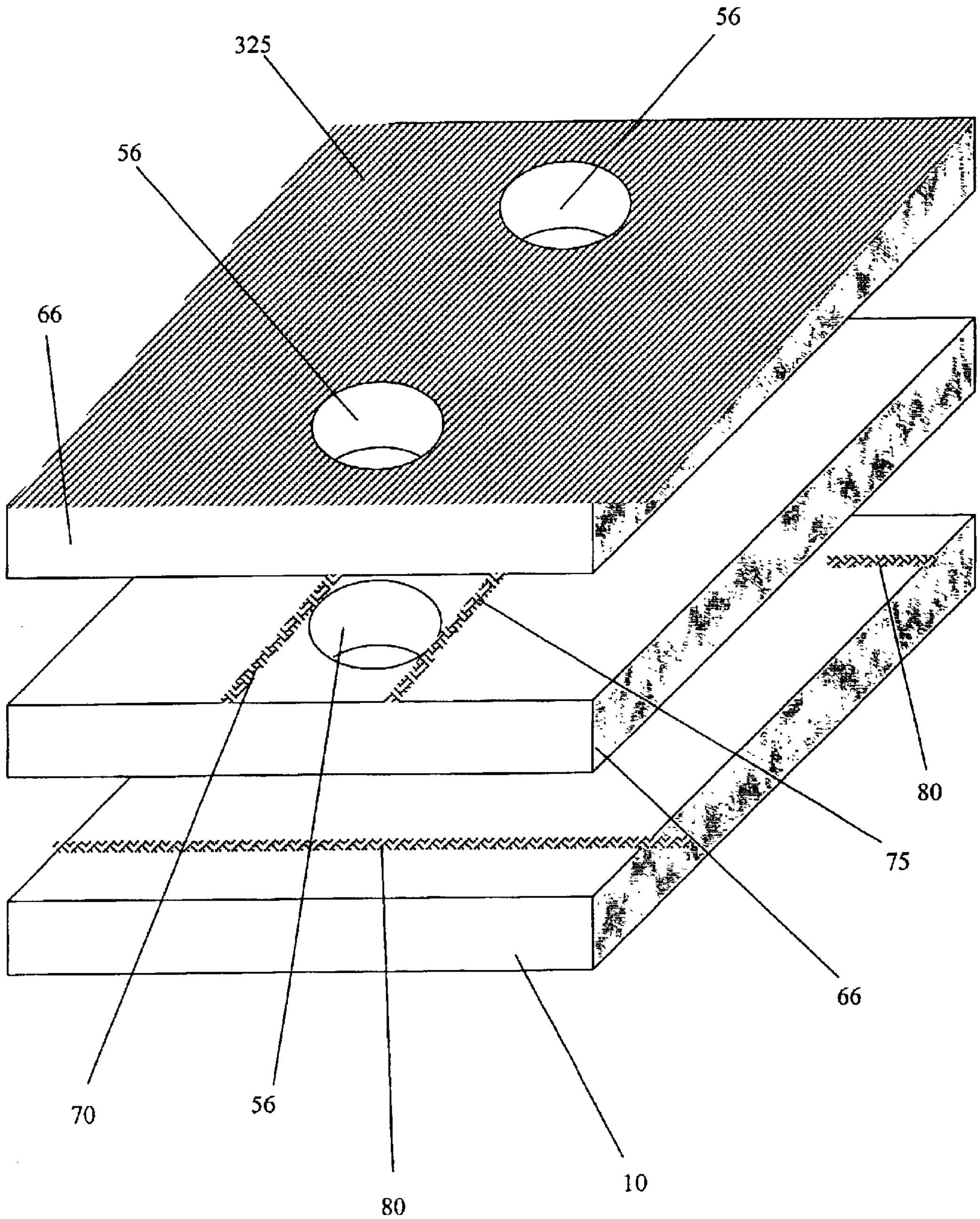



Fig. 14

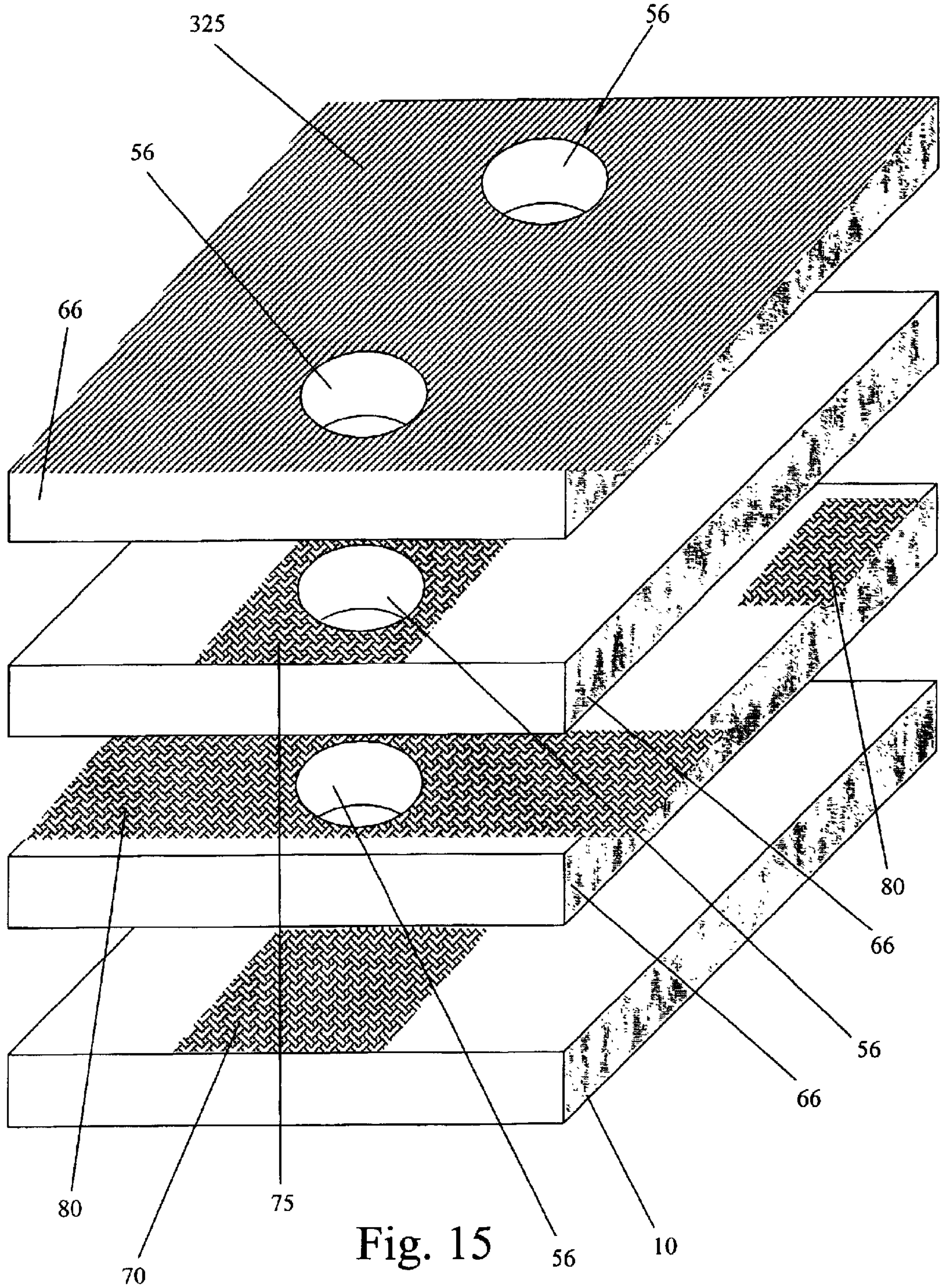



Fig. 15

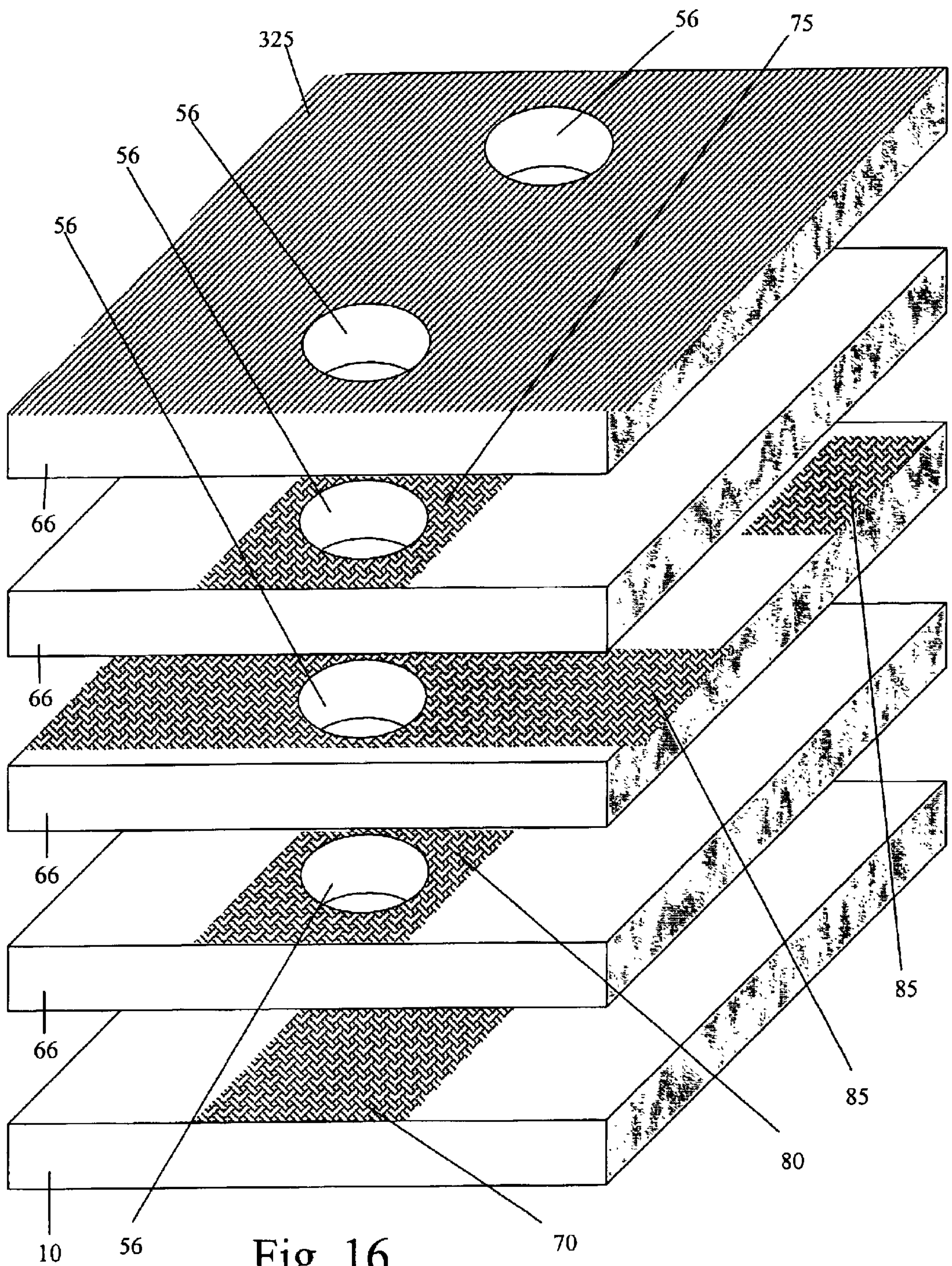



Fig. 16

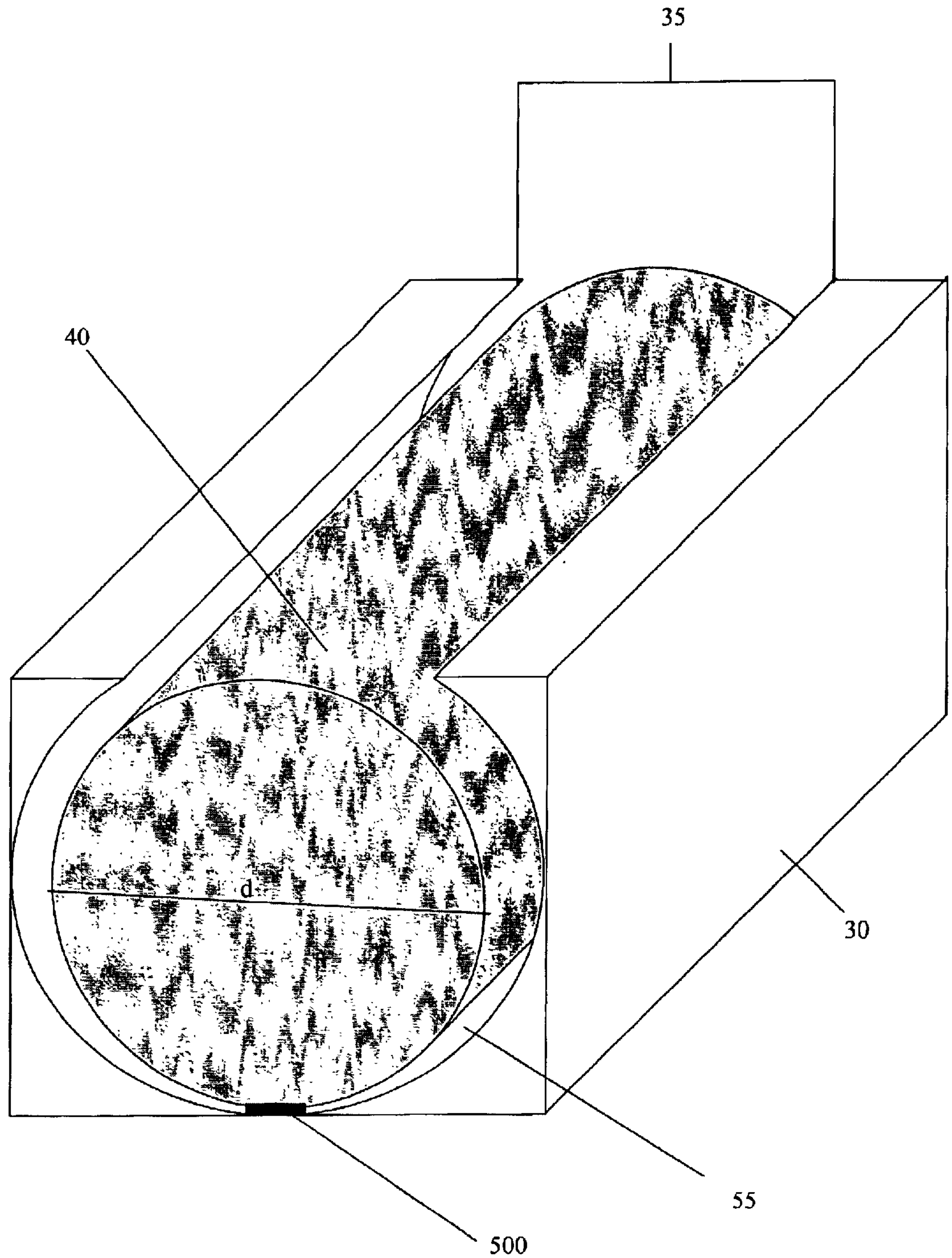



FIG. 17

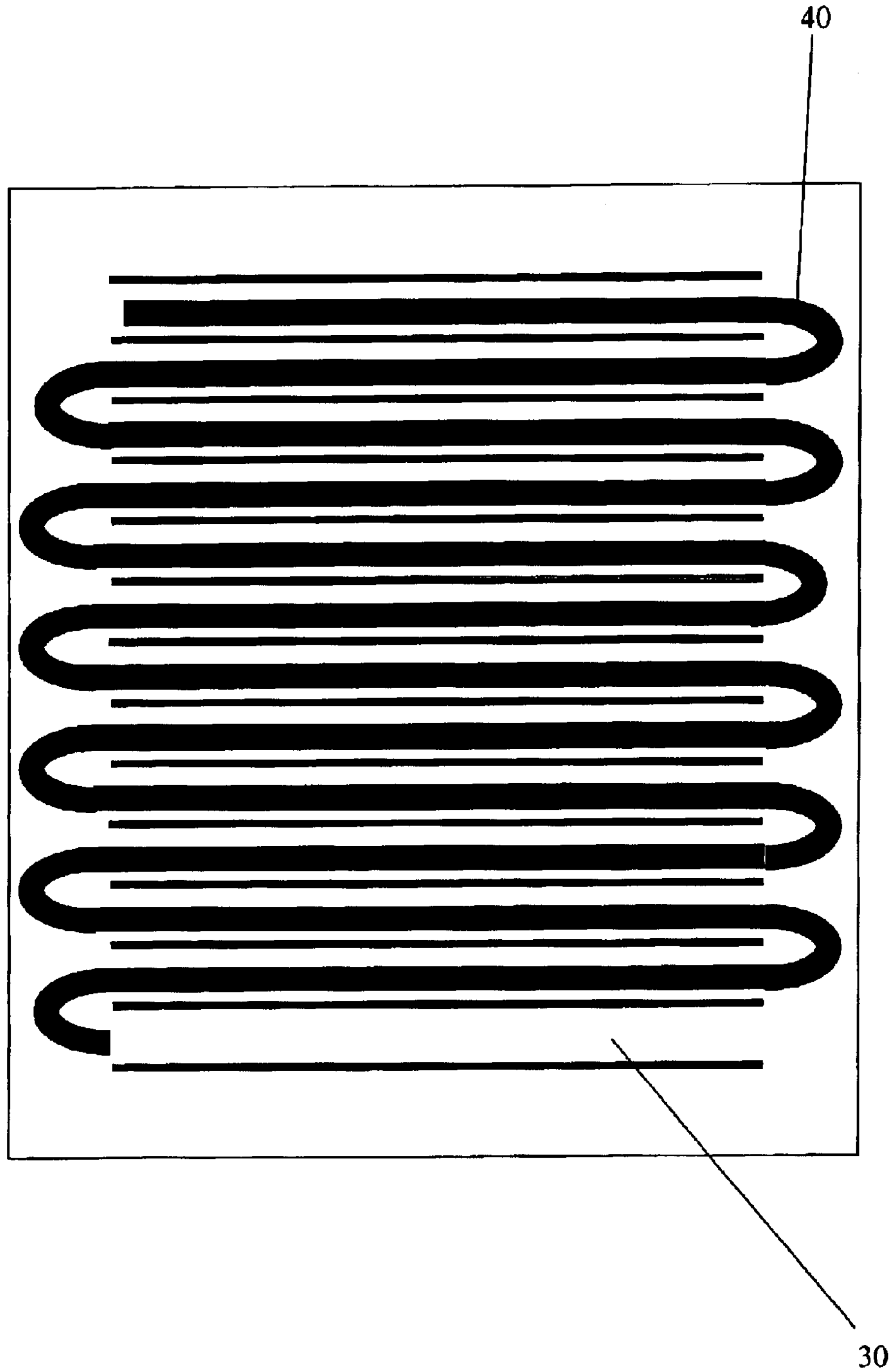



FIG. 18

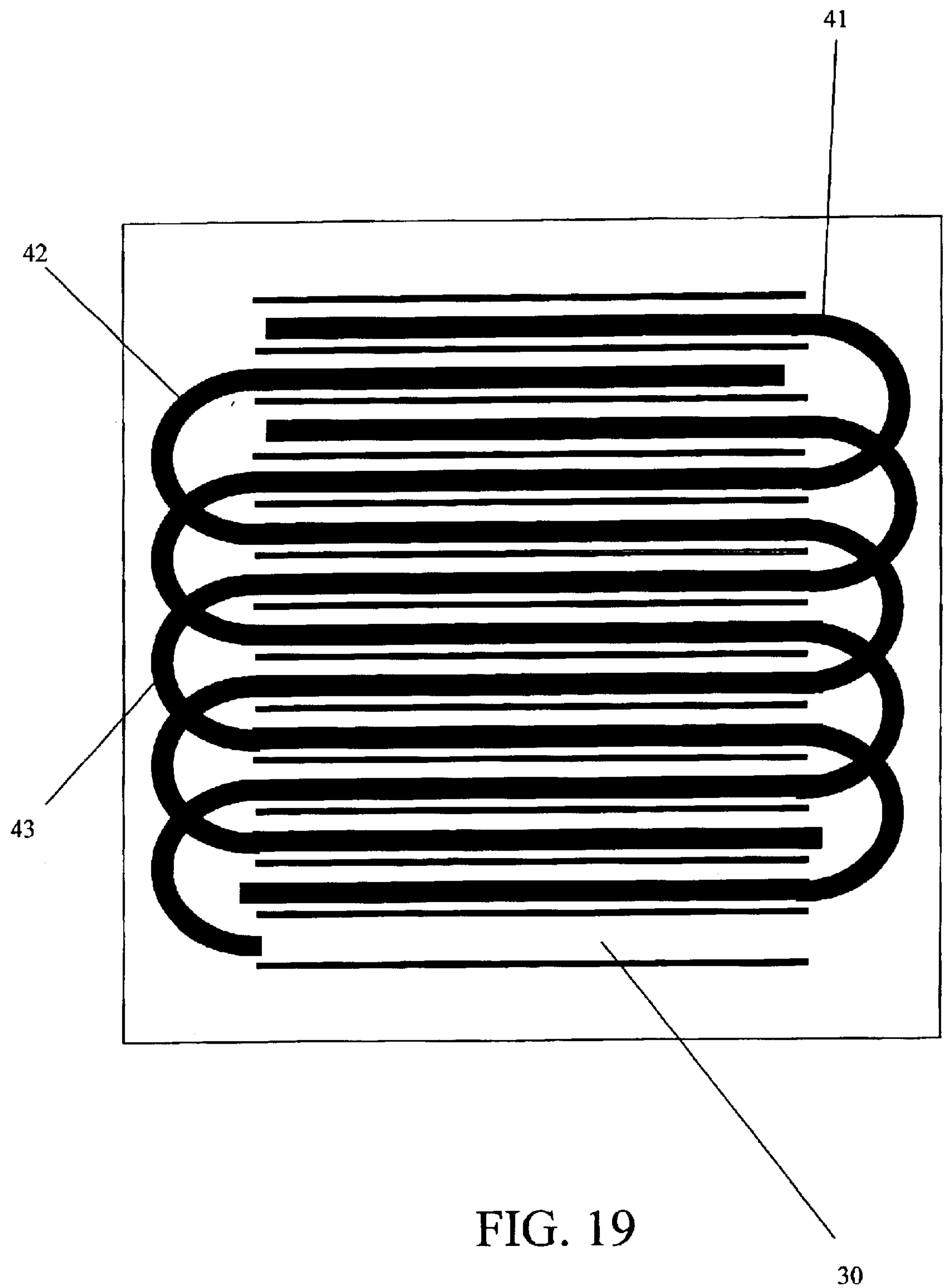



FIG. 19

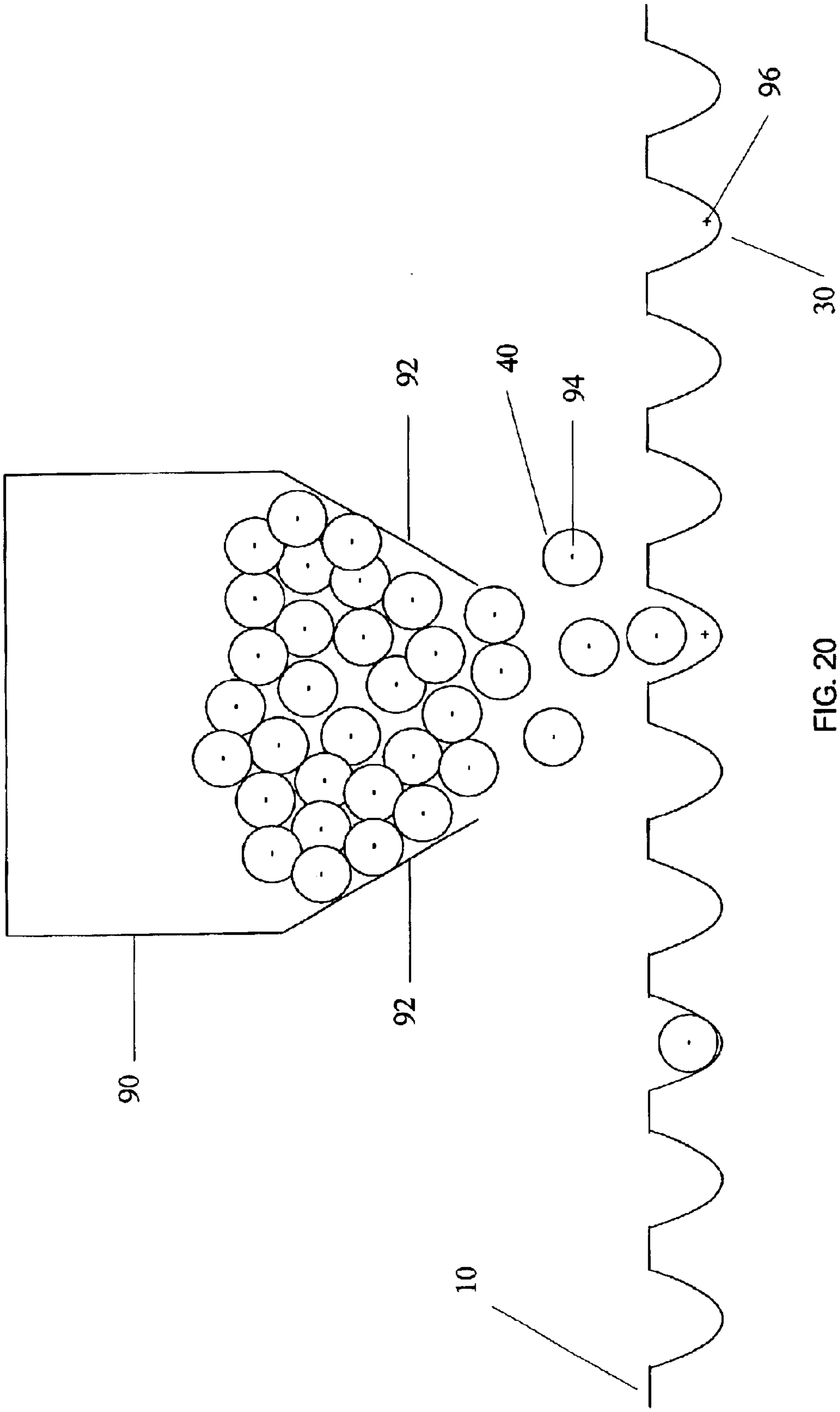



FIG. 20

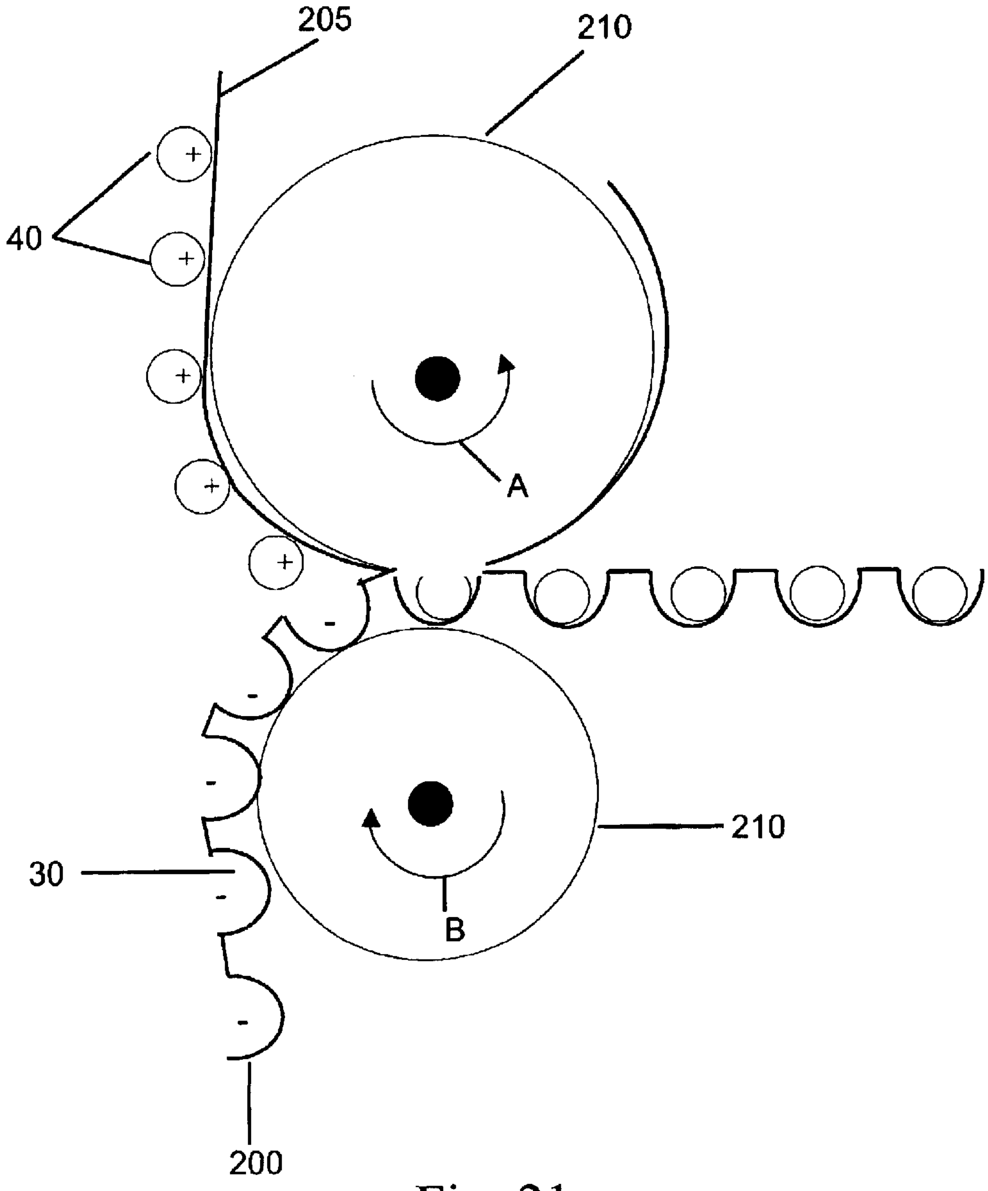



Fig. 21

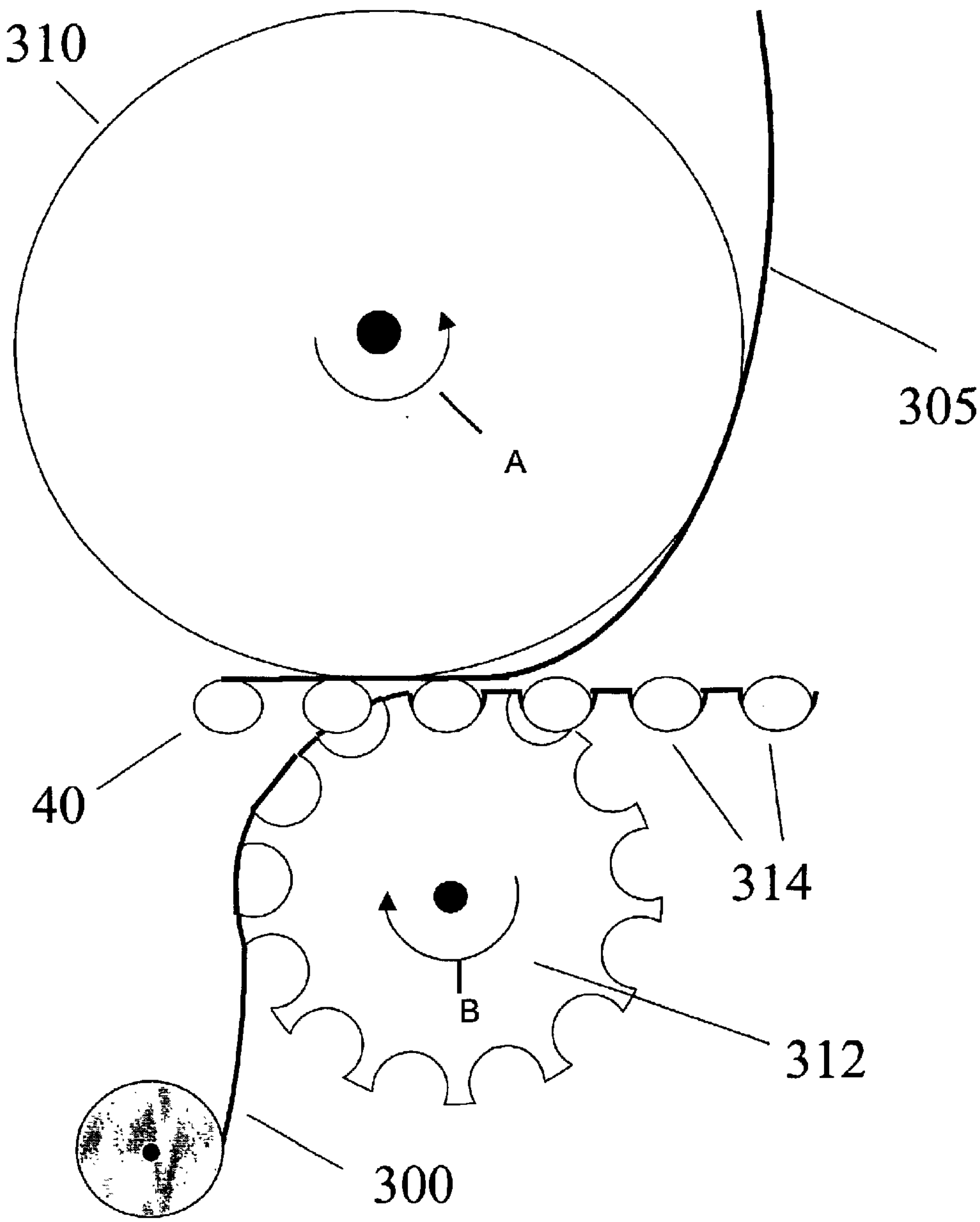



Fig. 22

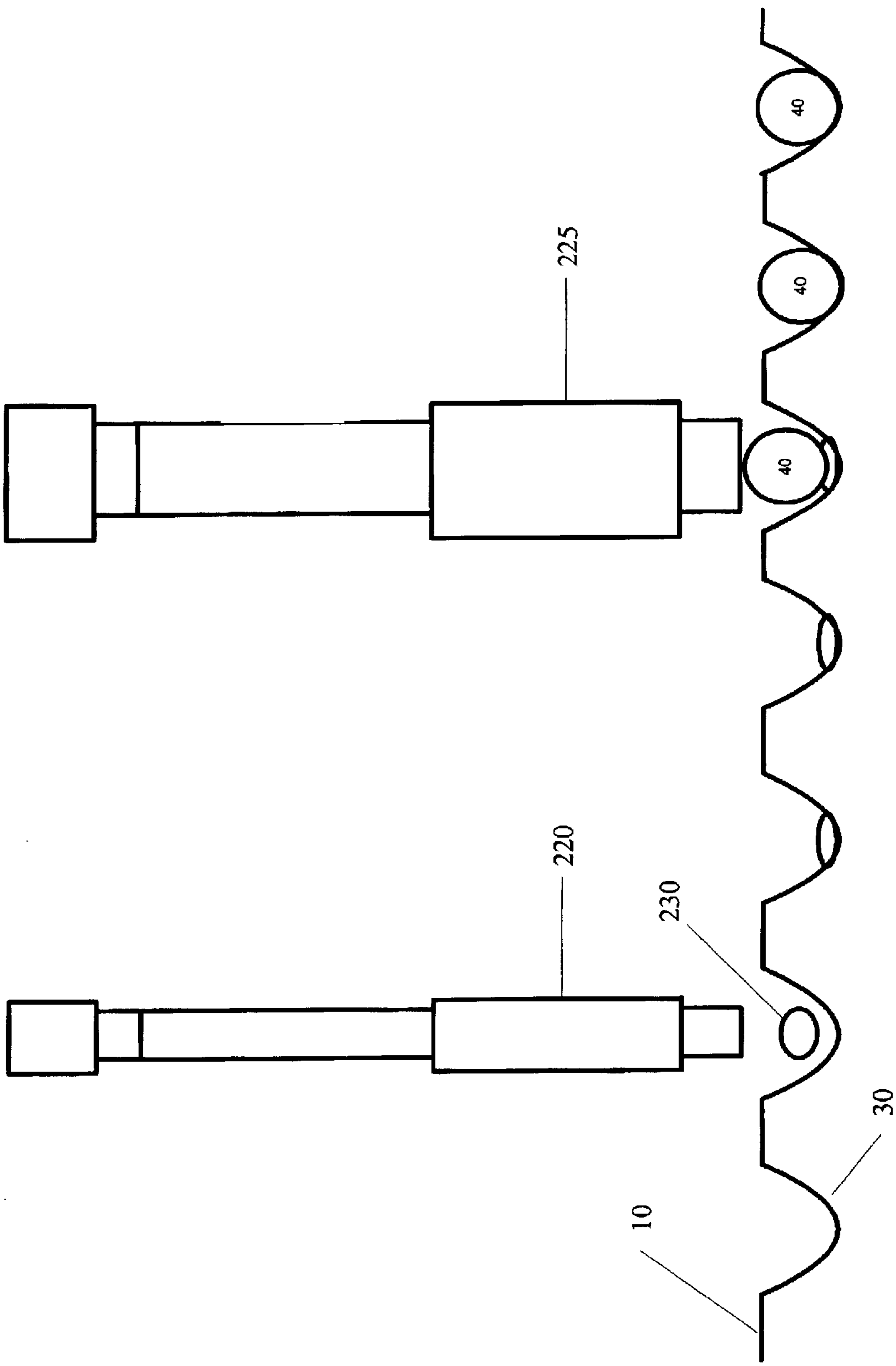



FIG. 23

# USE OF PRINTING AND OTHER TECHNOLOGY FOR MICRO-COMPONENT PLACEMENT

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of co-pending application Ser. No. 09/697,344, filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889, entitled Method for Making A Light-Emitting Panel, and is related to the following co-owned, co-pending applications: Ser. No. 09/697,358, filed Oct. 27, 2000, entitled: Micro-Component for Use in a Light-Emitting panel; Ser. No. 09/697,498, filed Oct. 27, 2000, now U.S. Pat. No. 6,620,012 entitled: Method for Testing a Light-Emitting Panel and the Components Therein; Ser. No. 09/697,345, filed Oct. 27, 2000, now U.S. Pat. No. 6,570,335 entitled: Method and System for Energizing a Micro-component In a Light-Emitting Panel; Ser. No. 09/697,346, filed Oct. 27, 2000, now U.S. Pat. No. 6,545,422 entitled: Socket for Use with a Micro-component in a Light-Emitting Panel; Ser. No. 10/214,740, entitled Liquid Manufacturing processes for Panel Layer Fabrication filed herewith; Ser. No. 10/214,716, entitled Method of On-Line Testing of a Light-Emitting Panel filed herewith; Ser. No. 10/214,764, entitled Method and Apparatus for Addressing Micro-components in a Plasma Display Panel filed herewith; and Ser. No. 10/214,768, entitled Design, Fabrication, Conditioning, and Testing of Micro-Components for Use in a Light-Emitting Panel filed herewith. Each of the above-identified applications is incorporated herein by reference in its entirety.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding



sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent micro-components formed of a closed transparent shell. Various methods have been used to contain the gas filled micro-components between the parallel plates. In one method, micro-components of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, micro-components are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled micro-components distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel.

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

An embodiment of the present invention includes a method for adhering micro-components to a partially conductive substrate having conductive areas printed thereon.

This method includes passing the partially conductive substrate within printing view of a first insertion tool containing an adherent; depositing a portion of the adherent onto the conductive areas of the partially conductive substrate; passing the partially conductive substrate having the portion of adherent thereon within printing view of a second insertion tool containing at least one micro-component; and depositing the at least one micro-component onto the portion of adherent located on the conductive area of the partially conductive substrate.

Another embodiment of the present invention includes a method for depositing a plurality of micro-components onto predetermined portions of a substrate. This method includes charging the predetermined portions of the substrate with a first charge; charging the plurality of micro-components with a second charge, wherein the first charge and the second charge are opposite charges; and introducing the plurality of charged micro-components to the charged substrate wherein the charged micro-components are electrostatically attracted to the charged predetermined portions of the substrate.

Another embodiment of the present invention includes a method for depositing a plurality of micro-components onto predetermined portions of a substrate. This method includes charging a first predetermined portion of the substrate with a first charge; charging a first set of the plurality of micro-components with a second charge, wherein the first charge and the second charge are opposite charges; introducing the first set of charged micro-components to the first charged portion of the substrate wherein the first set of charged micro-components is electrostatically attracted to the first charged portion of the substrate; facilitating removal of micro-components from the first set of charged micro-components that did not adhere to the first charged portion of the substrate by means of a force applied to the substrate; charging a second predetermined portion of the substrate with the first charge; charging a second set of the plurality of micro-components with the second charge, wherein the first charge and the second charge are opposite charges; introducing the second set of charged micro-components to the second charged portion of the substrate wherein the second set of charged micro-components is electrostatically attracted to the second charged portion of the substrate; applying a force to the substrate in order to remove micro-components from the second set of charged micro-components that did not adhere to the second charged portion of the substrate; charging a third predetermined portion of the substrate with the first charge; charging a third set of the plurality of micro-components with the second charge, wherein the first charge and the second charge are opposite charges; introducing the third set of charged micro-components to the third charged portion of the substrate wherein the third set of charged micro-components is electrostatically attracted to the third charged portion of the substrate; and applying a force to the substrate in order to remove micro-components from the third set of charged micro-components that did not adhere to the third charged portion of the substrate.

Another embodiment of the present invention includes a system for placing multiple micro-components into predetermined portions of a substrate. This system includes means for charging the multiple micro-components with a first charge; means for charging the predetermined portions of the substrate with a second charge, wherein the first charge and the second charge are opposite; means for introducing the multiple micro-components to the predetermined charged portions of the substrate; and means for removing any of the multiple micro-components that are not placed within the predetermined charged portions of the substrate.

Another embodiment of the present invention includes a method for placing micro-components into the sockets of a substrate. This method includes placing a first mask having first holes in predetermined locations over the substrate, wherein the first holes are positioned over a first set of sockets within the substrate; introducing multiple micro-components for emitting a first color to the mask; applying a force to at least one of the first mask and the substrate in order to facilitate placement of the micro-components into the first set of sockets within the substrate; placing a second mask having second holes in predetermined locations over the substrate, wherein the second holes are positioned over a second set of sockets within the substrate; introducing multiple micro-components for emitting a second color to the mask; applying a force to at least one of the second mask and the substrate in order to facilitate placement of the micro-components into the second set of sockets within the substrate; placing a third mask having third holes in predetermined locations over the substrate, wherein the third holes are positioned over a third set of sockets within the substrate; introducing multiple micro-components for emitting a third color to the mask; and applying a force to at least one of the third mask and the substrate in order to facilitate placement of the micro-components into the third set of sockets within the substrate.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

FIG. **20** shows a system for electrostatically placing micro-components according to an embodiment of the present invention.

FIG. **21** shows a system for electrostatically placing micro-components according to an embodiment of the present invention.

FIG. **22** shows a system for placing micro-components within a substrate according to an embodiment of the present invention.

FIG. **23** shows a system for placing micro-components on a substrate according to an embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used. The methods and tools described herein may be used to place micro-components in sockets **30** or alternatively on the flat, i.e., un-dimpled, surface of the substrate.

In an embodiment of the present invention, the at least one micro-component is placed in each socket using an electrostatic sheet transfer ("EST") process. In a first specific implementation of the EST process, the substrate, particularly the sockets already formed within the substrate, are given predetermined units of charge. Similarly, each of a plurality of individual micro-components are given a predetermined amount of charge, opposite to that of the charge on the substrate. In an embodiment of the present invention, means for charging the substrate comprises a laser-charged drum containing a charge pattern, wherein the drum transfers the charge pattern to the predetermined portions of the substrate. Next, the charged substrate is flooded with the plurality of charged micro-components. Referring to FIG. **20**, the means for flooding the charged substrate **10** with the oppositely charged micro-components **40** includes a chute **90** that uses a timed released mechanism, preferably processor controlled, in order to release an approximate number of micro-components at a predetermined time in the fabric making process. The chute is suspended above the fabric and as the appropriately charged substrate section passes beneath the chute, a removable barrier **92**, i.e., an electrically controlled gate, is triggered which allows the micro-components **40** to flood the substrate **10**. The micro-components **40** can be charged **94** prior to entering the chute **90** or while in the chute. The charges have an electrostatic attraction between certain of the charged sockets **30** and certain of the plurality of charged micro-components, such that the charged micro-components adhere to the charged sockets. The charged sockets **30** have an opposite charge **96** to that of the micro-components **40**. In order to remove excess micro-components, i.e., those that did not form an electrostatic bond with a charged socket, the substrate is shaken or blown air is directed at the substrate.

In order to place a particular color-emitting micro-component in a desired socket, this first specific implementation of the EST process requires that during the manufacturing process, the process steps are repeated for each desired color. The charge is applied directly to the substrate in those regions, i.e., sockets, wherein the micro-components having a first desired color are to be placed. The micro-components having a first color are then swept across the substrate and stick to the charged regions. Repelled micro-components are removed from the substrate before those regions, i.e., sockets, wherein the micro-components having a second desired color are to be placed are charged and the micro-components having a second color are swept across the substrate. These steps are repeated until the desired pattern of color-emitting micro-components is formed on the substrate.

Referring to FIG. **21**, in a second specific implementation of the EST process, similar, in principle, to electrophotography, a charged first substrate **200** is electrically contacted to a plurality of charged micro-components **40** located on a second substrate **205**. The micro-components **40** are attracted to the first charged substrate **200** and adhere to the first charged substrate. In order to charge the substrate, or more particularly, the socket portions **30** of the substrate, a processor controlled charging means, i.e., laser, diode array, electron beam or the like is used. As part of the manufacturing process, a roll of substrate material is continuously passed by the charging means and charged accordingly. The charging means is controlled by a processor and as such is able to distribute charge in locations, i.e., at the socket locations, and amounts as directed by the manufacturer, to achieve desired panel size and resolution. Further to the process, the second substrate **205** containing the oppositely charge micro-components **40** is passed by the first charged substrate **200** and the micro-components are peeled off of the second substrate and adhere to the charged areas, e.g., sockets **30**, of the first charged substrate. In an embodiment of the present invention illustrated in FIG. **21**, in order to facilitate the step of continuously passing the first and second substrates **200, 205** in electrostatic proximity to one another, the first and second substrates are passed along rollers **210**. The rollers **210** are rotated in opposite directions A and B. While FIG. **21** shows two rollers **210**, there may be multiple rollers and/or moving belts utilized in the continuous process.

In an alternative embodiment, referring to FIG. **22**, illustrates method and system for placing micro-components wherein the placement is purely mechanical. A first pliable substrate **300**, such as a plastic or polymeric material or a polymeric material warmed to the point of pliability, is forcibly contacted to a plurality of micro-components **40** located on a second substrate **305**. The micro-components **40** cause the pliable first charged substrate **300** to deform in accordance with the shape of the micro-components. The micro-components release from a loose hold on the second substrate **305** and remain in the self-made sockets in the first charged substrate, forming a socket/micro-component **314**. In an embodiment of the present invention illustrated in FIG. **22**, in order to facilitate the step of continuously passing the first and second substrates **300**, **305** in mechanical proximity to one another, the first and second substrates are passed along rollers **310** and **312**. The roller **312** has socket shaped indentations into which the pliable substrate **300** is pushed by the micro-components **40** as they are forcibly contacted to one another. Another embodiment uses a roller **312** without indentations in conjunction with a pliable substrate **300** that is thicker than the depth of the self-made sockets. The rollers **310** and **312** are rotated in opposite directions A and B. While FIG. **22** shows two rollers **310** and **312**, there may be multiple rollers and/or moving belts utilized in the continuous process.

As described with respect to the first specific implementation of the EST process, where micro-components emitting different colors are to be placed at particular locations within the charged substrate, the process requires steps for ensuring that the various color-emitting micro-components are placed accordingly. As such, in the second implementation of the EST process, the first substrate is selectively charged by the charging means first in the area or areas where micro-components emitting a first color are to be placed. A second substrate containing only charged micro-components that emit the first color is passed by the charged first substrate and the micro-components are picked off of the second substrate by the electrostatic force that exists between the oppositely charged first charged sheet area(s) and the micro-components emitting a first color. Next, the first substrate is selectively charged by the charging means in the area or areas where micro-components emitting a second color are to be placed. A third substrate containing only charged micro-components that emit the second color is passed by the charged first substrate and the micro-components are picked off of the third substrate by the electrostatic force that exists between the oppositely charged first charged sheet area(s) and the micro-components emitting a second color. This process is repeated for the required number of color-emitting micro-components.

As an alternative to the iterative process described above, a second substrate is selectively patterned with charged micro-components that emit varying colors. One skilled in the art recognizes that for various viewing technologies, the patterns include the primary colors of red, green, and blue. Micro-components having these colors are grouped so as to form pixels. In this alternative embodiment, the second selectively patterned substrate is electrically contacted to a first selectively charge substrate, e.g., charged at the socket locations, and in response to the electrostatic forces between the oppositely charged sockets and micro-components, the micro-components are peeled off of the second selectively patterned substrate and placed in the sockets of the first selectively charged substrate. The pattern of the micro-components is maintained through the peel-off and placement process.

Referring to FIG. **23**, in another embodiment of the present invention, the micro-components **40** are placed on a substrate **10**, i.e., in sockets **30**, using insertion tools **220** and **225**, which are similar to ink jet heads. In this particular example, a first insertion tool **220** is used to adhere drops of bonding material **230**, i.e., conducting epoxy or the like, as well as the micro-components **40** themselves onto a substrate **10**. The micro-component placement process can be used as part of a continuous web or discrete step manufacturing process. In a particular continuous web process, a substrate is supplied to the manufacturing line, i.e., web-line. The substrate approaches the insertion portion of the web-line already laden with at least a first set of conductors possibly with sockets formed therein for receiving micro-components. For exemplary purposes only, the conductors may approximately 150 microns wide, running orthogonal to the direction of movement of the substrate along the web-line and the micro-components may be approximately 0.33 millimeters wide. The conductors are separated by approximately 400 microns as measured from center to center. As this standardized continuous line of conductor laden substrate passes through the insertion portion of the web-line, the insertion tools insert adherent and micro-components on the substrate and/or within appropriate sockets. The pattern of micro-component placement can be either manually, mechanically, or processor controlled. The insertion tools are programmed through the processor so as to vary the size, color (e.g., red, green, blue), type (e.g., micro-component) and location of the micro-component placement as desired. Alternatively, the insertion tools are such that the sockets of the substrate are first coated with the desired phosphor coating in order to construct the display pixels as needed, i.e., red, green, blue, followed by insertion of the a micro-component into each of the coated sockets.



The insertion tools can use various different methods and devices to direct the micro-components toward a the substrate, i.e., the sockets. For example, electrostatic, piezoelectric, and acoustic devices utilize ejecting transducers and/or actuators to control the ejection and placement of the micro-components. These transducers and or actuators are controlled by an insertion processor. In the embodiments described herein, the insertion processor activates the transducers or actuators in conjunction with movement of the substrate relative to the insertion tool(s). By controlling the activation of the transducers or actuators and the substrate movement, the insertion processor can direct the micro-components to impact the substrate in a specific pattern.

In order to control the placement of micro-components that deviate from the intended trajectory, the micro-components can be electrostatically deflected upon leaving the insertion tool. Charges placed on electrodes on the insertion tool are controlled in order to steer charged micro-components in desired directions to compensate for movement of the insertion tool. In an alternative embodiment, the electrodes underlying the sockets in the substrate or on the insertion tool are used to induce charges on the micro-components and accelerate them toward the substrate and appropriate socket. Additionally, an electric field can be used to accelerate the micro-components subsequent to ejection.

In another embodiment of the present invention, the use of an EST process and insertion tools are combined. In this alternative embodiment, the insertion tools are utilized to coat the sockets within the substrate with the appropriate phosphor coating. One of the EST processes described above is used to place at least one micro-component within each of the coated sockets.

In still a further embodiment of the present invention, the micro-components are placed within the sockets on the substrate through a process of applying force to the substrate. This force can be an inertial force, such as from vibration, air pressure forces, or others (e.g., agitation) applied by a force application tool. In this further embodiment of the present invention, the application of force is used as a final or fine alignment step. The rough alignment step is the initial introduction of the micro-components to the surface of the substrate. Referring to the electrostatic flooding embodiments described above, agitation can be used in order to effectively seal the electrostatic attraction between the micro-components and the sockets or, alternatively, agitation can be used in order to rid the surface of the substrate of extra micro-components that have not been placed in an appropriate socket. In another embodiment of the present invention, air pressure forces are used to enhance or replace the electrostatic forces that attract the micro-component into the socket, where the air pressure forces are generated by applying a vacuum at the bottom of the socket.

In a further embodiment of the present invention, the micro-components are placed into the appropriate sockets within the substrate using masks in conjunction with a force application tool. In this embodiment, a first mask is placed over the substrate, wherein there are holes in the mask that are patterned so as to have holes in predetermined locations according to display requirements for receipt of a first color of micro-component. Once the mask is in place, a chute containing micro-components having the first color are flooded onto the mask and the force application tool is used to shake the micro-components through the holes and into the sockets in the substrate. The first mask is then removed and the process is repeated for the second and third colored micro-components using second and third patterned masks. In further embodiments, the micro-components may differ in size, for example, the green micro-components have a first size and are larger than the blue micro-components which have a second size and are larger than the red micro-components having a third size. In an alternative embodiment, the masks may be patterned accordingly to accommodate the differing sizes of the micro-components.

The continuous web process, including the insertion portion, is a dynamic manufacturing process. The process allows for the construction of a display fabric that is adaptable to a wide variety of technological applications based on size, resolution, power restrictions, and the like. The resulting display fabric is reconfigurable based on intended application. Further, in another embodiment of the present invention, the insertion portion of the continuous web process includes application of curable liquid dielectric layers, and the like, to the substrate containing the first set of conductors. A further discussion of this layering technology is described in the disclosure filed on Mar. 2, 2004 as application Ser. No. 10/789976 entitled Liquid Manufacturing Processes for Panel Layer Fabrication which is incorporated herein by reference in its entirety. These dielectric coatings offer protection to the underlying conductors during the cutting process, whereby the display fabric is cut into multiple display panels. Due to the adaptability of the display fabric, the fabric may be cut into displays of the same size or into displays of different sizes. The prior art manufacturing processes do not allow for this multiple size adaptability. One of the most significant reasons for this limitation is the need to leave room at the edge of the panels for electrical connection lines and the like. With the present invention, even a display cut from the center of the fabric will have dielectric protected conductors at the edges to facilitate connection thereto. The dielectric is removed or peeled away from the substrate at the edges, exposing the conductors and allowing for the appropriate connections to be made.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. Further, rare gas halide mixtures such as xenon chloride, xenon fluoride and the like are also suitable plasma-forming gases. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed above. This description is not intended to be limiting. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate.

Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement (black mask) coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the fist substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17**, and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A method for adhering micro-components to a partially conductive substrate having conductive areas printed thereon, comprising:

passing the partially conductive substrate within printing view of a first insertion tool containing an adherent;

depositing a portion of the adherent onto the conductive areas of the partially conductive substrate;

passing the partially conductive substrate having the portion of adherent thereon within printing view of a second insertion tool containing at least one micro-component; and

depositing the at least one micro-component onto the portion of adherent located on the conductive area of the partially conductive substrate.

**2**. The method according to claim **1**, wherein the first and second insertion tools utilize piezoelectric actuators during the deposition of the portion of the adherent and the at least one micro-component.

**3**. The method according to claim **1**, wherein the partially conductive substrate contains a socket therein for receiving the portion of the adherent and the at least one micro-component.

**4**. The method according to claim **1**, wherein the at least one micro-component contains a rare gas halide.

5. A method for depositing a plurality of micro-components onto predetermined portions of a substrate comprising:

charging the predetermined portions of the substrate with a first charge;

charging the plurality of micro-components with a second charge, wherein the first charge and the second charge are opposite charges; and

introducing the plurality of charged micro-components to the charged substrate wherein the charged micro-components are electrostatically attracted to the charged predetermined portions of the substrate.

6. A method for depositing a plurality of micro-components onto predetermined portions of a substrate comprising:

charging a first predetermined portion of the substrate with a first charge;

charging a first set of the plurality of micro-components with a second charge, wherein the first charge and the second charge are opposite charges;

introducing the first set of charged micro-components to the first charged portion of the substrate wherein the first set of charged micro-components is electrostatically attracted to the first charged portion of the substrate;

facilitating removal of micro-components from the first set of charged micro-components that did not adhere to the first charged portion of the substrate by means of a force applied to the substrate;

charging a second predetermined portion of the substrate with the first charge;

charging a second set of the plurality of micro-components with the second charge, wherein the first charge and the second charge are opposite charges;

introducing the second set of charged micro-components to the second charged portion of the substrate wherein the second set of charged micro-components is electrostatically attracted to the second charged portion of the substrate;

applying force to the substrate in order to remove micro-components from the second set of charged micro-components that did not adhere to the second charged portion of the substrate;

charging a third predetermined portion of the substrate with the first charge;

charging a third set of the plurality of micro-components with the second charge, wherein the first charge and the second charge are opposite charges;

introducing the third set of charged micro-components to the third charged portion of the substrate wherein the third set of charged micro-components is electrostatically attracted to the third charged portion of the substrate; and

applying force to the substrate in order to remove micro-components front the third set of charged micro-components that did not adhere to the third charged portion of the substrate.

7. The method according to claim **6**, wherein the first, second, and third sets of micro-components represent each of the three primary colors.

8. The method according to claim **6**, wherein the force applied is ultrasonic.

9. The method according to claim **6**, wherein the first, second, and third predetermined portions of the substrate are within sockets formed in the substrate.

10. The method according to claim **6**, wherein the first, second, and third predetermined portions of the substrate are proximate to a conductor.

11. The method according to claim **9**, wherein each of the sockets is proximate to at least one conductor.

12. The method according to claim **6**, wherein the micro-components contain a rare gas halide.

13. A continuous process for fabricating a plurality of light-emitting panels comprising:

providing a first continuous line of substrate having a plurality of parallel conductors thereon;

passing the substrate within printing view of a first insertion tool containing an adherent;

depositing portions of the adherent onto area of the parallel conductors;

passing the substrate having the portions of adherent thereon within printing view of second insertion tool containing multiple micro-components; and

depositing the multiple micro-components onto the portions of adherent located on the parallel conductors;

disposing a second substrate over the first substrate such that the plurality of micro-components are sandwiched between the first substrate and the second substrate; and

cutting the first substrate and the second substrate to form the plurality light-emitting panels.

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US006801001B2

(12) **United States Patent**
**Drobot et al.**

(10) **Patent No.: US 6,801,001 B2**
(45) **Date of Patent: Oct. 5, 2004**

(54) **METHOD AND APPARATUS FOR ADDRESSING MICRO-COMPONENTS IN A PLASMA DISPLAY PANEL**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 174 days.

(21) Appl. No.: **10/214,764**

(22) Filed: **Aug. 9, 2002**

(65) **Prior Publication Data**

US 2003/0214243 A1 Nov. 20, 2003

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/697,345, filed on Oct. 27, 2000, now Pat. No. 6,570,335.

(51) **Int. Cl.**[7] .................................................. **G09G 3/10**
(52) **U.S. Cl.** .................................................. **315/169.3**
(58) **Field of Search** ........................... 315/169.3, 169.4; 313/483, 484, 491, 581, 582; 445/24, 33

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 5,914,150 A | 6/1966 | Porter et al. | 427/77 |
| 3,559,190 A | 1/1971 | Blitzer et al | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 A | 11/1976 | Mayer et al. | 340/324 M |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).
Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
International Search Report for Application No. PCT/US01/51439, date Sep. 23 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

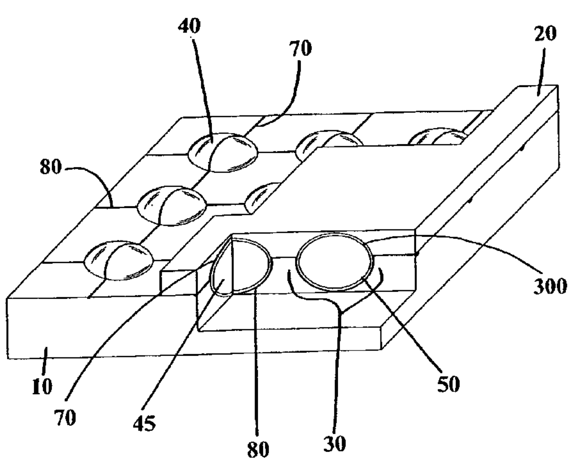
(List continued on next page.)

*Primary Examiner*—Tuyet Vo
*Assistant Examiner*—Minh Dieu A
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

An improved light-emitting display having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large trigger voltage is supplied across the micro-component by up to two triggering electrodes and ionization can be maintain by a sustain voltage supplied by up to two sustain electrodes. The display is further divided into a plurality of panels that can be individually addressed in parallel, preferably directly through the back of the panels and can include voltage multiplying circuitry to decrease the power demands for addressing circuitry. Alternative methods of addressing the micro-components include the use of directed light and arrangements of electrodes to address multiple micro-components with a single electrode.

**46 Claims, 27 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 3,998,618 | A | | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 | A | | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 | A | | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 | A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | * | 11/1985 | Dick | 345/67 |
| 4,563,617 | A | | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,917,646 | A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | | 11/2001 | Sasaki et al. | 239/568 |
| 6,607,413 | B2 | * | 8/2003 | Stevenson et al. | 445/24 |
| 6,655,788 | B1 | * | 12/2003 | Freeman | 347/58 |
| 6,657,772 | B2 | * | 12/2003 | Loxley | 359/296 |
| 6,672,921 | B1 | * | 1/2004 | Liang et al. | 445/24 |
| 2001/0008825 | A1 | | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | | 1/2002 | Iguchi et al. | 427/10 |

| | | | | |
|---|---|---|---|---|
| 2002/0016075 A1 | 2/2002 | Peng et al. | ................. | 438/700 |
| 2002/0017864 A1 | 2/2002 | Watanabe et al. | ........... | 313/586 |
| 2002/0022565 A1 | 2/2002 | Sreeram et al. | ............... | 501/16 |
| 2002/0024295 A1 | 2/2002 | Miyashita et al. | .......... | 313/495 |
| 2003/0025855 A1 * | 2/2003 | Holman et al. | ............... | 349/86 |

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

Sheats, James, "Introduction to Organic Light–Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll–to–Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http:www.star.stanford.edu/~vlf/plasma_display/index.htm.

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21–25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self–Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar., 2001. pp. 17–17–24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet:http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics –To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco Plasma Wall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco Plasma Wall PI–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco Plasma Wall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper – Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb., 1999, pp. 14–15.

Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Kurihara, M., Makabe, T., "Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct., 1999, pp. 1372–1378.

Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

"Transparent Conductive Coatings," Copyright 1998, 4 pp.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep., 1997, pp. 1241.

Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.

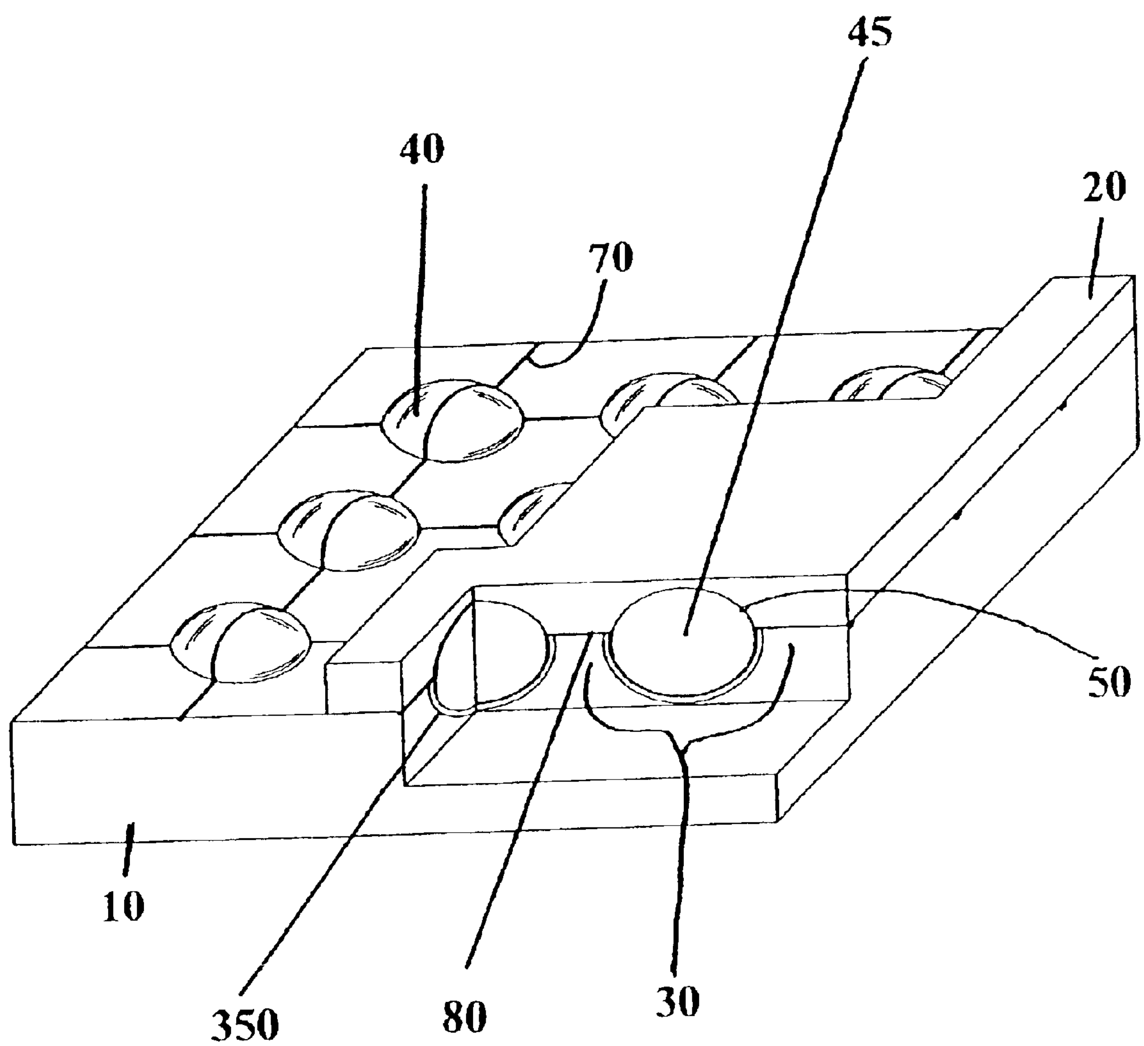
"Flat Panel Displays in Perspective," 44 pp., Sep., 1995.

Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

* cited by examiner

Fig. 1



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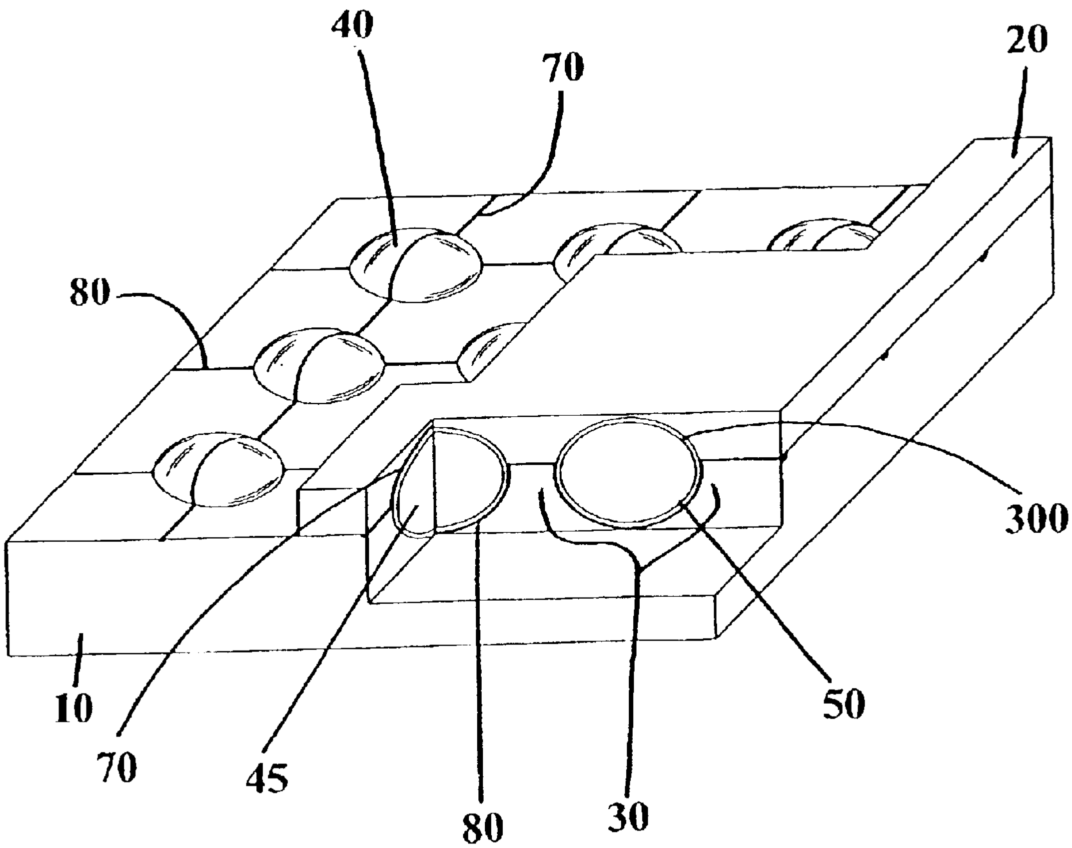

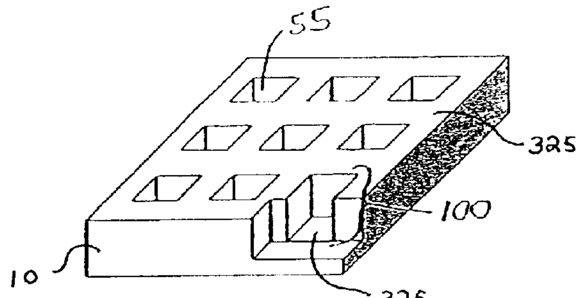


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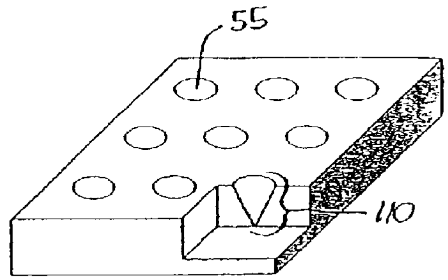


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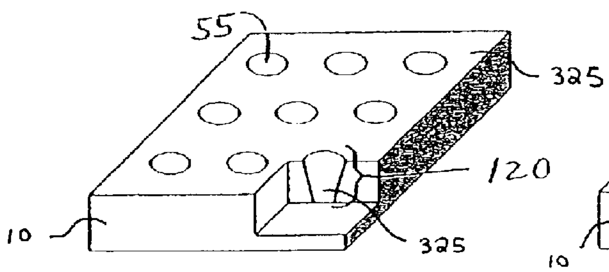


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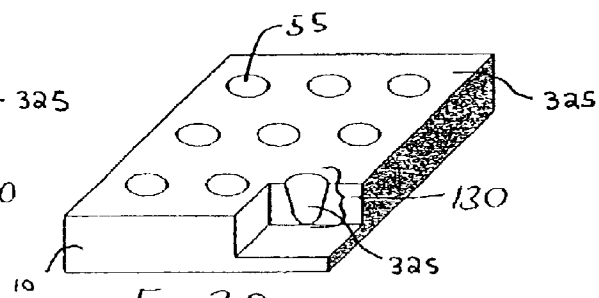


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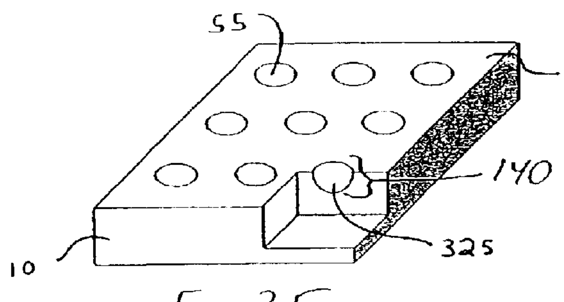


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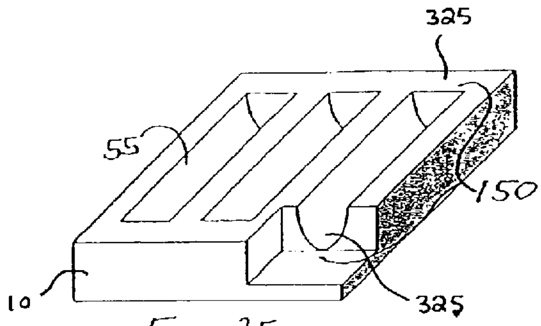


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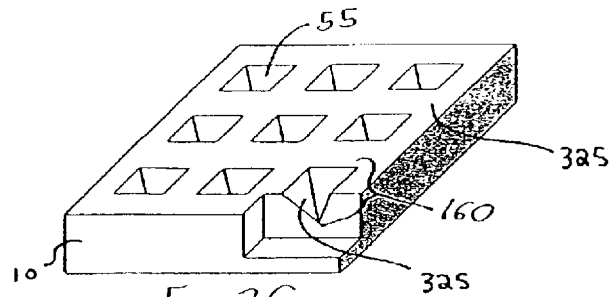


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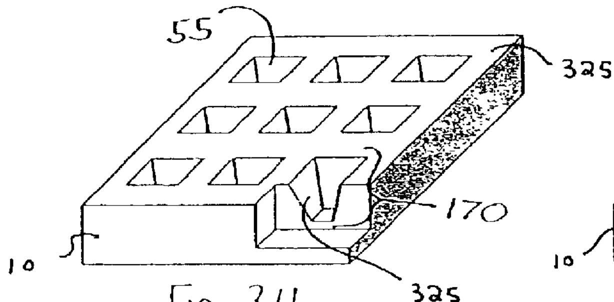


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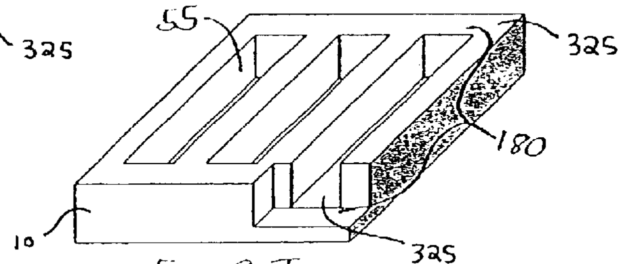


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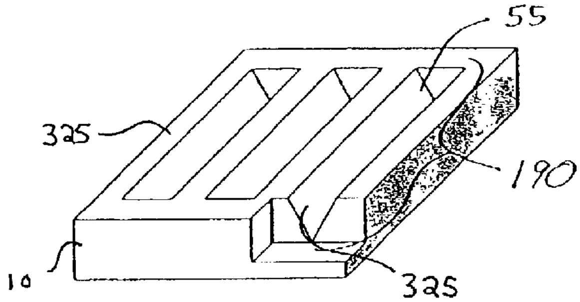
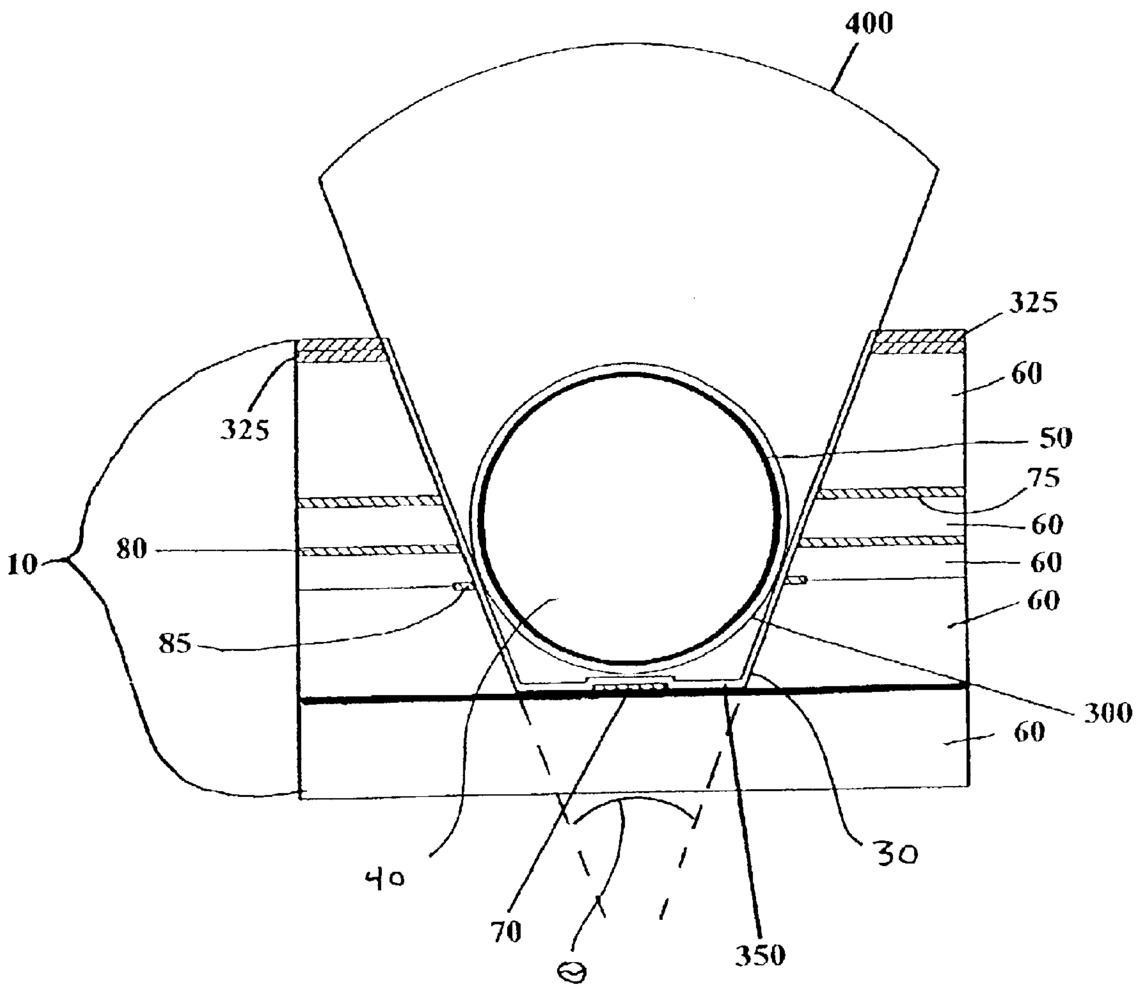



Fig. 3 J

Fig. 4



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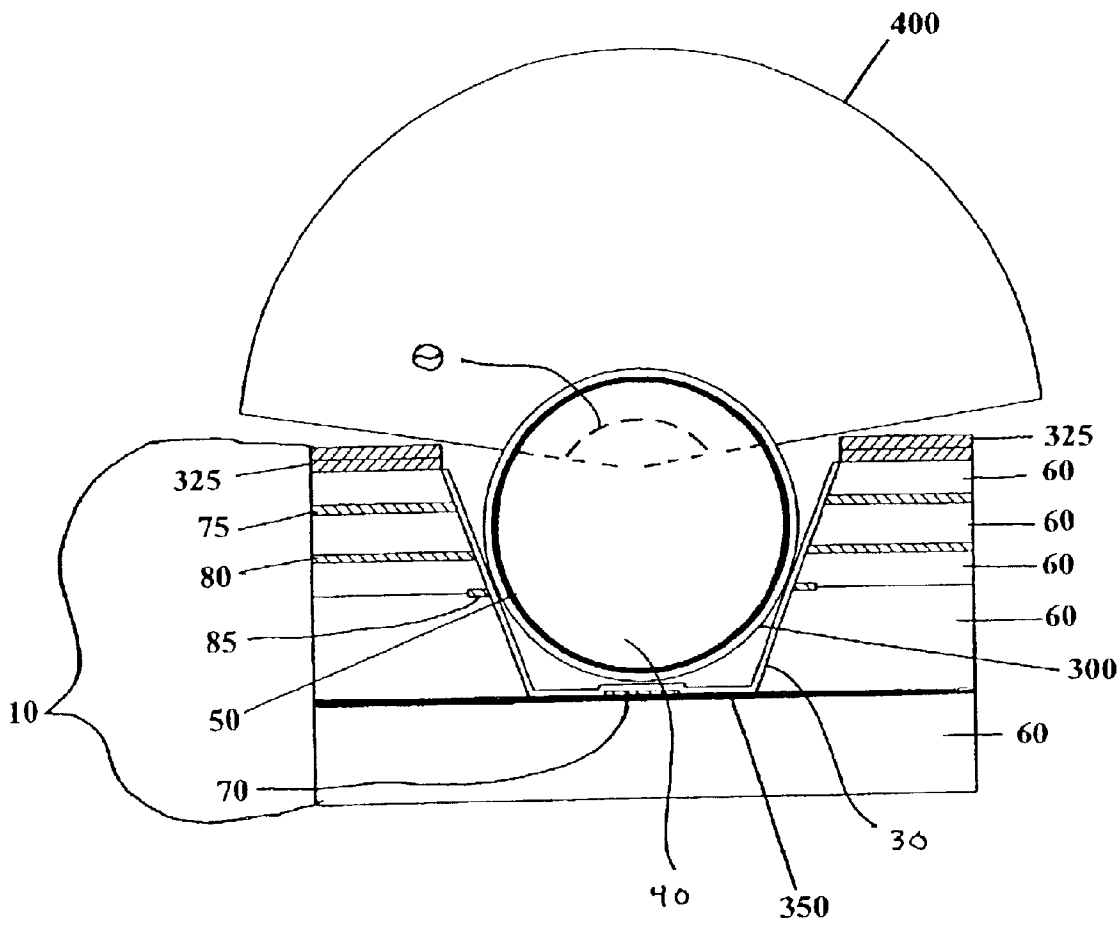


Fig. 6A

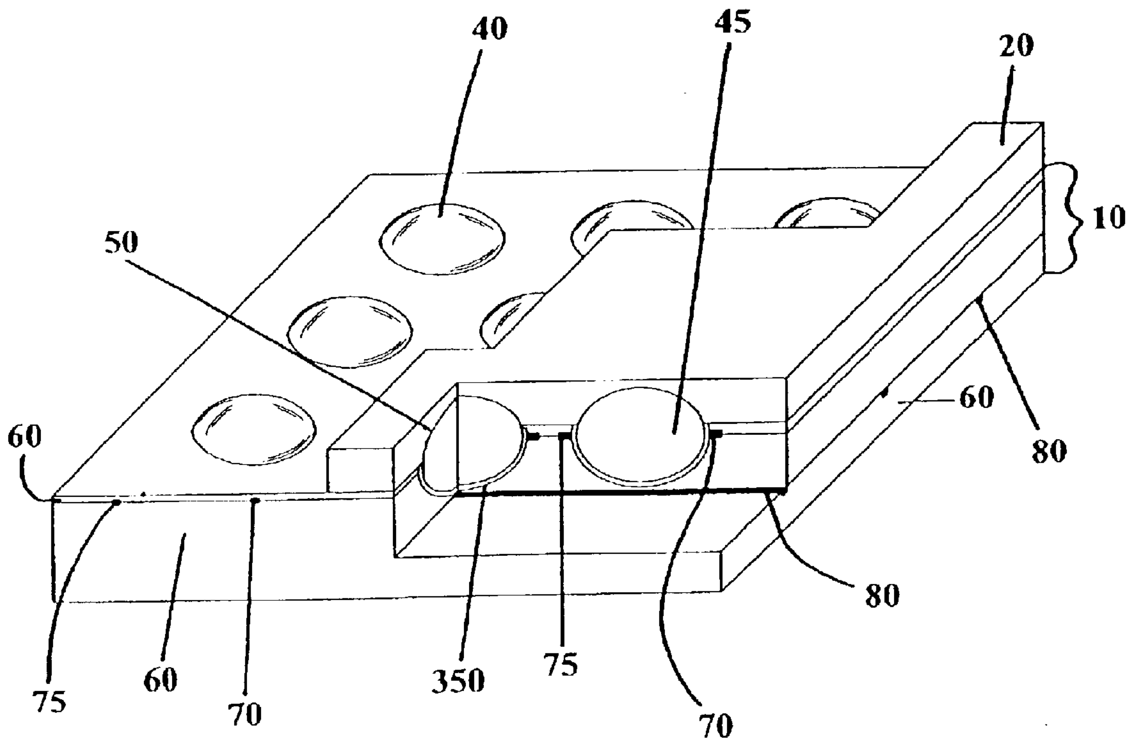


Fig. 6B

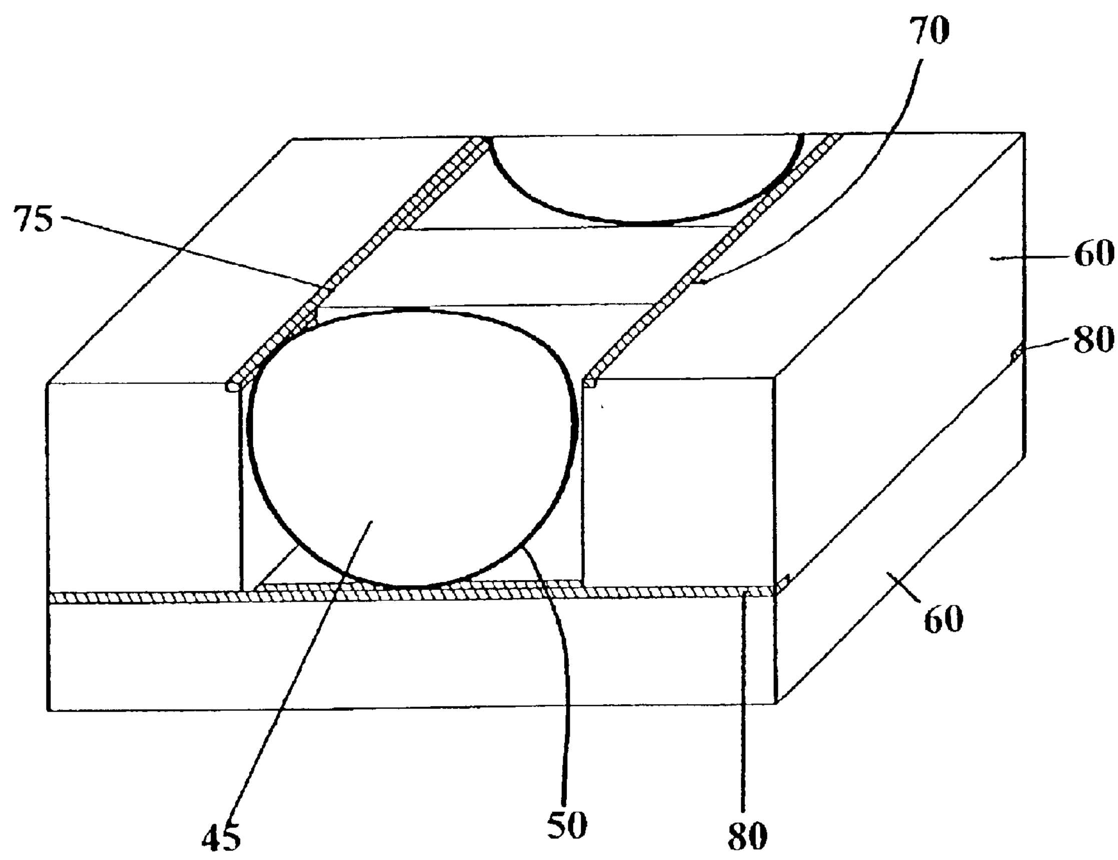


Fig. 7A

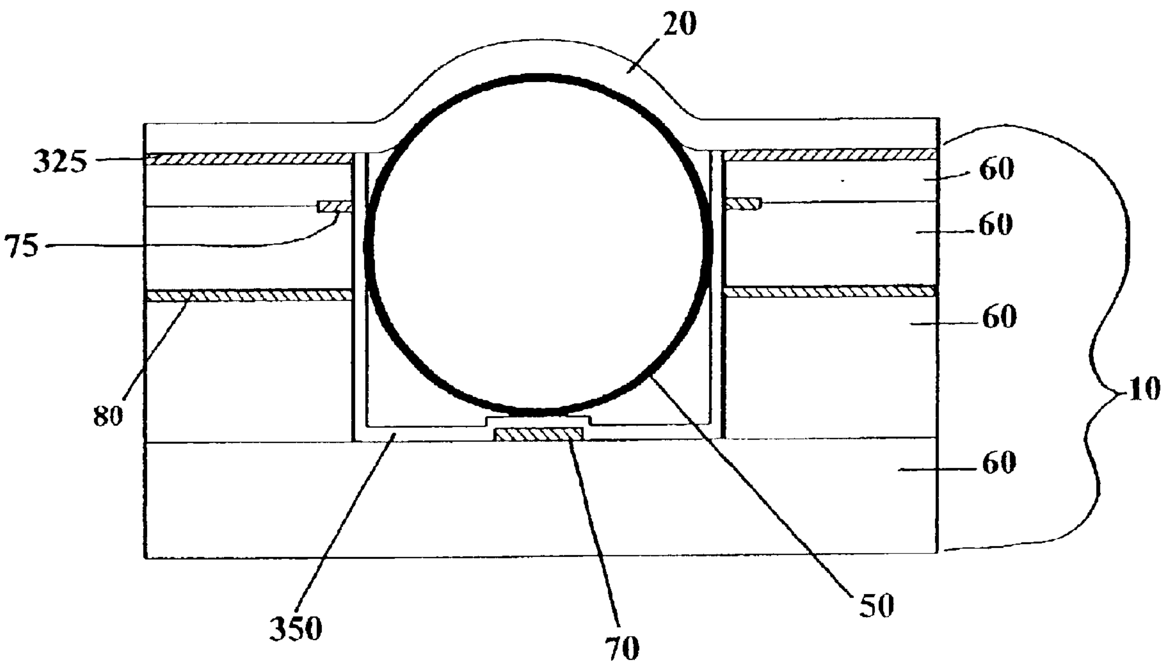


Fig. 7B

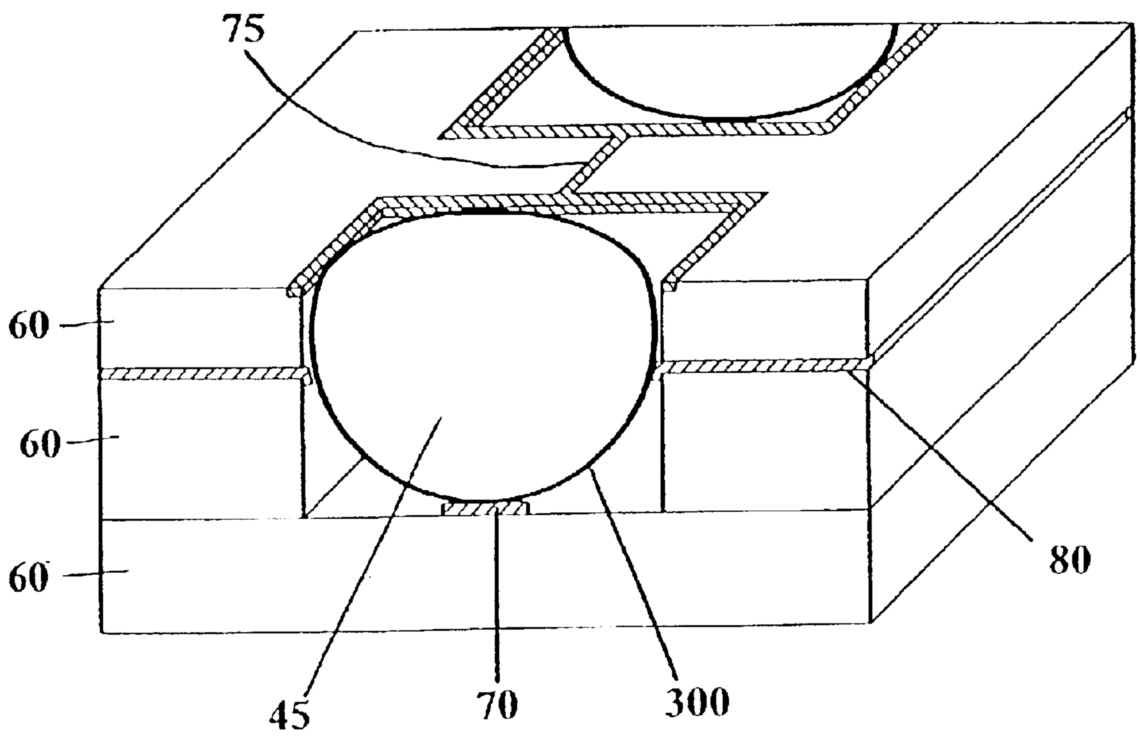


Fig. 8

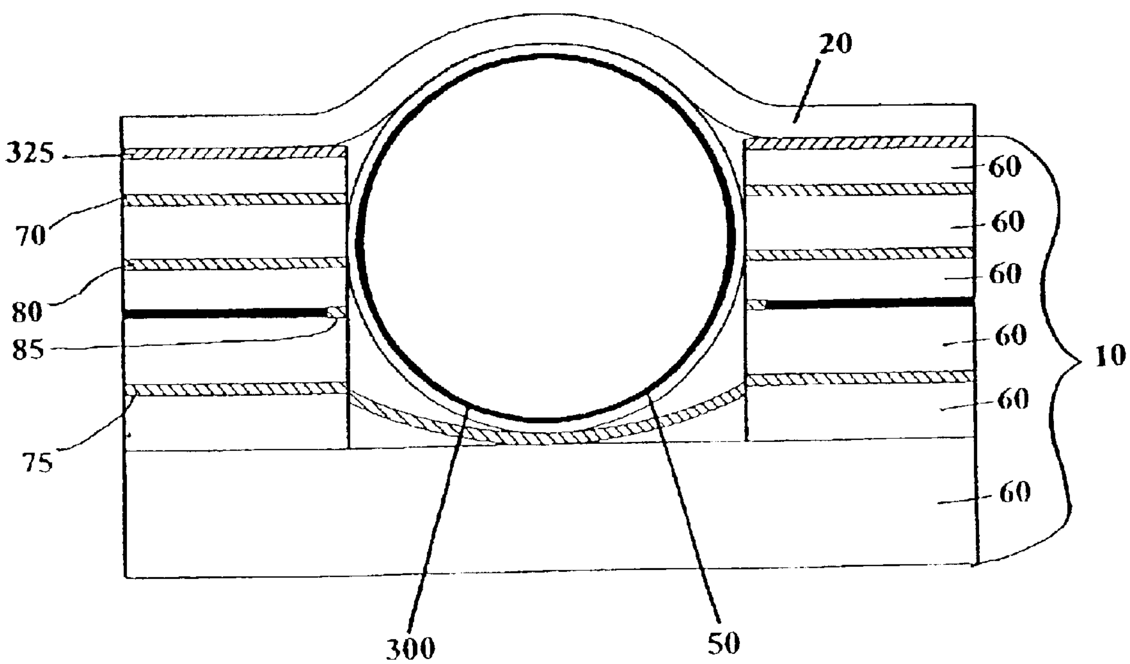


Fig. 9

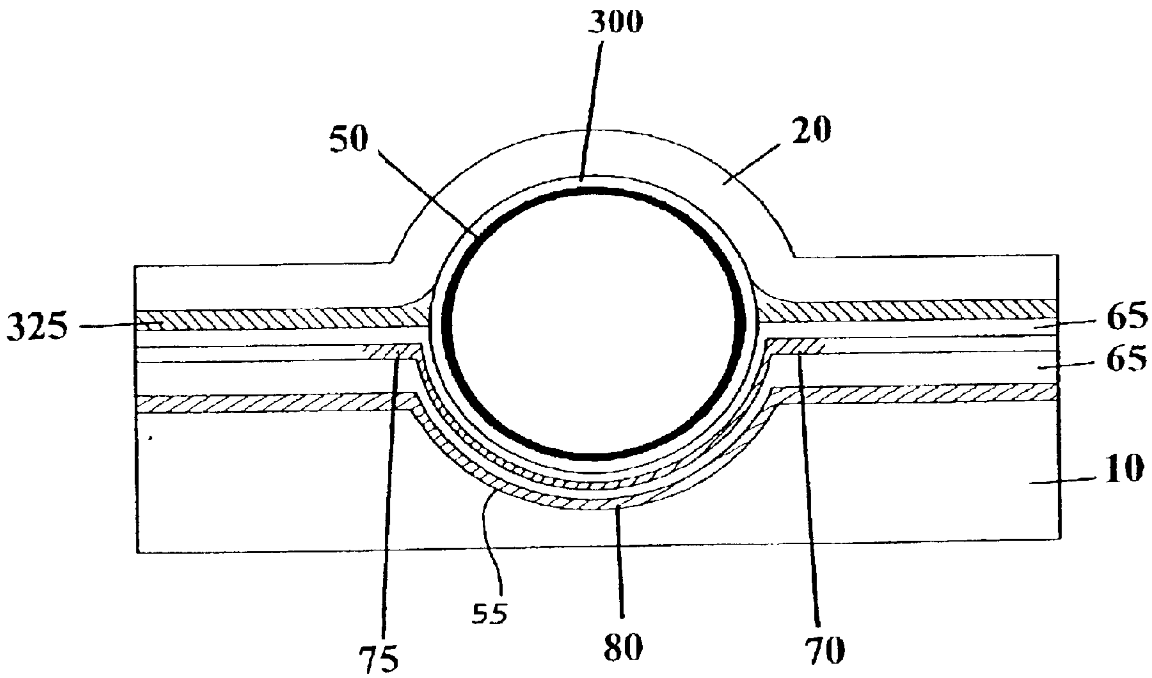


Fig. 10

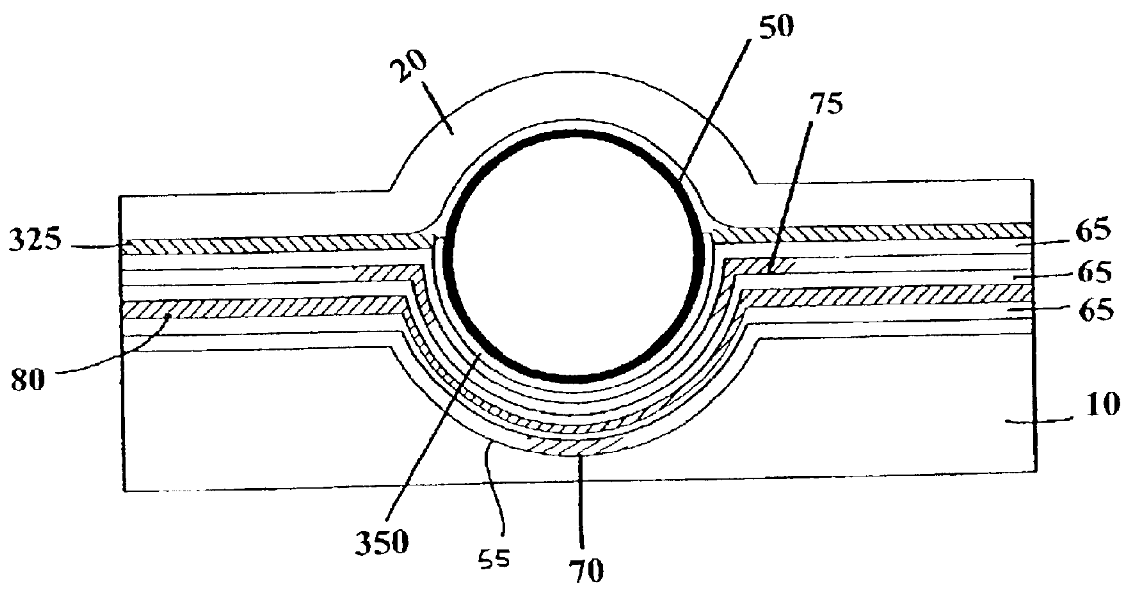
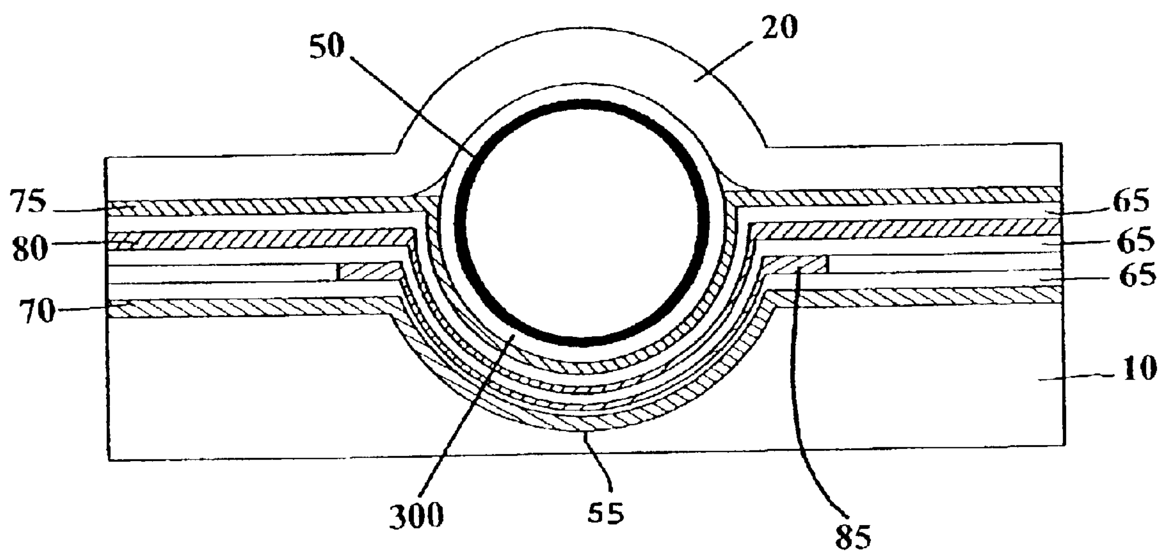


Fig. 11



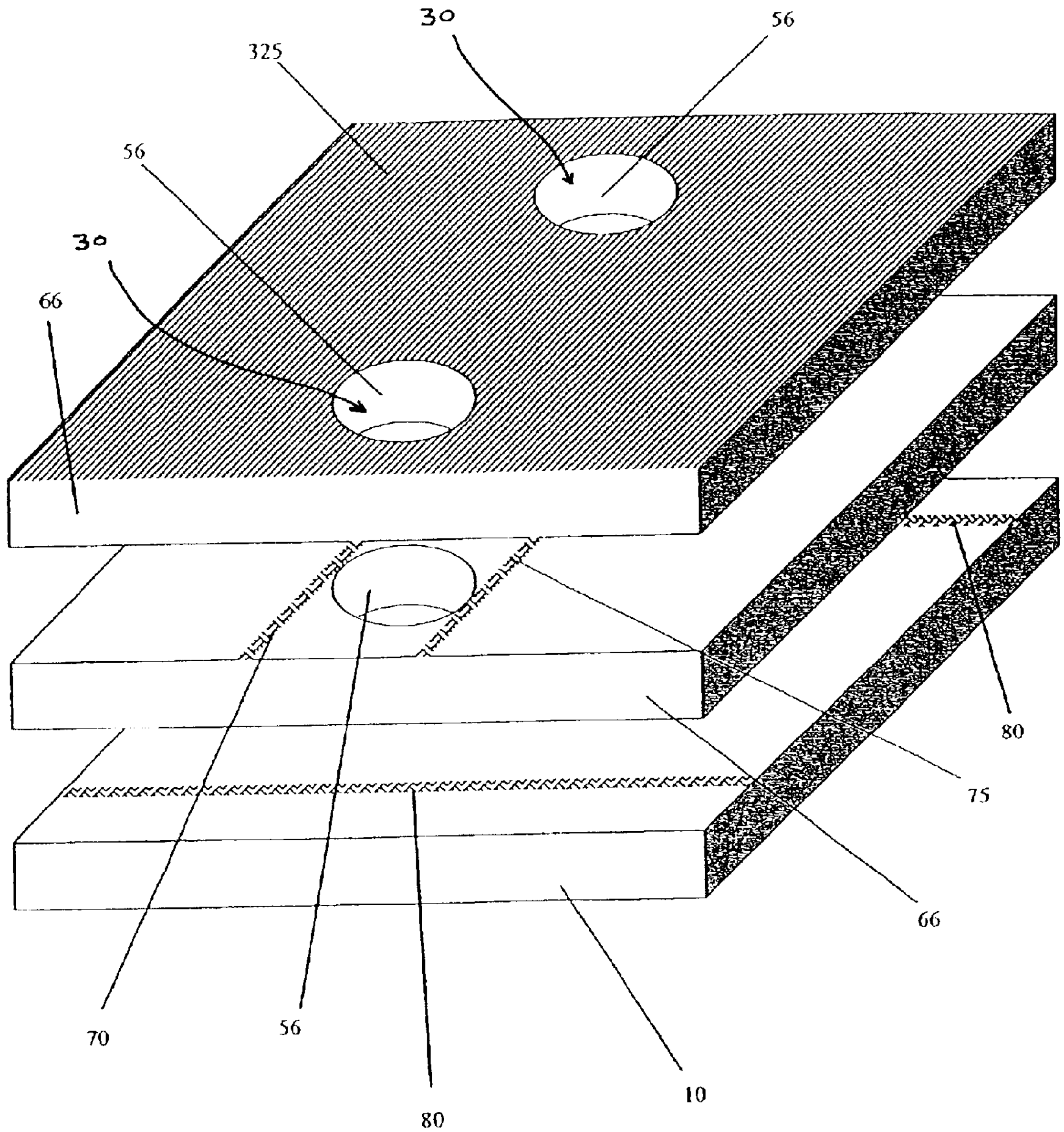



Fig. 12

Fig. 13

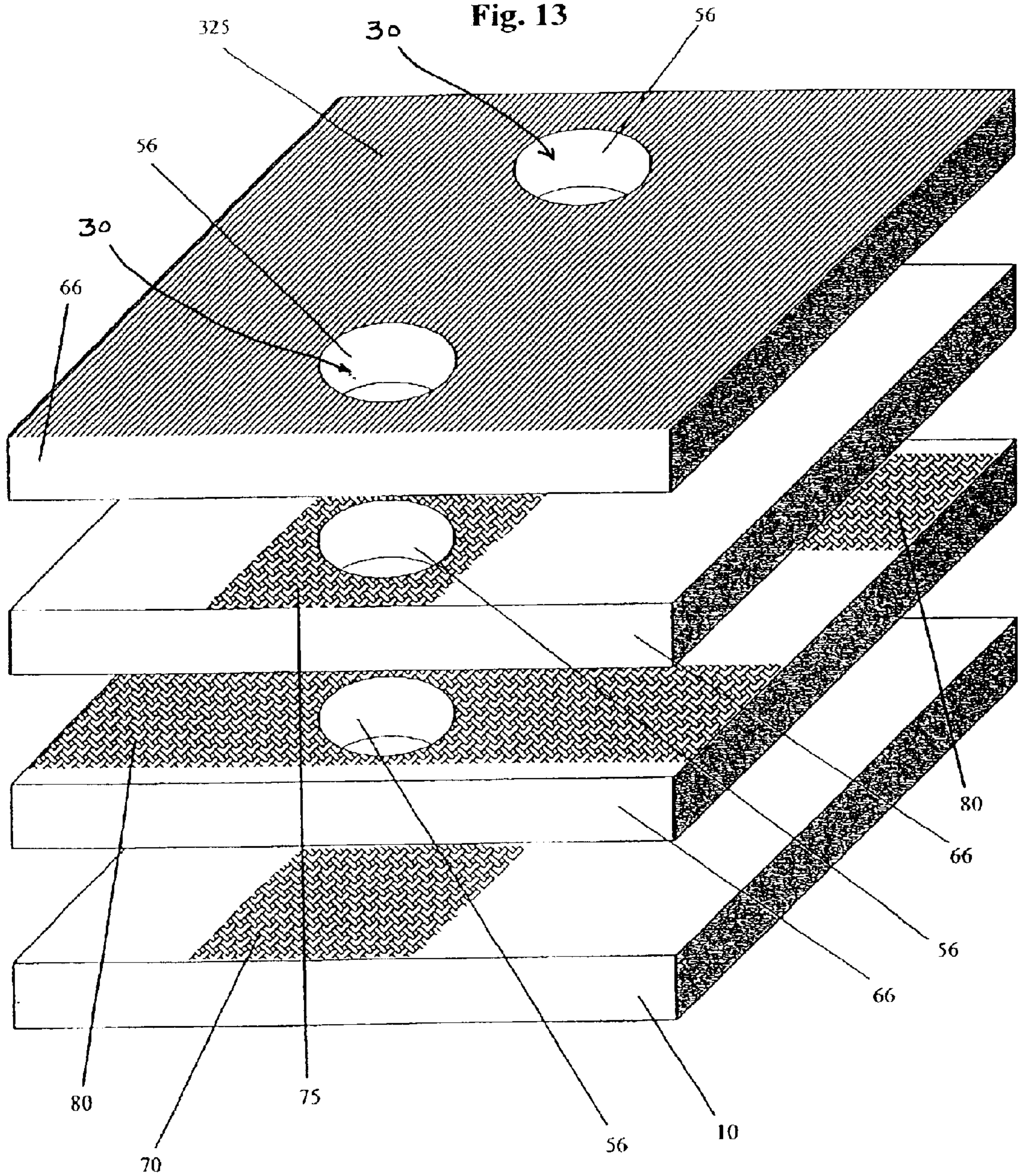
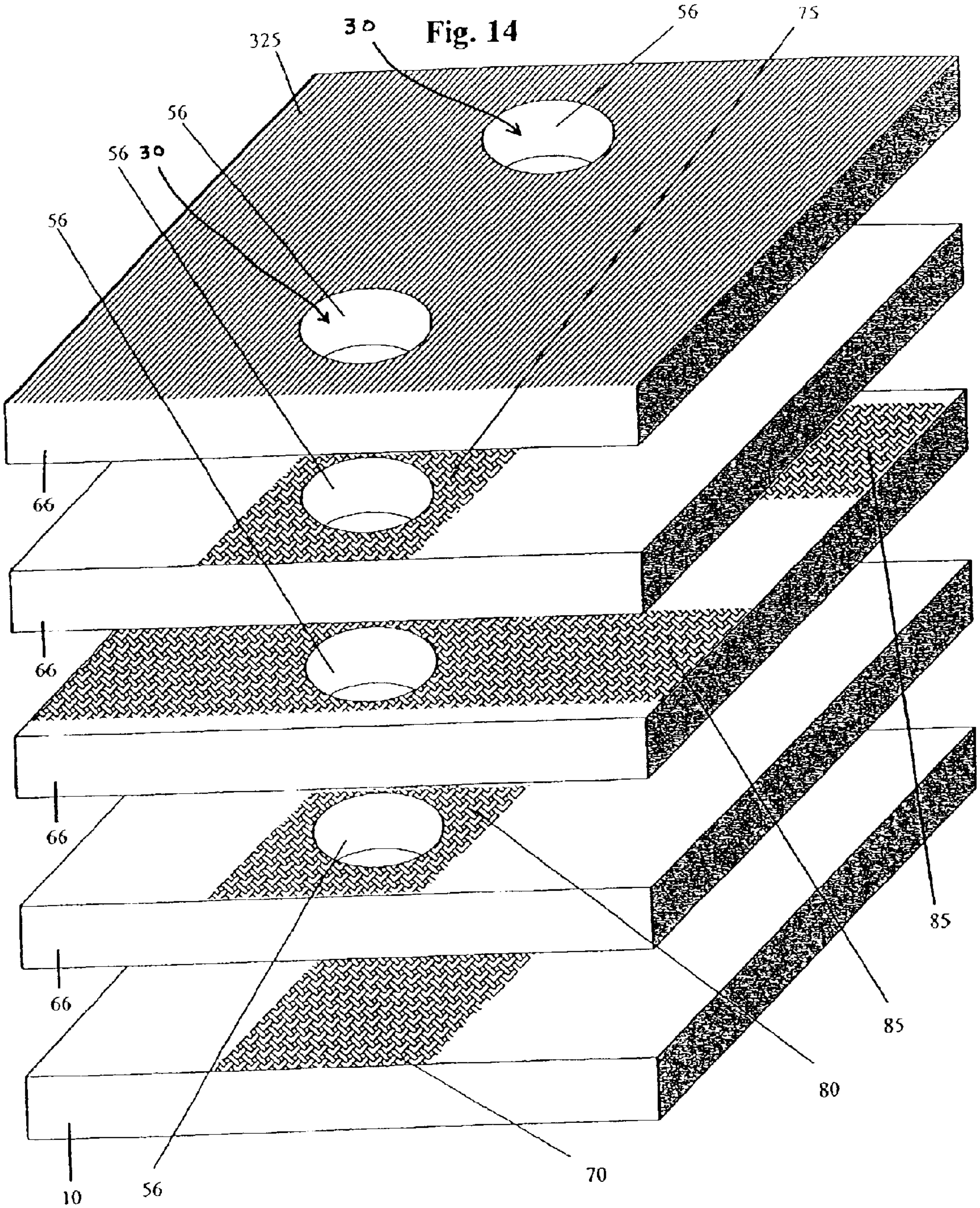


Fig. 14



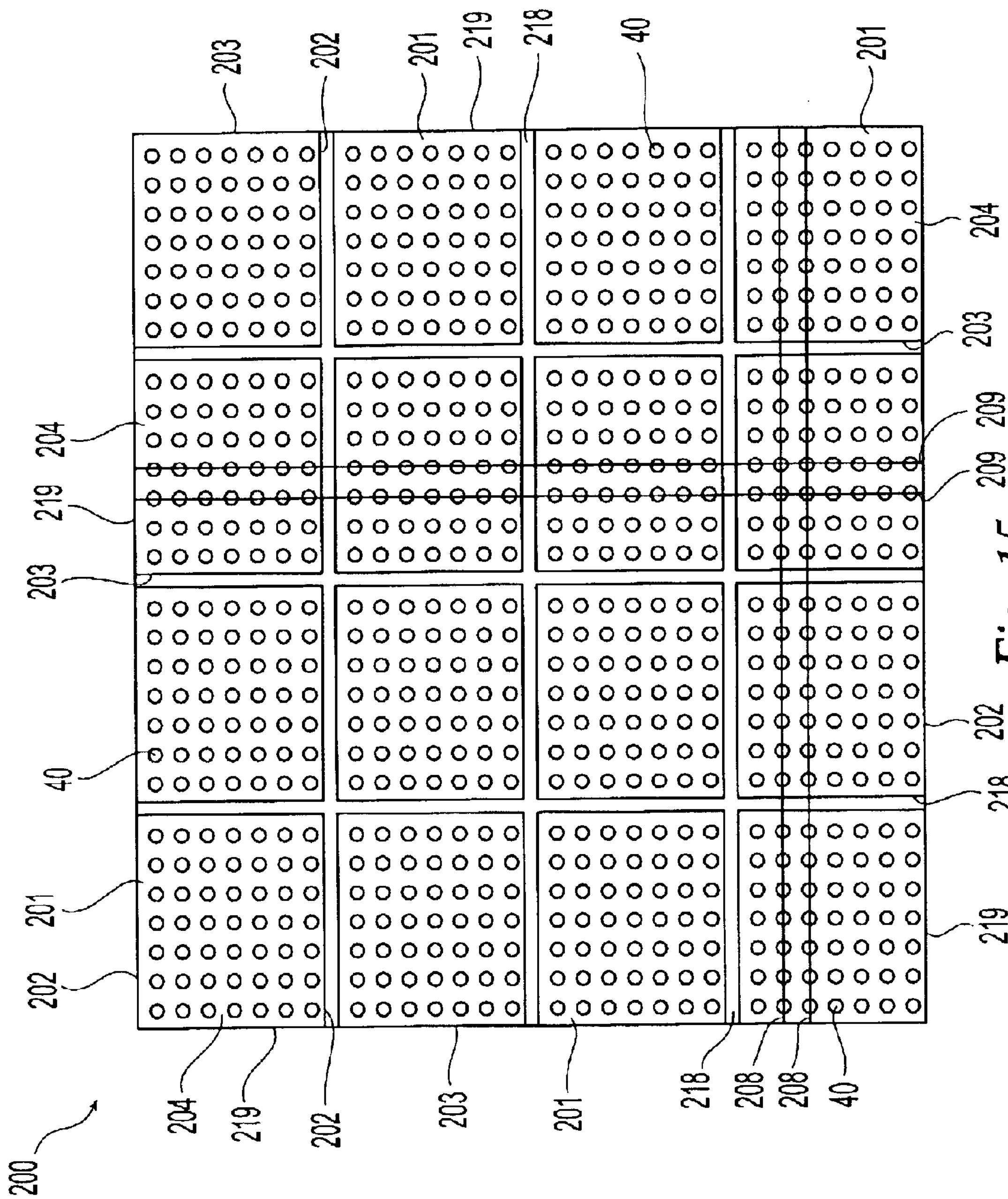



Fig. 15

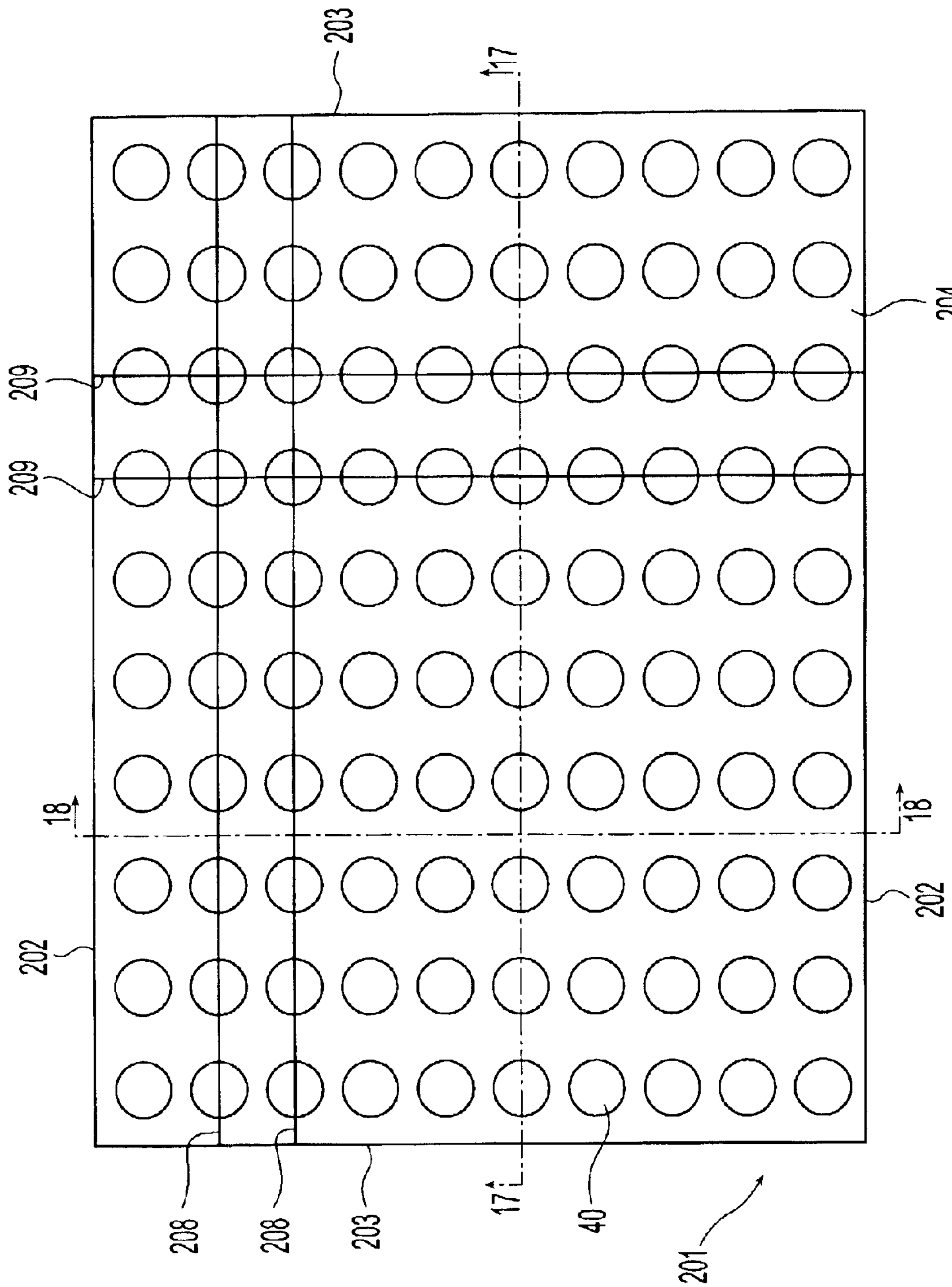



*Fig. 16*

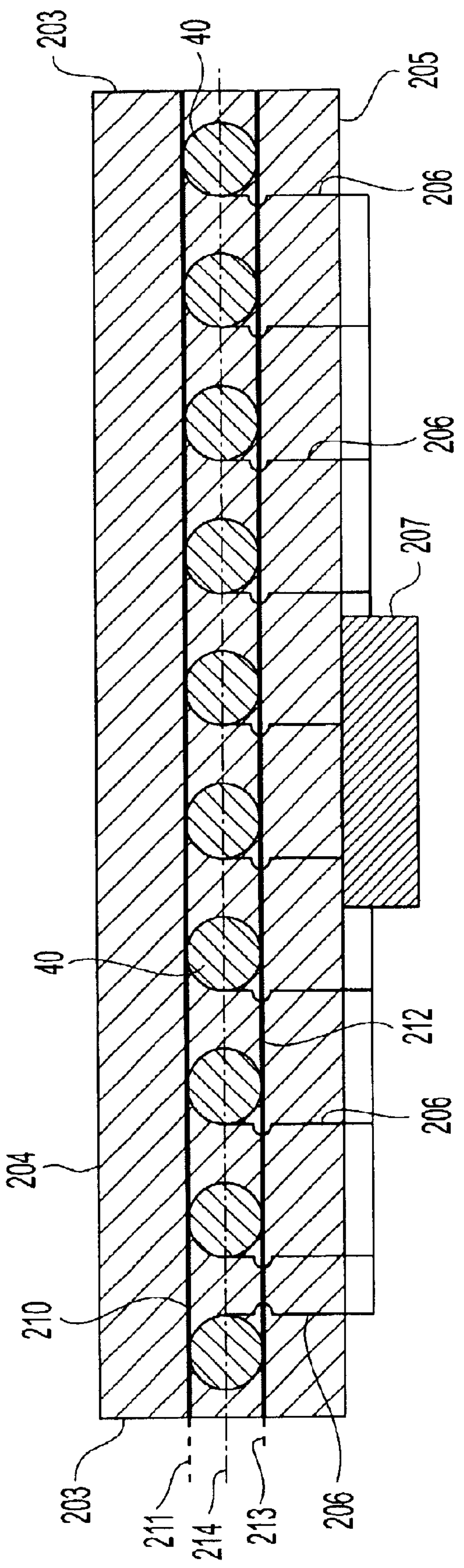



*Fig. 17*

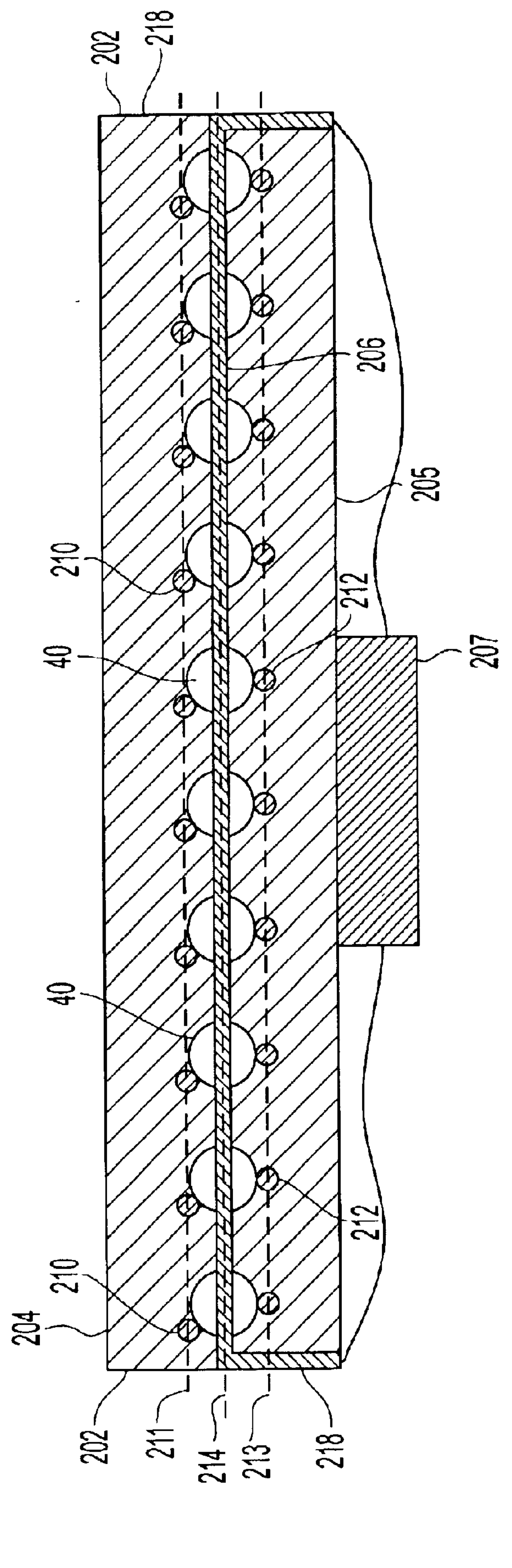



Fig. 18

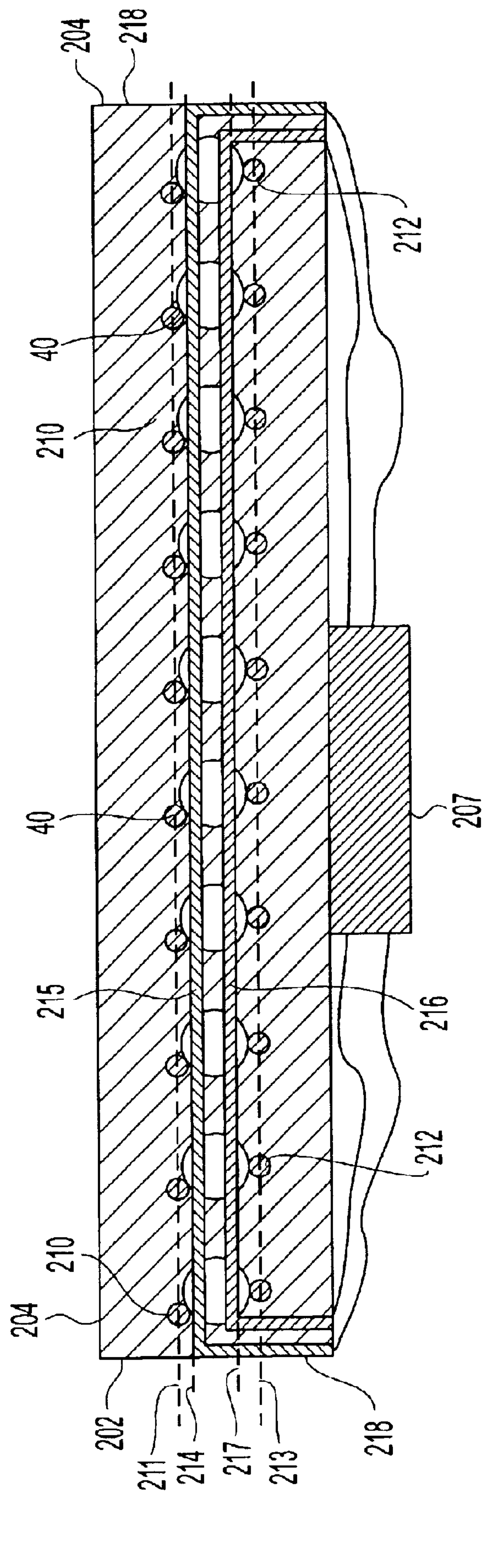

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Fig. 19

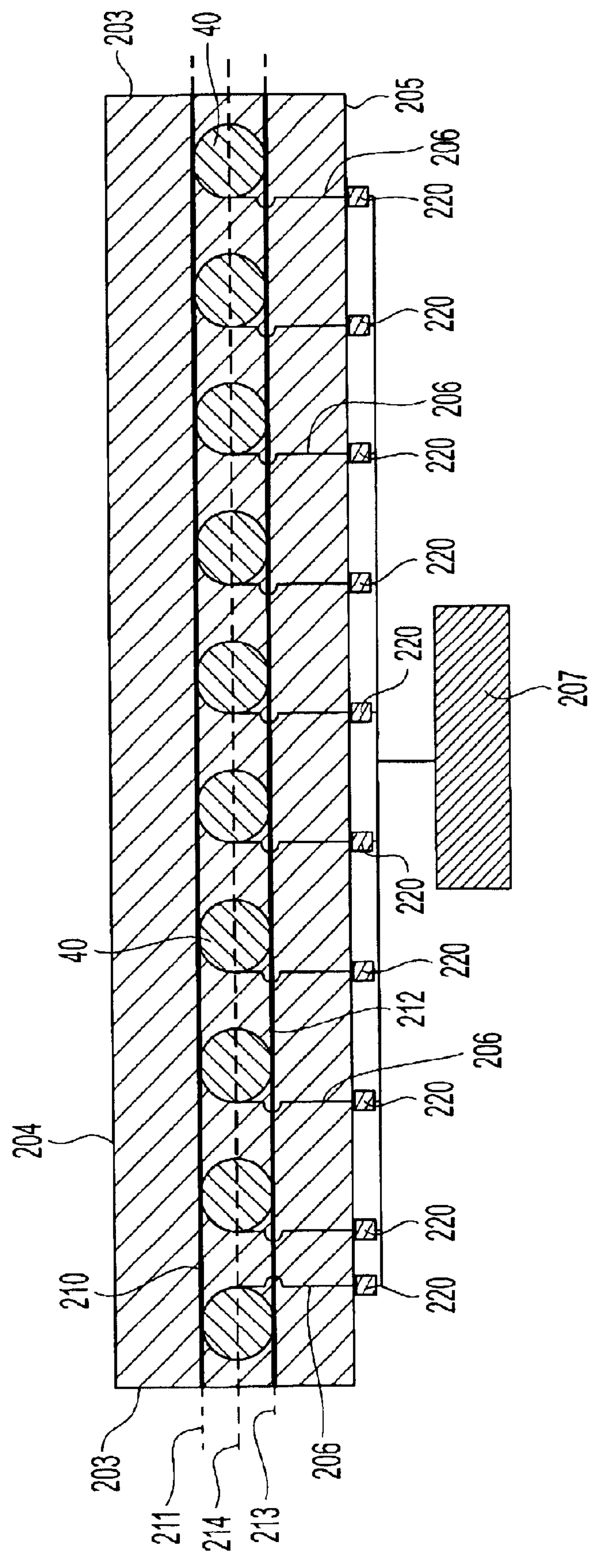
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Fig. 20

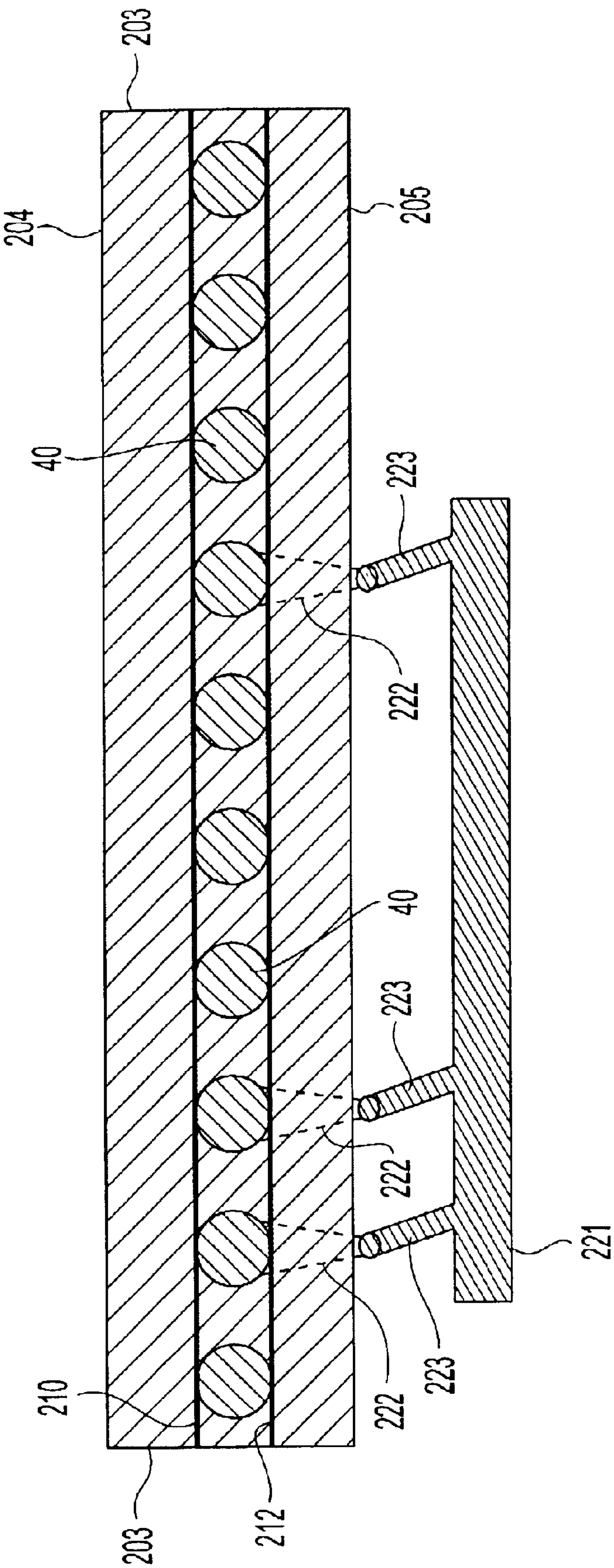


Fig. 21

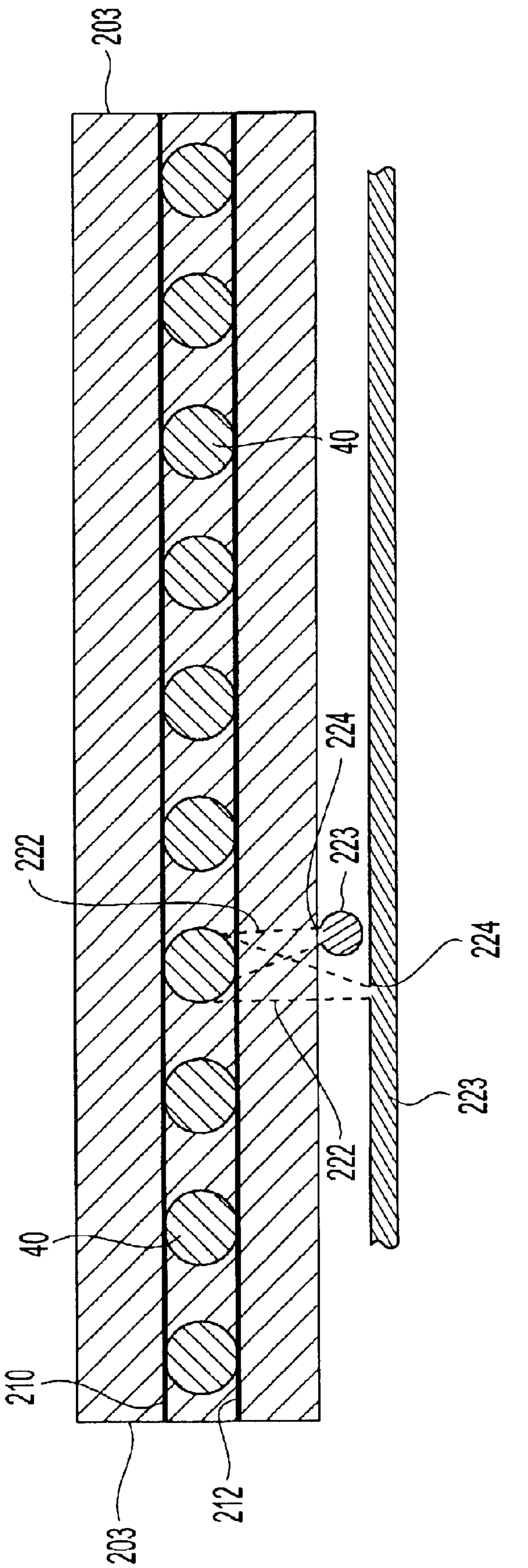


Fig. 22

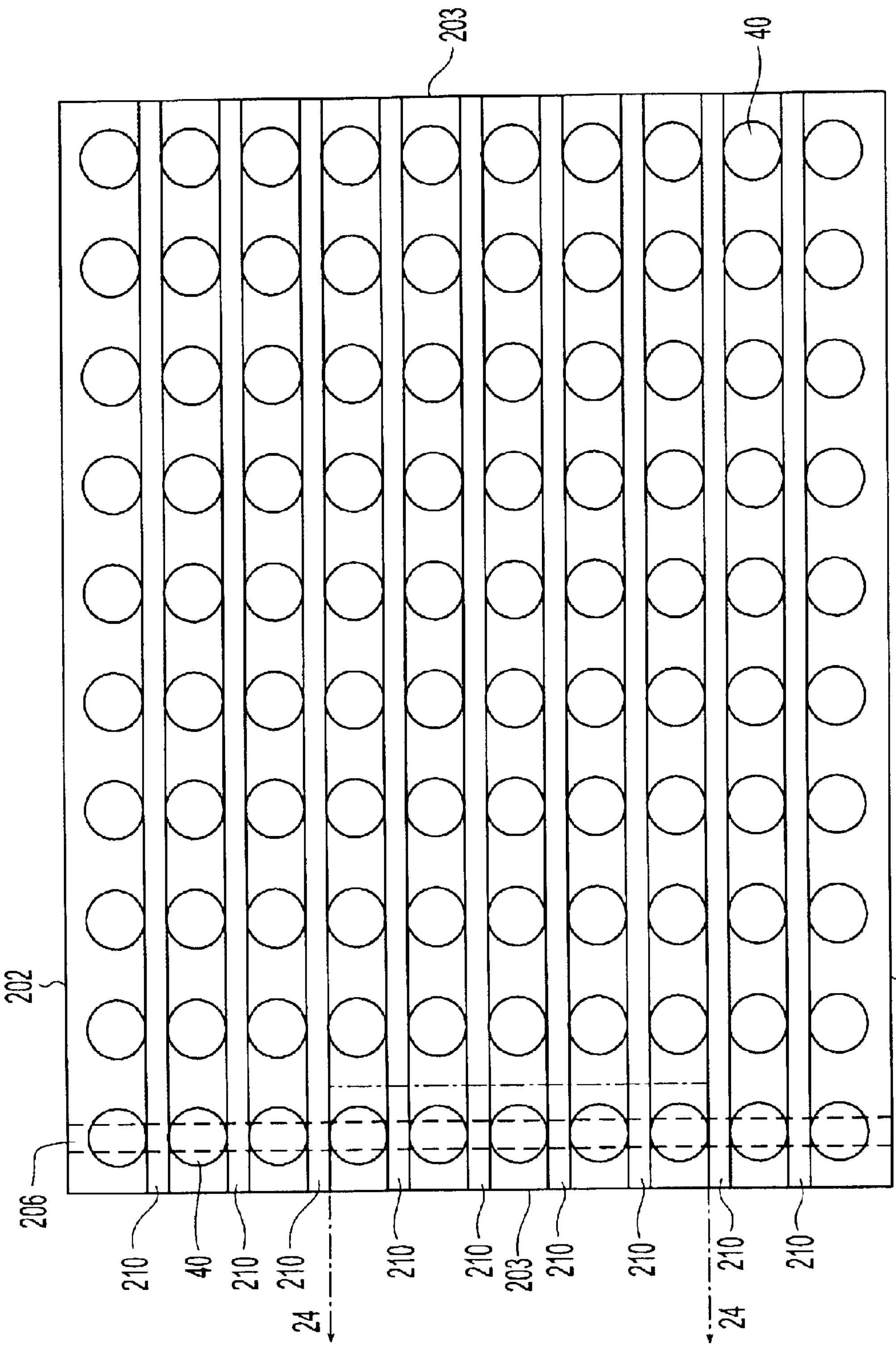
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*Fig. 23*

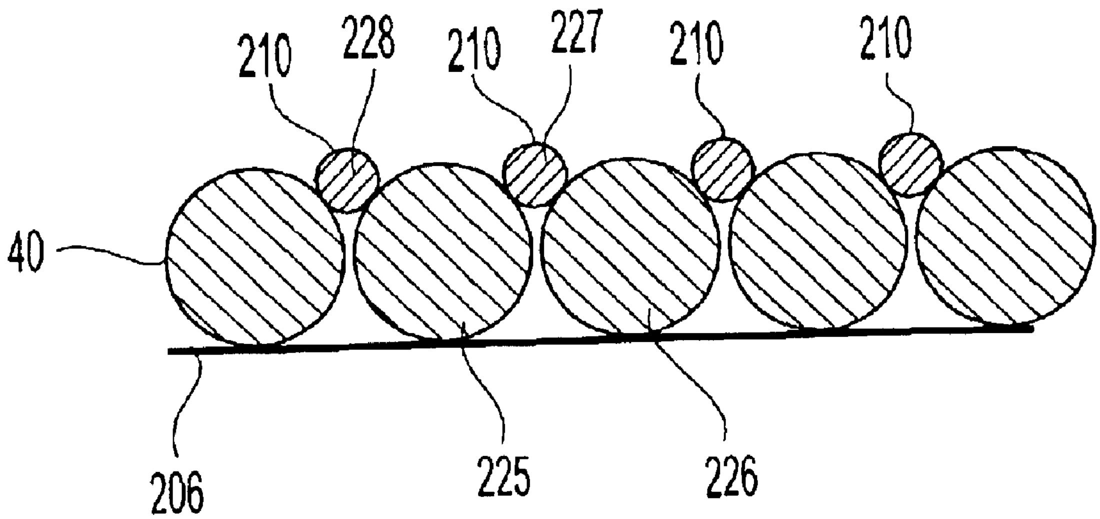


*Fig. 24*

# METHOD AND APPARATUS FOR ADDRESSING MICRO-COMPONENTS IN A PLASMA DISPLAY PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The following application is a Continuation-In-Part of co-pending U.S. patent application Ser. No. 09/697,345 filed Oct. 27, 2000 now U.S. Pat. No. 6,570,335.

The entire disclosures of U.S. patent application Ser. Nos. 09/697,498, 09/697,346, 09/697,358, and 09/697,344 all of which were filed on Oct. 27, 2000 are hereby incorporated herein by reference. In addition, the entire disclosures of the following applications filed on the same date as the present application are hereby incorporated herein by reference: Method for On-line Testing of a Light-Emiting Panel; Design, Fabrication, Testing and Conditioning of Micro-Components for Use in a Light-Emitting Panel; Liquid Manufacturing Process for Panel Layer Fabrication; and Use of Printing and Other Technology for Micro-Component Placement.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods and systems for addressing and energizing micro-components in a light-emitting display.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.



Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is

particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## SUMMARY OF THE INVENTION

The present invention provides a light-emitting display or panel that can function as a large-area radiation source, as an energy modulator, as a particle detector, or as a flat-panel display such as a plasma-type display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

The light-emitting display is used as a large area radiation source. By configuring the light-emitting display to emit ultraviolet (UV) light, the display has application for curing, painting, and sterilization. With the addition of one or more phosphor coatings to convert the UV light to visible white light, the display also has application as an illumination source.

Alternatively, the light-emitting display may be used as a plasma-switched phase array by configuring the display in a microwave transmission mode. The display is configured such that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the display can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift, directing the microwaves out of a specific aperture in the display, or a combination thereof.

Additionally, the light-emitting display is used for particle/photon detection. In this embodiment, the light-emitting display is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting display is used as a flat-panel display. This display can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making it ideally suited for home, office, theaters and billboards. In addition, this display can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one embodiment of the present invention, a light-emitting display is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes, forming plasma and emitting radiation.

In another embodiment of the present invention, the plurality of sockets include a cavity that is patterned in the first substrate and at least two electrodes adhered to the first substrate, the second substrate or any combination thereof.

The plurality of sockets can include a cavity that is patterned in the first substrate and at least two electrodes that are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting display without the radiation crossing the electrodes.

In another embodiment, the first substrate includes a plurality of material layers and a socket formed by selectively removing a portion of the plurality of material layers to form a cavity. At least one electrode is disposed on or within the material layers.

The socket can include a cavity patterned in a first substrate, a plurality of material layers disposed on the first substrate so that the plurality of material layers conform to the shape of the socket and at least one electrode disposed within the material layers.

In one embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity.

The present invention is also directed to methods of addressing and triggering selected micro-components in the light-emitting display and to configurations of the light-emitting display that support these addressing methods. For example, the light-emitting display can be divided, either logically or physically into a plurality of electrically coupled panels. Each one of these panels can be provided with separate circuitry to address and trigger the micro-components contained within that particular panel. The function of sustaining the micro-components components is preferably handled simultaneously for all of the micro-components in the display. The panels can be addressed in parallel, providing for more efficient display operation. In addition, the triggering electrodes can be attached to voltage sources directly through the back of the panel or at the junctions of the panels, simplifying the circuitry and addressing schemes and increasing manufacturing flexibility by enabling the manufacture of multiple display sizes on a single fabrication line.

In order to decrease the voltages necessary to address and trigger selected micro-components as well as to eliminate the cost associated with high voltage electronics, the display includes one or more voltage multipliers. When combined with a display divided into panels, at least one voltage multiplier is provided for each panel. Addressing of micro-components can then be handled with low voltage, i.e. from about 0 volts up to about 20 volts, circuitry and then this low voltage can be increased or ramped-up by the voltage multiplier just prior to delivery to the selected micro-components.

Selected individual micro-components in the display of the present invention can also be triggered using light. A pure two electrode configuration is used to simultaneously subject all of the micro-components to a sustain voltage below the trigger voltage. Light or photons from a light source are then directed to the selected micro-components, causing an effective decrease in the triggering voltage of the gas of those micro-components and producing radiation.

Another arrangement of light-emitting display provides for adequate operation of the display using only about half the number of sustain electrodes. In this arrangement, the sustain electrodes are disposed between parallel rows of micro-components, and each sustain electrode is electrically connected to the micro-components in both rows between which it is disposed. Therefore, one sustain electrode can be used to address two micro-components simultaneously, one micro-component on either side of the sustain electrode. Therefore, the total number of sustain electrodes needed to address all of the micro-components is reduced, preferably by about 50%.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. **1** depicts a portion of a light-emitting display showing the basic structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention;

FIG. **2** depicts a portion of a light-emitting display showing the basic structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention;

FIG. **3**A shows an example of a cavity that has a cube shape;

FIG. **3**B shows an example of a cavity that has a cone shape;

FIG. **3**C shows an example of a cavity that has a conical frustum shape;

FIG. **3**D shows an example of a cavity that has a paraboloid shape;

FIG. **3**E shows an example of a cavity that has a spherical shape;

FIG. **3**F shows an example of a cavity that has a cylindrical shape;

FIG. **3**G shows an example of a cavity that has a pyramid shape;

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape;

FIG. **3**I shows an example of a cavity that has a parallelepiped shape;

FIG. **3**J shows an example of a cavity that has a prism shape;

FIG. **4** shows the socket structure from a light-emitting display of an embodiment of the present invention with a narrower field of view;

FIG. **5** shows the socket structure from a light-emitting display of an embodiment of the present invention with a wider field of view;

FIG. **6**A depicts a portion of a light-emitting display showing the basic structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration;

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes;

FIG. **7**A depicts a portion of a light-emitting display showing the basic structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration;

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode;

FIG. **8** depicts a portion of a light-emitting display showing the basic structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes;

FIG. **9** depicts a portion of a light-emitting display showing the basic structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration;

FIG. **10** depicts a portion of a light-emitting display showing the basic structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration;

FIG. **11** depicts a portion of a light-emitting display showing the basic structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes;

FIG. **12** shows an exploded view of a portion of a light-emitting display showing the basic structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration;

FIG. **13** shows an exploded view of a portion of a light-emitting display showing the basic structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration;

FIG. **14** shows an exploded view of a portion of a light-emitting display showing the basic structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes;

FIG. **15** is a schematic representation from the front of a light-emitting display of the present invention constructed from a plurality of panels;

FIG. **16** is a schematic representation of one panel thereof;

FIG. **17** is a view line **17—17** of FIG. **16**;

FIG. **18** is a view of an embodiment of the panel through line **18—18** of FIG. **16**;

FIG. **19** is a view of another embodiment of the panel of in the view of FIG. **18**;

FIG. **20** is another embodiment of the view of FIG. **17** containing voltage multipliers;

FIG. **21** is a schematic representation of the view of FIG. **17** of an embodiment of the panel for use with photo-addressing;

FIG. **22** is a schematic representation of another embodiment of a panel of FIG. **21** photo-addressing;

FIG. **23** is a schematic representation from the front of an embodiment of the panel providing for a decreased number of sustain electrodes; and

FIG. **24** is a view through line **24—24** of FIG. **23**.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting display. In particular, preferred embodiments are directed to light-emitting displays and to a web fabrication process for manufacturing light-emitting displays.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting display includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrates may be made of a material that dissipates heat from the light-emitting display. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting displays, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting display according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, aspherical, capillary shaped and capillary shaped with pinched regions also referred to as sausage shaped. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting display according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. Further, rare gas halide mixtures such as xenon chloride, xenon flouride and the like are also suitable plasma-forming gases. Rare gas halides are efficient radiators having radiating wavelengths over the approximate range of 190 nm to 350 nm., i.e., longer than that of pure xenon (147 to 170 nm). Using compounds such as xenon chloride that radiates near 310 nm results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed above. As this description is not limiting, one skilled in the art would recognize other gasses or gas mixtures that could also be used. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

There are a variety of coatings **300** (FIG. **2**) and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting display. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** (FIG. **1**) may be disposed on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

The micro-component **40** structures of the present invention yield a more efficient utilization of both the time available and the energy necessary to excite one or more micro-components. In conventional displays, adjacent pixels are not completely or adequately isolated from one another, and the ultraviolet, visible, and infrared radiation and charged species (ions and/or electrons) generated in one pixel can either excite phosphors in communicating pixels or change charge accumulations that will affect the triggering of these pixels. The time required for this cross-talk from an operating pixel to affect communicating pixels is shorter than the duration of a typical "frame", that is, less that about a thirtieth of a second. The result is poor display performance such as a fuzzy picture. In order to prevent the effects of the radiation and/or charged species from one pixel affecting communicating pixels, the electrodes of the affected pixels need to be completely reset into a known charge state. The pixel is then turned back on or re-addressed. Typically, this occurs multiple times per frame, costing energy and frame time. Micro-component structures that eliminate the need to reset pixels multiple times during each frame save the energy required for such resetting, raising the display efficiency, and allow more time per frame for light emission, raising the display brightness. Resetting pixels multiple times per frame is not required in the sphere-shaped and sausage-capillary-shaped micro-component arrangements of the present invention. Because the gas within each micro-component is separated from gas in the other micro-components and the micro-components are separated by dielectric material, the radiation and charged species generated in the micro-components of the present invention do not affect adjacent micro-components during a frame. Therefore, each pixel does not have to be reset but instead can be addressed once and left running for an entire frame or, if desired, for multiple frames. The light-emitting display of the present invention provides the benefits of getting more lumens out of a display, saving the power and frame time associated with resetting each pixel multiple times per frame, and preventing the generation of excess visible radiation associated with resetting pixels that reduces the display contrast.

As is best shown in FIGS. **3A–3J**, a cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. Suitable shapes for the cavity **55** include, but are not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

Referring to FIGS. **4** and **5**, the size and shape of the socket **30** influence the performance and characteristics of the light-emitting display and are selected to optimize the display's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. For example, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

As illustrated, for example, in FIGS. **3A–3J**, in one embodiment of the light-emitting display, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be one or more layers of a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the light-emitting display as illustrated in FIGS. **4–5**, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either on or within the material layers, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers. The socket **30** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In yet another embodiment of the light-emitting display as shown for example in FIGS. **9–11**, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **65** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **65** may be accomplished by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In an embodiment for making the light-emitting display including a plurality of sockets, as illustrated, for example, in FIGS. **12**–**14**, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming the socket **30**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In each of the above embodiments describing methods of making a socket in a light-emitting display, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above, suitable enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, tuned-circuits, and combinations thereof. In a preferred embodiment of the present invention the enhancement materials may be placed in, or proximate to, each socket by transfer processes, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, mechanical means or combinations thereof.

In another embodiment of the present invention, the method for making the light-emitting display includes disposing at least one electrical enhancement (e.g. transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, tuned-circuits, and combinations thereof), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. Alternate substances or means may also be used to move the electrical enhancements across the substrate. Air can be used to move the electrical enhancements across the substrate. In an embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in the light-emitting display for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, augmenting the frequency at which a micro-component is lit and combinations thereof. In addition, the electrical enhancements may be used in conjunction with the light-emitting display driving circuitry to alter the power requirements necessary to drive the light-emitting display. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting display. In one embodiment, a controller is provided that is connected to the electrical enhancements and is capable of controlling their operation. Having the ability to individually control the electrical enhancements at the pixel or subpixel level provides a means by which the characteristics of individual micro-components may be altered or corrected after fabrication of the light-emitting display. These characteristics include, but are not limited to, the luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting display.

The electrical potential necessary to energize a micro-component **40** is supplied through at least two electrodes. The electrodes may be disposed in the light-emitting display using any technique known to one skilled in the art including, but not limited to, any transfer process, photolithography, xerographic-type processes, plasma deposition, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In a general embodiment of the present invention, a light-emitting display includes a plurality of electrodes, wherein at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting display includes a plurality of electrodes, wherein at least two electrodes are arranged so that the voltage supplied to the electrodes causes one or more micro-components to emit radiation throughout the field of view of the light-emitting display without crossing or intersecting either of the electrodes.

Referring to FIGS. **1** and **2**, in one embodiment where the sockets **30** each include a cavity patterned in the first substrate **10**, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. The electrodes can be placed in the substrates either before the cavity is formed or after the cavity is formed. A sustain electrode **70** is adhered on the second substrate **20** and an address or trigger electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partially disposed within the socket.

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material,layers at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. As is shown, for example, in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, the second sustain electrode **75** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and the first sustain electrode **70** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration, and the address function will be performed between at least one of the sustain electrodes and the address electrode. Energizing a micro-component with this arrangement of electrodes should produce increased luminosity. In a preferred embodiment of the present invention as is shown in FIG. **8**, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing or triggering functions from the sustain electrodes. This arrangement should provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. In addition, by separating the sustain and address electrodes and using different voltage sources to provide the address and sustain functions, different types of voltage sources may be used to provide the address or sustain functions. For example, a lower voltage source can be used to address the micro-components.

In the embodiments as shown in FIGS. **9**–**11** where a cavity **55** is patterned in the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**. At least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. Electrodes formed on the first substrate may be placed either before the cavity is patterned or after the cavity is patterned. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, the second sustain electrode **75** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and the first sustain electrode **70** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration, and the address function will be performed between at least one of the sustain electrodes and the address electrode. Energizing a micro-component with this arrangement of electrodes should produce increased luminosity. As is shown in FIG. **11**, in a preferred embodiment of the present invention, the second sustain electrode **75** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and the first sustain electrode **70** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration separates the addressing function from the sustain electrodes. This arrangement should facilitate simpler and cheaper methods of addressing, sustaining and erasing, because complicated switching methods will not be required since different voltage sources can be used for the sustain and address electrodes. By separating the sustain and address electrodes and using different voltage sources to address and sustain the micro-components, a lower or different type of voltage source may be used to provide the address or sustain functions. For example, a lower voltage source can be used to address the micro-components.

In the embodiments as illustrated in FIGS. **12**–**14**, where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **12**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **13**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. In this mid-plane addressing or triggering configuration, the sustain function is performed by the two sustain electrodes as in the co-planar configuration, and the address or trigger function is performed between at least one of the sustain electrodes and the address electrode. Energizing a micro-component using this arrangement of electrodes should produce increased luminosity. In a preferred embodiment of the present invention as shown in FIG. **14**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration separates the addressing function from the sustain electrodes. This arrangement should provide a simpler and less expensive means of addressing, sustaining and erasing selected micro-components, because complicated switching means are not required as different voltage sources can be used for the sustain and address electrodes. By separating the sustain and address electrodes and using different voltage sources to address and sustain the micro-components a lower or different type of voltage source may be used to provide the address or sustain functions. For example, a lower voltage source can be used to address the micro-components.

The present invention is also directed to devices and methods for addressing selected pixels, subpixels or micro-components in the light emitting or plasma display. The devices and methods employ arrangements and methods of operation of light-emitting displays that increase the operating efficiency of these displays.

Referring to FIG. **15**, to provide for improved addressing of micro-components, the light-emitting display **200** is broken down, either physically or logically into a plurality of electrically interconnected panels **201**. A light emitting display can contain one or more of these panels **200**. Each panel **201** contains an array of micro-components or pixels such as a 1×1, 10×10, or 100×100 micro-component **40** or pixel grid or array.

As is best shown in FIGS. **15–17** each panel **201** includes first and second sets of opposing edges **202, 203**, a front **204** and a back **205** opposite the front **204**. Both the front **204** and the back **205** of the panel **201** are bound by the first and second sets of opposing edges **202, 203**. The front **204** contains a plurality of the micro-components **40** of the present invention which are capable of emitting radiation when exposed to a triggering voltage. Preferably, the micro-components **40** emit ultra violet radiation. The voltages necessary to address, trigger, and sustain selected micro-components **40** in the panels **201** can be supplied by the various arrangements of the electrodes, substrates, and dielectrics of the present invention.

As is best shown in FIG. **17**, at least one triggering electrode **206** is provided in the panel **201** and is electrically coupled to at least one of the micro-components **40**. In this embodiment, the triggering electrode **206** is passed through the panel **201** to the back **205** of the panel **201**. At least one voltage source **207** is located at the back **205** of the panel **201** between the first and second sets of edges **202, 203** and is electrically coupled to the triggering electrode **206**. Suitable voltage sources **207** are capable of supplying a triggering voltage to the micro-components **40** through the triggering electrode **206**. Alternatively, the panel **201** includes a plurality of triggering electrodes **206** electrically coupled to the plurality of micro-components **40**. In addition, a plurality of voltage sources **207** can be electrically coupled to the plurality of triggering electrodes **206**.

As is best illustrated in FIG. **16** the micro-components **40** within each panel **201** are addressed using row and column type addressing devices or drivers. Therefore, the plurality of micro-components **40** in each panel **201** are disposed in a common plane and are arranged in that plane in a grid pattern having a plurality of parallel rows **208** and a plurality of parallel columns **209** arranged orthogonal to the plurality of rows **208**. Preferably, each micro-component **40** is at a point of intersection of a row **208** and column **209** or where the rows **208** and columns **209** cross each other.

Each panel **201** also includes a plurality of parallel sustain electrodes electrically coupled to the micro-components. Preferably, the sustain electrodes are arranged parallel to one of the rows and columns. The sustain electrodes can be disposed in various layers or locations throughout the panel **201** and the substrates or layers that make up each panel **201**. In a preferred embodiment as is shown in FIG. **17**, the sustain electrodes are divided and arranged into a first set of sustain electrodes **210** disposed in a first plane **211** parallel to the front **204** and back **205** and a second set of sustain electrodes **212** disposed in a second plane **213** spaced from the first plane **211** and parallel thereto.

The triggering electrodes **206** for delivering the necessary triggering voltage to the micro-components **40** are electrically coupled to each micro-component **40** at a third plane **214** parallel to the first plane **211** and located between the first plane **211** and the second plane **213**. Alternatively, the triggering electrodes **206** are provided as a plurality of parallel triggering electrodes **206** electrically coupled to the plurality of micro-components **40**. In one embodiment, shown in FIG. **18** and referred to as a triode embodiment because it contains two sustain and one triggering electrode for a total of three electrodes in contact with each micro-component **40**, the triggering electrodes **206** are arranged to cross, although not necessarily intersect or contact, the first and second sets of sustain electrodes perpendicularly and are disposed in the third plane **214** parallel to the first plane **211** and located between the first and second planes. Other triode arrangements are also possible as shown for example in FIG. **13**.

In another embodiment shown in FIG. **19** and referred to as a electrode embodiment because it contains two sustain electrodes and two triggering electrodes for a total of four electrodes to address each micro-component **40**, the triggering electrodes **206** are arranged orthogonal to the first and second sets of sustain electrodes **210, 212**. Similar to the triode arrangement, the triggering electrodes include a first set of triggering electrodes **215** contained in the third plane **214** that parallel to the first plane **211** and disposed between the first and second planes. In this embodiment, the triggering electrodes also include a second set of triggering electrodes **216** arranged in a fourth plane **217** parallel to the first plane **211**, spaced from the third plane **214**, and located between the first and second planes. Other tetrode arrangements are also possible as shown for example in FIG. **14**.

The light-emitting display **200** can be constructed from at least one of these panels **201**. Preferably, the light-emitting display includes a plurality of the panels **201** arranged in the configuration and shape of the desired display **200** and electrically coupled together. The triggering electrodes **206** can be connected to the micro-components through the back **205** of each of the panels **201**, or each panel **201** can have the micro-components **40** contained therein addressed by an addressing driver or voltage source **207** attached to that panel **201** as shown in FIGS. **18** and **19**. The plurality of voltage sources **207** are electrically coupled to the triggering electrodes **206** at or adjacent the junctions **208** between the panels **201**. The triggering electrodes **206** are preferably arranged in parallel rows that are parallel to either the rows **208** or columns **209** of the panel **201** and perpendicular to the sustain electrodes **210, 212**. The plurality of sustain electrodes **210, 212** are electrically coupled to each micro-component **40** and are capable of simultaneously subjecting all of the micro-components **40** in the entire light-emitting display **200** to a voltage less than the triggering voltage. Connections to a sustain voltage source are made at the edges **219** of the display **200**, and electrical connectivity or continuity among the sustain electrodes in the various panels **210, 212** is maintained at the junctions **218** of the panels **201** (FIG. **15**).

The arrangement of the light emitting display **200** utilizing panels **201** as basic units in larger displays provides benefits and advantages in the manufacture and application of the light-emitting display **200**. Since each panel **201** contains its own set of triggering electrodes, voltage sources and drivers, all of the micro-components **40** in the display do not have to be addressed or triggered as a single display where electrical connections to the triggering electrodes are only made at the edges **219** of the display **200** and all of the micro-components in a row or column of the entire display can only be addressed as a single long series of micro-components. The display **200** is broken down into units or panels and individual micro-components are addressed on a panel-by-panel basis or in a parallel manner. This facilitates the assembly and construction of larger displays, avoids the problems of signal attenuation associated with long lengths of electrodes, and eliminates the problem of increased address times associated with pulse separation in series-type addressing schemes. Further, since the voltages and currents used to sustain and trigger the micro-components **40** generate radio frequencies that interfere with other electronic devices, these radio frequencies must be shielded. Bringing the triggering electrodes through the back **205** of the panels **201**, either directly or at the panel junctions **218**, makes it easier to shield these generated frequencies.

The panels **201** can be physically cut from an assembled web during a continuous manufacturing process or can be defined on a larger display by connecting the individual display panels. The size selected for each panel **201** is preferably the most efficient for making the variety of sizes of light-emitting displays **200** desired. Preferably, the panels **201** are the smallest pieces or units of a display **200** and are not further divided or cut during manufacture.

The triggering voltages can be applied directly by the triggering electrodes **216**, particularly in the tetrode configuration, or can be applied by combining voltages from the sustain and triggering electrodes. Since the cost of the electronics to handle the addressing and triggering of the micro-components increases significantly at higher voltages, it is desirable to decrease or minimize the triggering voltage necessary to cause the micro-components **40** to emit radiation.

One solution is to apply to the micro-component **40** a sustain voltage that is below the triggering voltage. The triggering electrodes **206** would then supply the additional voltage to selected micro-components **40** necessary to trigger emissions. The sustain voltage is applied to all of the micro-components simultaneously through a common electrical bus (not shown) located at the edges **219** of the display **200**. In addition to requiring a lower triggering voltage, this arrangement facilitates the use of sustain electrodes **210, 212** near the front **204** and back **205** of the panels **201** or display **202** where the use of high conductivity metals can be more easily implemented. The triggering voltages would then be applied at interstitial layers where high conductivity materials may be difficult to implement.

Plasma displays emit RF radiation that must be shielded to protect other electronic equipment that is located near the display. In the present invention using a micro-component-based display structure, the panel structure is thinner than conventional plasma display structures, and the drive electronics can be mounted on the back surface of the panel. This allows the connections between the drive electronics and the plasma discharges to be shorter, meaning that the RF radiators are smaller and less effective as radiators. Therefore, the RF shielding requirements of the present invention are less than conventional plasma displays.

In another embodiment as shown, for example in FIG. **20** of the present invention, a voltage multiplier or voltage multiplying circuitry **220** is electrically coupled between the voltage source **207** and the triggering electrode **206**. Suitable voltage multipliers **220** are capable of increasing a supply voltage from the voltage source **220** to the triggering voltage. In one embodiment, the supply voltage or address voltage can be up to about 20 volts. In another embodiment, the supply voltage is about 10 volts. In order to achieve the necessary voltages to trigger an emission in the selected micro-components **40**, suitable voltage multipliers **220** are capable of multiplying a supply voltage from the voltage source **207** by a factor of at least 5. Any type of circuitry capable of producing the necessary voltage increase can be used in the voltage multiplier **220** of the present invention. For example, the voltage multiplier **220** can be a capacitive multiplier. In addition, the voltage multiplier **220** can contain thin film transistors.

The voltage multiplier **220** can be used in combination with the various micro-component **40** and electrode configurations of the light-emitting displays **200**, assembled webs, and panels **201** of the present invention. For example, the voltage multiplier **220** can be combined with the triode and tetrode configurations. In addition, the voltage multiplier **220** can be combined with the back-plane-type addressing or can be employed by itself in the end-type addressing schemes. For example, the light-emitting display **200** of the present invention containing at least one panel **201** having a plurality of micro-components **40**, at least one triggering electrode **206** electrically coupled to at least one of the micro-components **40**, and at least one voltage source **207** electrically coupled to the triggering electrode **206** can include the voltage multiplier **220** of the present invention electrically coupled between the voltage source **207** and the triggering electrode **206**.

In addition to decreasing the voltages necessary to trigger the micro-components **40** and decreasing the length of the triggering electrodes **206** through a back-plane-type addressing arrangement, additional arrangements of the present invention further decrease the amount and size of the electronics necessary to operate the light-emitting display **200** of the present invention by decreasing the number of electrodes required to operate the display. Since the micro-components are light or photosensitive, a light or photon source can be used to address selected micro-components **40** in the light-emitting display. For example, the light-emitting display **200** can include a plurality of micro-components **40** electrically coupled to a plurality of sustain electrodes **210, 212** that are capable of simultaneously subjecting all of the micro-components **40** to a sustain voltage less than the triggering voltage as described above. As is best shown in FIG. **21**, a light delivery device **221** is provided that is capable of simultaneously delivering an amount of light **222** to one or more selected micro-components **40**. The amount of light **222** directed to the selected micro-components **40** is sufficient to create enough free charges, electrons, photo-electrons or carriers in the gas contained in the selected micro-components **40** to depress the required triggering voltage of the gas to a level less than the applied sustain voltage.

Any number of light delivery devices are suitable for use in the present invention to deliver the sufficient amount of light. The light delivery device includes at least one light source. Suitable light sources include lasers, incandescent lights, fluorescent lights, light emitting diodes, and combinations thereof. In addition to the source of light itself, the light delivery device includes a delivery mechanism **223**. In one embodiment, the delivery mechanism includes a plurality of optical fibers. Preferably, as illustrated in FIG. **22**, these optical fibers **223** contain points or holes **224** that allow amounts of light **222**, preferably controllable amounts of light, to pass from or leak out of the optical fiber **223** at predefined or controllable locations. The light delivery device **221** may also contain one or more optical filters, lenses, mirrors, or combinations thereof to direct and control the delivered light **222** as necessary. The light may also be delivered by the waveguides in an integrated photonics system, by a dielectric wedge with controlled escape of internally reflected light across its width, and/or by free-space scanning of one or more laser beams. Since triggering is accomplished with directed light, triggering electrodes are not needed. Therefore, a pure two sustain electrode **210, 221** system can be used.

Referring to FIGS. **23** & **24** in addition to eliminating the triggering electrodes **206** or as an alternative to eliminating the need for triggering electrodes **206**, configurations of the light-emitting display **200** of the present invention are possible which decrease or minimize the number of sustain electrodes **210, 212** in the display **200**. For example, the light-emitting display **200** can include a plurality of sustain electrodes **210** arranged in a plurality of parallel rows and a plurality of trigger electrodes **206** perpendicularly crossing the sustain electrodes **210** to form a grid. Each of the plurality of micro-components **40** contained in the display **200** is electrically coupled to the trigger electrodes **206** and disposed between and electrically coupled to two adjacent parallel rows of sustain electrodes **210** so as to increase the fill factor between adjacent micro-components. The fill factor is a measurement of the amount of dark space between the adjacent rows of micro-components. Decreasing the fill factor decreases the amount of dark space.

In order to address selected micro-components in this decreased sustain electrode configuration a triggering or addressing voltage is simultaneously delivered to at least two micro-components **225, 226** disposed in adjacent parallel rows using one address electrode **206** and one sustain electrode **227** that is electrically coupled to both micro-components **225, 226** and generally disposed there between. The actual micro-component **225** of the two micro-components **225, 226** to be sustained is selected, and a sustaining voltage is supplied to that micro-component **225** through the two sustain electrodes **227, 228** located on either side of the selected micro-component **225**. Selection of the micro-components **225, 226** to be triggered is handled by the controller and control circuitry for the light-emitting display. Preferably, the control logic used will address and sustain the micro-components so that only one of the two micro-components initially addressed will actually be fully triggered to emission.

When the apparatus for photo-addressing selected micro-components is used, all of the micro-components in the panel or light-emitting display are simultaneously exposed to a sustain voltage less than the triggering voltage necessary to cause the gas contained in the micro-components to emit radiation. The one or more gas containing micro-components to be energized are selected, and an amount of light **222** sufficient to create enough free charges to depress the required triggering voltage in the selected micro-components **40** to a level less than the applied sustain voltage is delivered to each selected micro-component. These micro-components **40** are then triggered to emit radiation and are sustained or terminated as desired by voltages delivered through the sustain electrodes **210, 212**. In one embodiment, at least two independent light sources, light delivery devices, or light delivery mechanisms that combine to create the sufficient amount of light are delivered to the selected micro-components. Preferably, optical fibers, waveguides in an integrated photonics system, a dielectric wedge with controlled escape of internally reflected light across its width, free-space scanning of one or more laser beams, or a combination of these are used to provide the two independent light sources.

In order to address selected micro-components in a panel **201** or display **200** using the voltage multiplier **200** of the present invention, one or more gas containing micro-components **40** to be energized or triggered are selected and are addressed using an addressing voltage less than the triggering voltage necessary to cause the contained gas to emit radiation. This address voltage is then increased to a level that is at least equal to the triggering voltage. This increased voltage is delivered to the micro-component, and the gas is energized. In an alternative embodiment, the address voltage is increased to a level less than the triggering voltage but sufficient to combined with other applied voltages, such as the sustain voltage, to trigger the selected micro-components **40**. In this embodiment, all of the micro-components **40** are simultaneously exposed to a sustain voltage less than the triggering voltage.

In order to address the light-emitting display **200** of the present invention as a plurality of connected panels **201** or unit displays, the display is divided, either physically or logically, into a plurality of the panels **201** of the present invention. The micro-components **40** to be energized are then selected and addressed in each panel separately. That is the micro-components are identified not only by location in the display **200** but also by panel **201** and location within that panel **201**. Once adequately addressed, a triggering voltage is delivered to the selected micro-components. In one embodiment, at least one addressing device or voltage source **207** is provided for each panel **201**, and the addressing device is attached directly to the panel **201**. Preferably, the addressing device is used to address the selected micro-components in the panel **201** to which it is attached.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A panel for use in a light-emitting display, the panel comprising:

a first set of opposing edges;

a second set of opposing edges;

a front bordered by the first and second opposing edges and comprising a plurality of micro-components capable of emitting radiation when exposed to a triggering voltage;

a back opposite the front;

at least one triggering electrode electrically coupled to at least one of the micro-components, the triggering electrode passing through the panel to the back; and

at least one voltage source electrically coupled to the triggering electrode

at the back between the first and second sets of edges.

2. The panel of claim 1, wherein the voltage source is capable of supplying a triggering voltage to the micro-components through the triggering electrode.

3. The panel of claim 1, further comprising:

a plurality of triggering electrodes electrically coupled to the plurality of micro-components; and

a plurality of voltage sources electrically coupled to the plurality of triggering electrodes.

4. The panel of claim 1, wherein the plurality of micro-components are arranged in a grid pattern having a plurality of parallel rows and a plurality of parallel columns perpendicular to the plurality of rows, each micro-component disposed at a point of intersection of a row and column.

5. The panel of claim 4, further comprising:

a plurality of parallel sustain electrodes electrically coupled to the micro-components.

6. The panel of claim 5, wherein the sustain electrodes are arranged parallel to one of the rows and columns.

7. The panel of claim 6, wherein the sustain electrodes further comprise:

a first set of sustain electrodes disposed in a first plane parallel to the front and back; and

a second set of sustain electrodes disposed in a second plane spaced from the first plane and parallel thereto.

8. The panel of claim 7, further comprising a plurality of parallel triggering electrodes electrically coupled to the plurality of micro-components.

9. The panel of claim 8, wherein the triggering electrodes are perpendicular to the first and second sets of sustain electrodes and are arranged in a third plane parallel to the first plane and disposed between the first and second planes.

10. The panel of claim 8, wherein the triggering electrodes further comprise:

a first set of triggering electrodes perpendicular to the first and second sets of sustain electrodes and arranged in a third plane parallel to the first plane and disposed between the first and second planes; and

a second set of triggering electrodes perpendicular to the first and second sets of sustain electrodes and arranged in a fourth plane parallel to the first plane, spaced from the third plane, and disposed between the first and second planes.

11. The panel of claim 1, further comprising a voltage multiplier electrically couple between the voltage source and the triggering electrode.

12. The panel of claim 11, wherein the voltage multiplier is capable of increasing a supply voltage from the voltage source to the triggering voltage.

13. The panel of claim 12, wherein the supply voltage is about 10 volts.

14. The panel of claim 11, wherein the voltage multiplier is capable of multiplying a supply voltage from the voltage source by a factor of at least 5.

15. The panel of claim 11, wherein the voltage multiplier is a capacitive multiplier.

16. The panel of claim 11, wherein the voltage multiplier comprises thin film transistors.

17. A light-emitting display comprising at least one panel according to claim 1.

18. The light-emitting display of claim 17, comprising a plurality of the panels electrically coupled together.

19. A light-emitting display comprising:

a plurality of panels electrically coupled to one another at a plurality of junctions, each panel comprising:

a plurality of micro-components capable of emitting radiation when exposed to a triggering voltage of sufficient strength, the micro-components arranged in a grid comprising a plurality of rows and plurality of columns perpendicular to the rows;

a plurality of sustain electrodes electrically coupled to each micro-component and capable of simultaneously subjecting all of the micro-components to a voltage less than the triggering voltage;

a plurality of triggering electrodes electrically coupled to each micro-component; and

a plurality of voltage sources electrically coupled to the triggering electrodes at the junctions.

20. A light-emitting display comprising:

a plurality of micro-components capable of emitting radiation when exposed to a triggering voltage;

a plurality of sustain electrodes electrically coupled to each micro-component and capable of simultaneously subjecting all of the micro-components to a sustain voltage less than the triggering voltage;

a light delivery device capable of simultaneously delivering an amount of light to one or more selected micro-components, the amount of light sufficient to create enough free charges in the selected micro-components to depress the required triggering voltage in the selected micro-components to a level less than the applied sustain voltage.

21. The light-emitting display of claim 20, wherein the light delivery device comprises at least one light source.

22. The light-emitting display of claim 21, wherein the light source is a laser, an incandescent light, a fluorescent light, or a light emitting diode.

23. The light-emitting display of claim 21, wherein the light delivery device further comprises a delivery mechanism.

24. The light-emitting display of claim 23, wherein the delivery mechanism comprises a plurality of optical fibers.

25. The light-emitting display of claim 23, wherein the delivery mechanism further comprises lenses or mirrors.

26. A light-emitting display comprising:

a plurality of sustain electrodes arranged in a plurality of parallel rows;

a plurality of trigger electrodes perpendicularly intersecting the sustain electrodes to form a grid;

a plurality of micro-spheres capable of emitting radiation when exposed to a triggering voltage of sufficient strength, each micro-sphere electrically coupled to the trigger electrodes and disposed between and electrically coupled to two adjacent parallel rows of sustain electrodes so as to increase the fill factor between adjacent micro-spheres.

27. A light-emitting display comprising:

a panel comprising a plurality of micro-components capable of emitting radiation when exposed to a triggering voltage;

at least one triggering electrode electrically coupled to at least one of the micro-components;

at least one voltage source electrically coupled to the triggering electrode; and

a voltage multiplier electrically couple between the voltage source and the triggering electrode.

**28**. The display of claim **27**, wherein the voltage multiplier is capable of increasing a supply voltage from the voltage source to the triggering voltage.

**29**. The display of claim **28**, wherein the supply voltage is about 10 volts.

**30**. The display of claim **27**, wherein the voltage multiplier is capable of multiplying a supply voltage from the voltage source by a factor of at least 5.

**31**. The panel of claim **27**, wherein the voltage multiplier is a capacitive multiplier.

**32**. The panel of claim **27**, wherein the voltage multiplier comprises thin film transistors.

**33**. A method for addressing one or more micro-components selected from a plurality of micro-components in a light emitting display by triggering a gas contained within the selected micro-components to emit radiation, the method comprising:

selecting one or more gas containing micro-components to be energized;

addressing the selected micro-components using an addressing voltage less than the triggering voltage necessary to cause the gas to emit radiation;

increasing the addressing voltage to at least the triggering voltage; and

energizing the gas.

**34**. The method of claim **33**, wherein:

the method further comprises simultaneously exposing all of the micro-components to a sustain voltage less than the triggering voltage; and

the step of increasing the addressing voltage further comprises increasing the addressing voltage to a level such that the sum of the increased addressing voltage and the sustain voltage at the selected micro-components is at least equal to the triggering voltage.

**35**. The method of claim **33**, wherein the address voltage is about 10 volts.

**36**. The method of claim **33**, wherein the step of increasing the addressing voltage multiplies the addressing voltage by a factor of at least five.

**37**. A method for addressing one or more micro-components selected from a plurality of micro-components in a light emitting display by triggering a gas contained within the selected micro-components to emit radiation, the method comprising:

dividing the display into a plurality of panels;

selecting one or more gas containing micro-components to be energized;

addressing the selected micro-components in each panel separately;

delivery a triggering voltage to the selected micro-components sufficient to cause the gas in the selected micro-components to emit radiation.

**38**. The method of claim **37**, further comprising providing at least one addressing device for each panel.

**39**. The method of claim **38**, wherein the addressing device is attached to the panel.

**40**. The method of claim **39**, wherein the addressing device is used to address the selected micro-components in the panel to which it is attached.

**41**. The method of claim **37**, further comprising:

addressing the selected micro-components using an addressing voltage less than the triggering voltage necessary to cause the gas to emit radiation; and

increasing the addressing voltage to at least the triggering voltage.

**42**. A method for addressing one or more micro-components selected from a plurality of micro-components in a light emitting display by triggering a gas contained within the selected micro-components to emit radiation, the method comprising:

simultaneously exposing all of the micro-components to a sustain voltage less than the triggering voltage necessary to cause the gas contained in the micro-components to emit radiation;

selecting one or more gas containing micro-components in to be energized;

delivering to each selected micro-component an amount of light sufficient to create enough free charges in the selected micro-components to depress the required triggering voltage in the selected micro-components to a level less than the applied sustain voltage.

**43**. The method of claim **42**, wherein the step of delivering a sufficient amount of light comprises causing at least two independent light sources that combine to create the sufficient amount of light to deliver this combined light to the selected micro-components.

**44**. The method of claim **43**, wherein the light sources comprise optical fibers.

**45**. A method for addressing one or more micro-components selected from a plurality of micro-components in a light emitting display by triggering a gas contained within the selected micro-components to emit radiation, the method comprising:

arranging the micro-components in a plurality of parallel rows;

providing a plurality of sustain electrodes arranged parallel to the micro-component rows, each sustain electrode disposed between adjacent rows of micro-components and electrically connected to the micro-components in those rows;

providing a plurality of address electrodes arranged perpendicular to the sustain electrodes and the rows of micro-components;

simultaneously delivering a triggering voltage to at least two micro-components disposed in adjacent rows using one address electrode and one sustain electrode disposed between the adjacent rows;

selecting a micro-component to be sustained; and

sustaining that micro-component by supplying a sustaining voltage to the micro-component through two sustain electrodes located on either side of the selected micro-component.

**46**. The method of claim **45**, wherein the sustain electrodes are disposed between adjacent rows of micro-components so as to increase the fill factor between the rows of micro-components.

* * * * *

US006822626B2

(12) **United States Patent**
**George et al.**

(10) **Patent No.: US 6,822,626 B2**
(45) **Date of Patent: Nov. 23, 2004**

(54) **DESIGN, FABRICATION, TESTING, AND CONDITIONING OF MICRO-COMPONENTS FOR USE IN A LIGHT-EMITTING PANEL**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/214,768**

(22) Filed: **Aug. 9, 2002**

(65) **Prior Publication Data**

US 2004/0175854 A1 Sep. 9, 2004

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 09/697,358, filed on Oct. 27, 2000, now Pat. No. 6,762,566.

(51) **Int. Cl.**[7] .................................................. **G09G 3/28**

(52) **U.S. Cl.** ...................... **345/60**; 315/169.3; 315/312; 315/313; 345/61; 345/67

(58) **Field of Search** ............................. 315/169.3, 312, 315/313; 345/60, 61, 67; 438/30, 149, 151, 152; 313/582

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 A | | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 A | | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 A | | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 A | | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 A | | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 A | | 11/1985 | Dick | 340/775 |
| 4,563,617 A | * | 1/1986 | Davidson | 315/312 |
| 4,591,847 A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 A | | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 A | | 4/1987 | Rezanka | 346/75 |
| 4,697,123 A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 A | | 3/1988 | Dick | 315/169.3 |
| 4,833,463 A | | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 A | | 12/1989 | Parker | 313/634 |
| 4,912,364 A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 A | | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 A | | 11/1991 | Aufderheide et al. | 156/269 |

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

(List continued on next page.)

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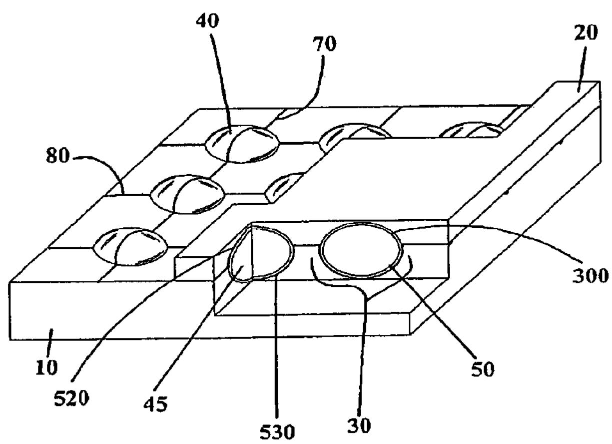
(57) **ABSTRACT**

A method of forming micro-components is disclosed. The method includes pretesting and conditioning of the micro-components. The micro-components that fail testing or conditioning are discarded, and those remaining are assembled into a panel.

**24 Claims, 14 Drawing Sheets**



## U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,194,027 | A | * | 3/1993 | Kruskopf et al. | 445/24 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | * | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | * | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | * | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | * | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | | 11/2001 | Sasaki et al. | 239/568 |
| 6,545,422 | B1 | * | 4/2003 | George et al. | 315/169.3 |
| 2001/0008825 | A1 | | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | | 2/2002 | Miyashita et al. | 313/495 |

## OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

Sheats, James, "Introduction to Organic Light–Emitting Diodes (OLEDs)"[online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll–to–Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www–star.stanford.edu/~vlf/plasma_display/index.htm.

Smilgys, Russell, et al, "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21–25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self–Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar., 2001, pp. 17–17–24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, no. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7 , 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/$e_{13}$ read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001, [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved form the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco Plasma Wall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Prodcuts/Plasma/PL42cx.htm.

"Runco PlasmaWall Pl–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco PlasmaWall™ PL–61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1–7.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb., 1999, pp. 14–15.

Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Kurihara, M., Makabe, T., "Two Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct., 1999, pp. 1372–1378.

Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

"Transparent Conductive Coatings,"Copyright 1998, 4 pp.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep., 1997, pp. 1241–.

Jacobson, et al., "The Last Book"[online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.

"Flat Panel Displays in Perspective," 44 pp., Sep., 1995.

Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

International Search Report for application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Preliminary Examination Report for application No. PCT/US01/42782, dated Jun. 4, 2003.

Preliminary Examination Report for application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

* cited by examiner

Fig. 1

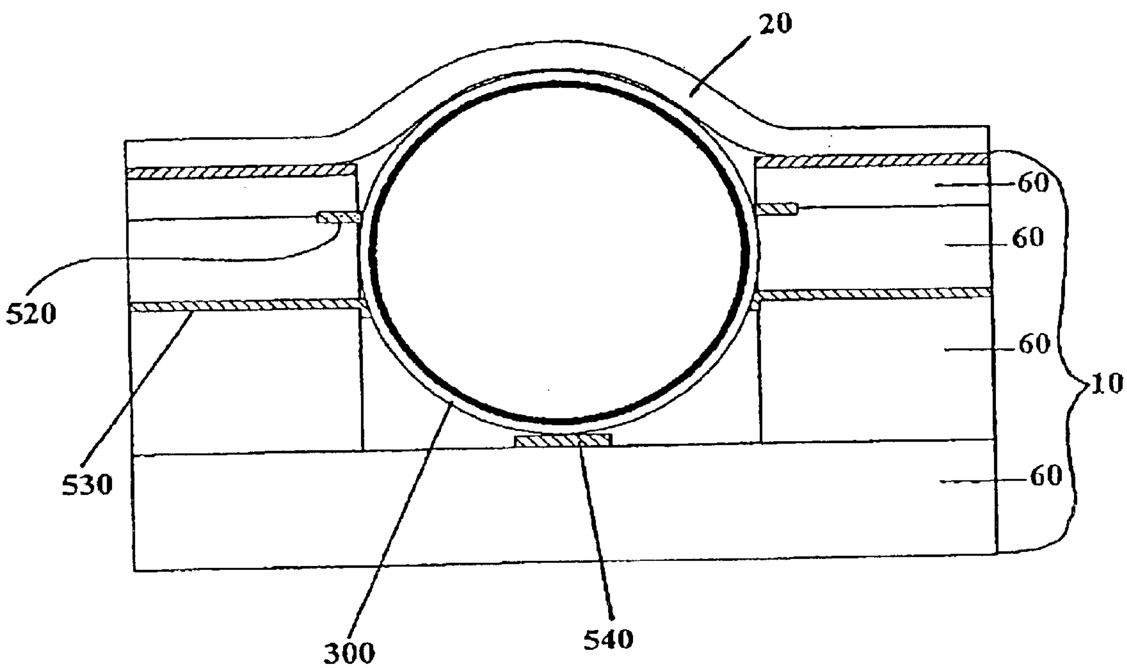
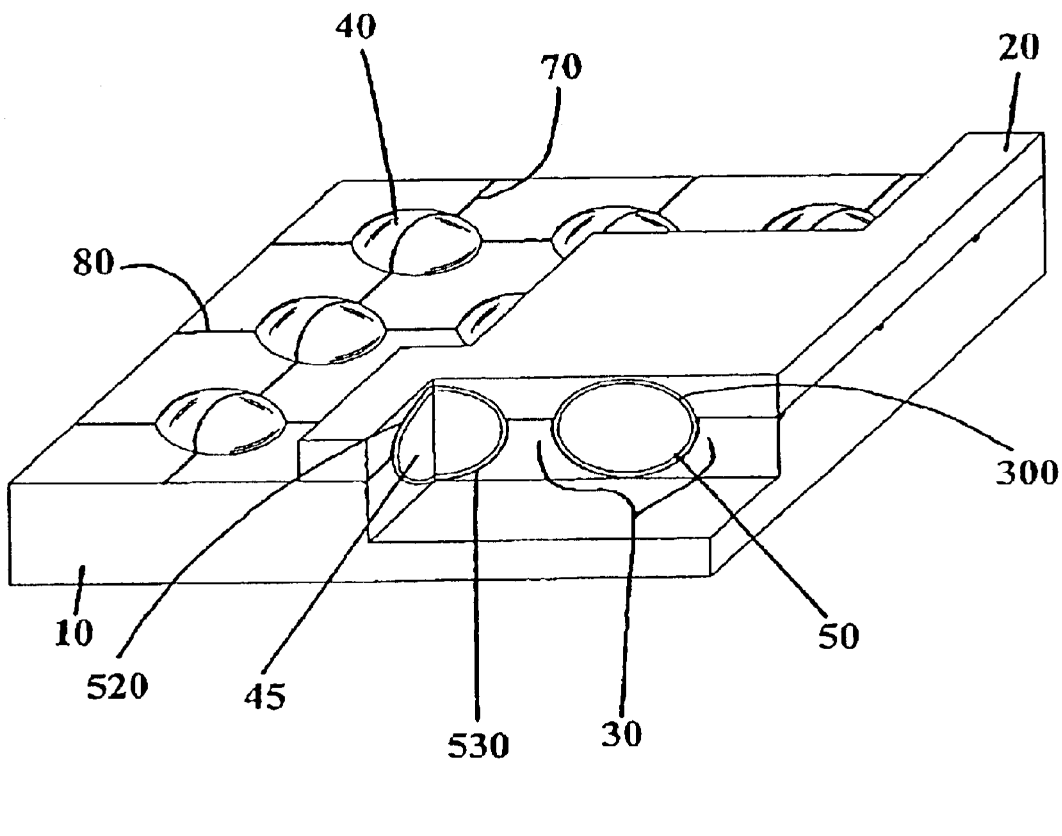


Fig. 2



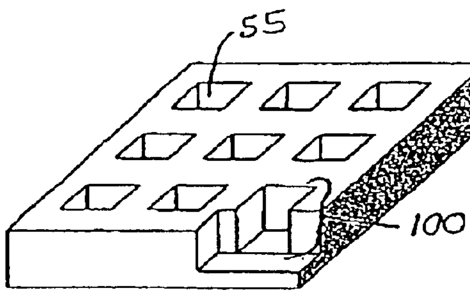



Fig. 3 A

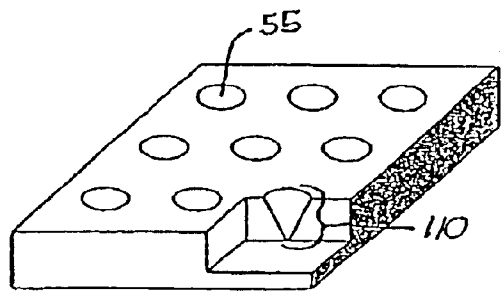



Fig. 3 B

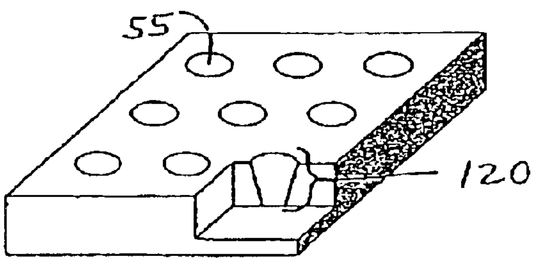



Fig. 3C

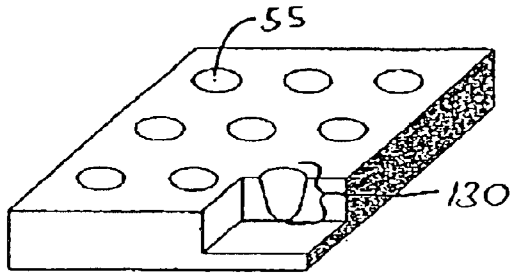



Fig 3 D

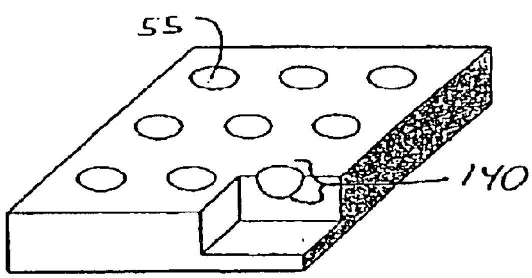



Fig 3E

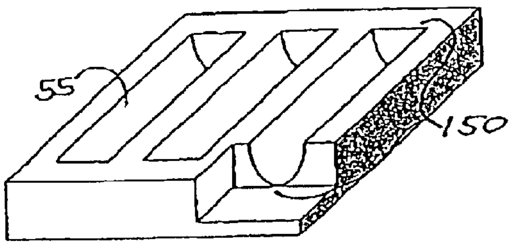



Fig. 3F

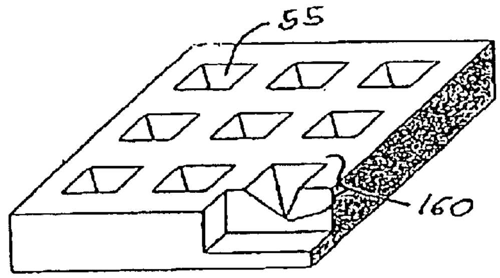



Fig. 3G

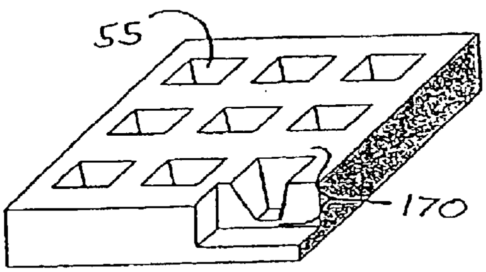



Fig. 3H

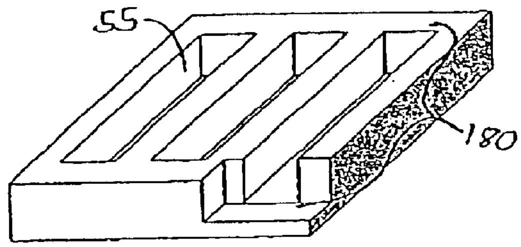



Fig. 3I

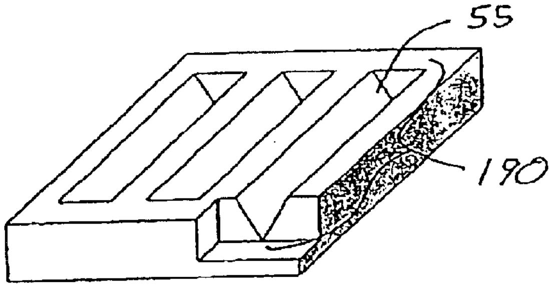



Fig. 3J

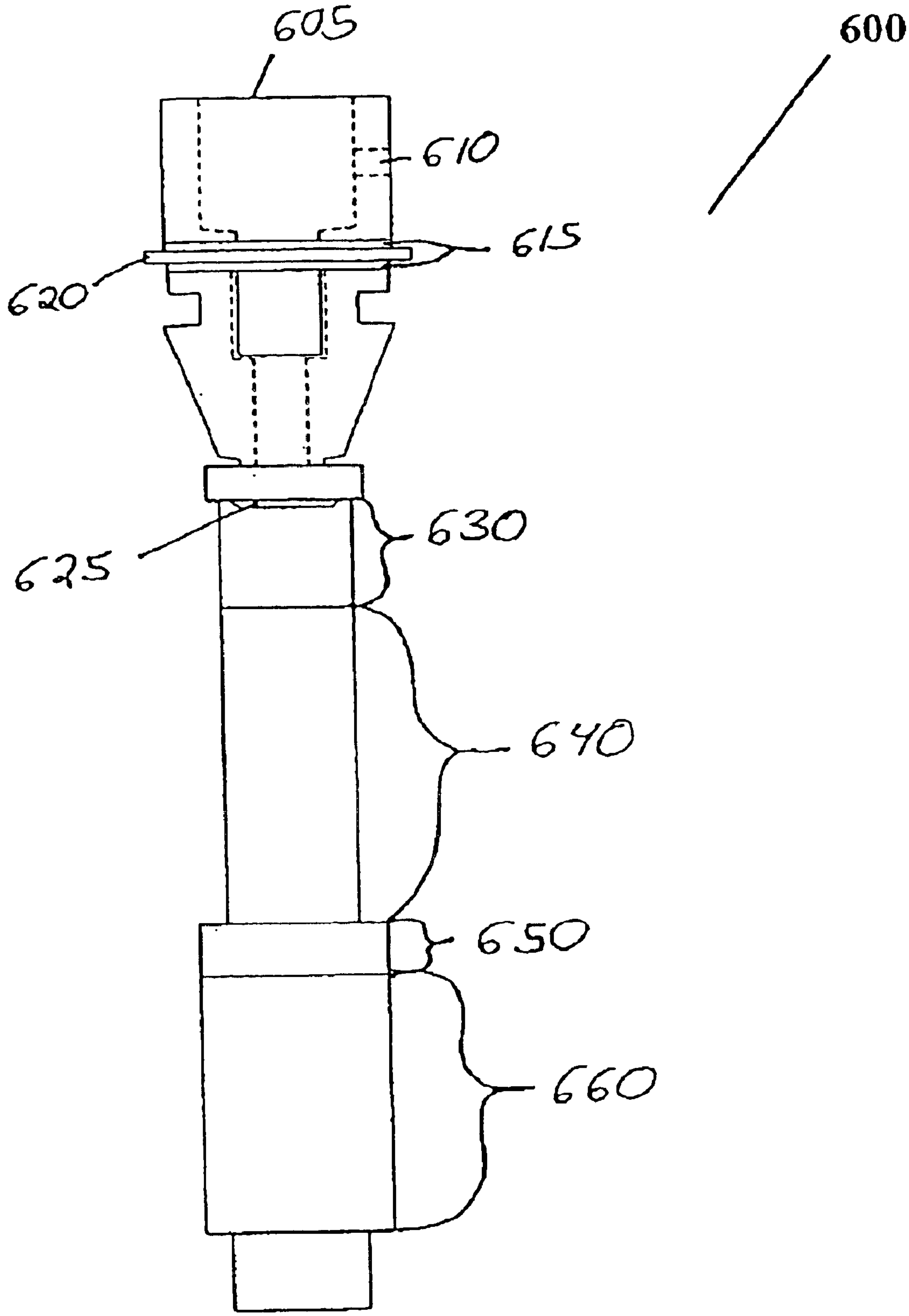



Fig. 4

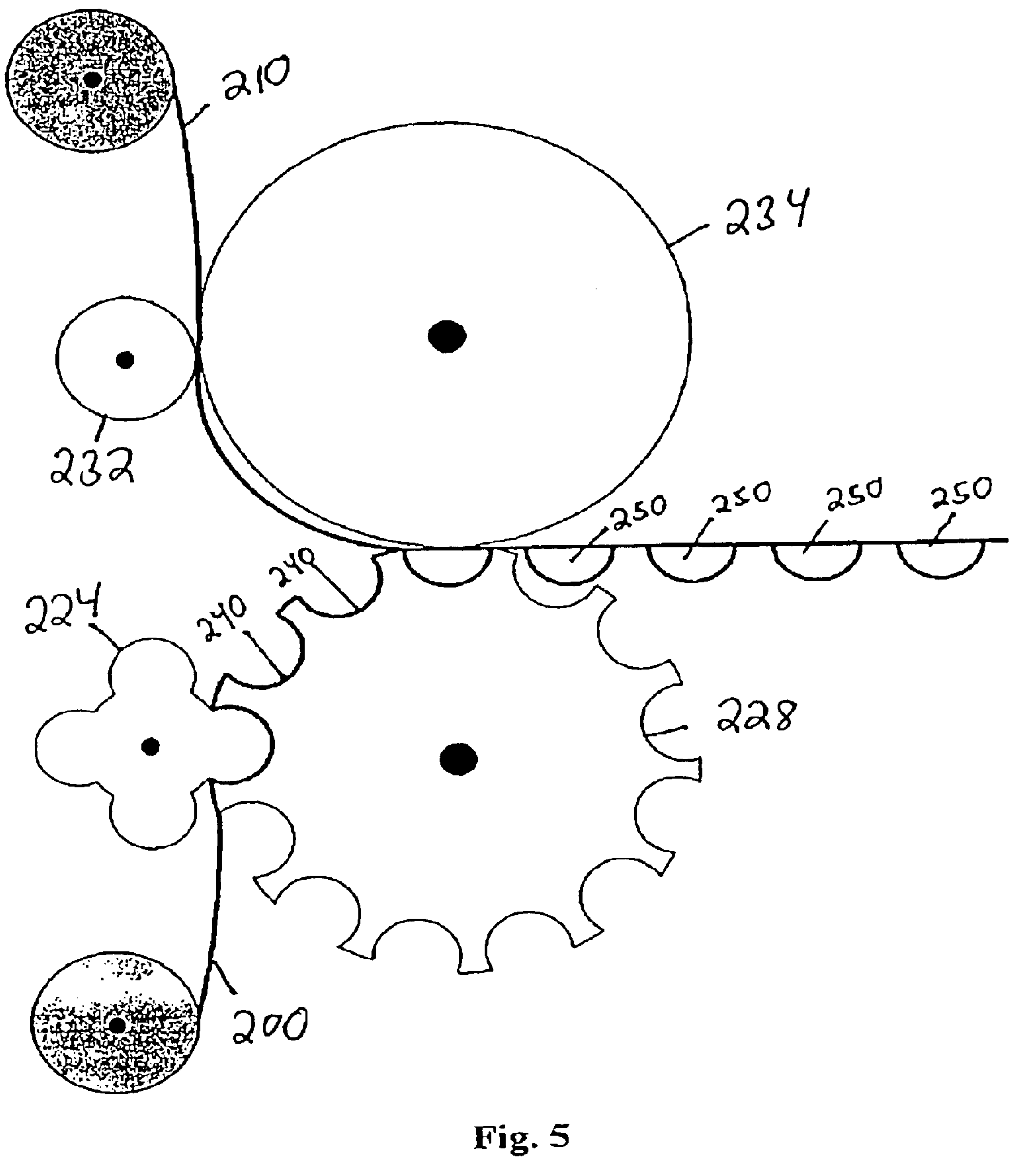
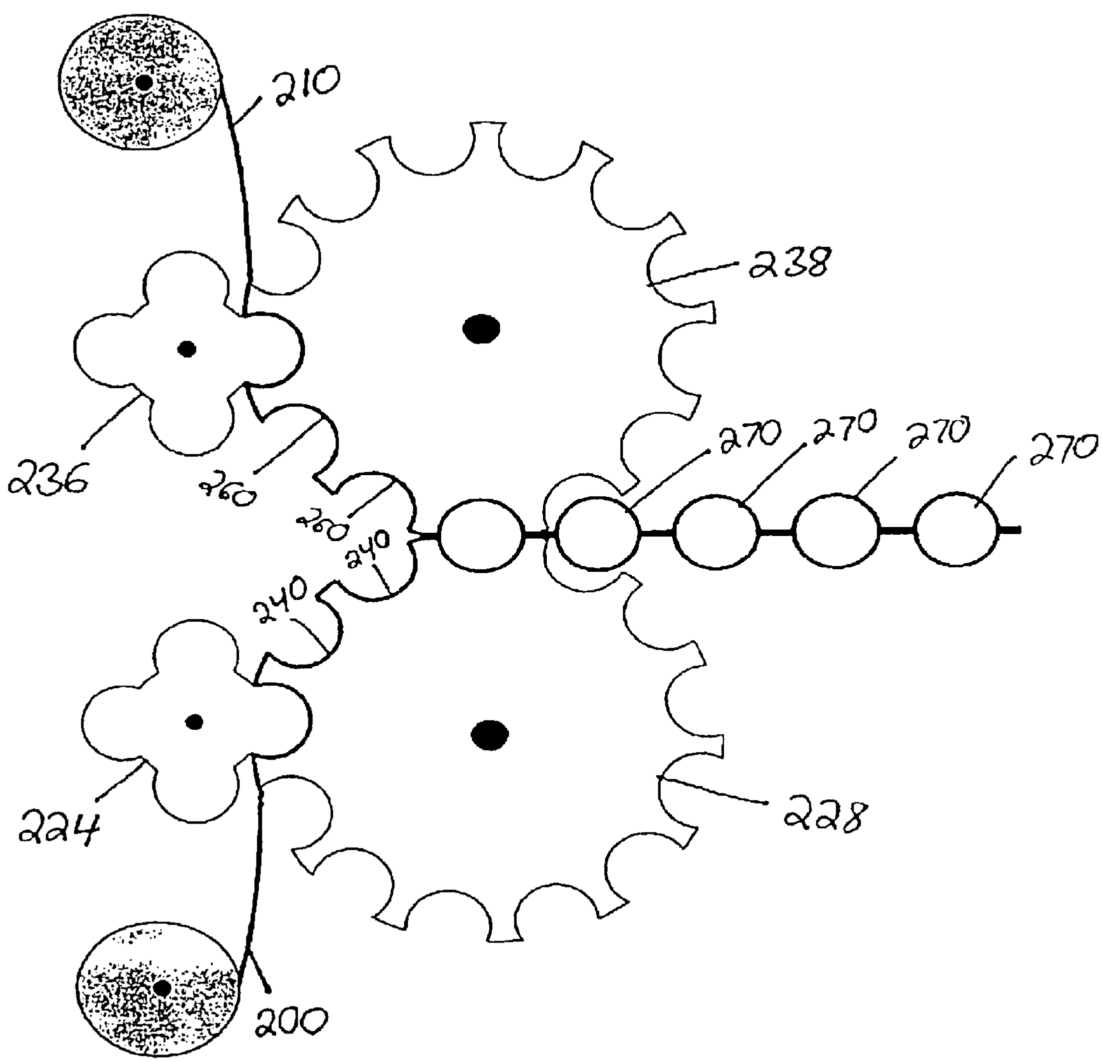
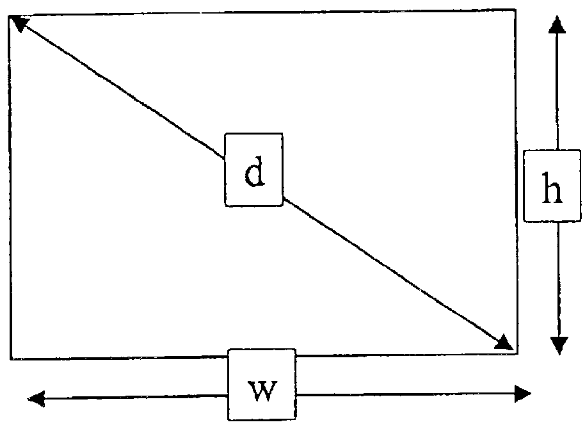



Fig. 5

Fig. 6



Example of Calculation of Pixel Size and Micro-component Size for 42-inch & 60-inch HDTV Displays (16:9 aspect ratio)




- Display Size
  - w=d*0.87
  - h=d*0.49
  - **42" diagonal 16 x 9 = 20.6 x 36.6 in**
  - **60" diagonal 16 x 9 = 52.2 x 29.4 in**

- Pixel Size
  - 1024 x 1024 pixels
  - **42" pixel dimensions=508 x 908 μm**
  - **60" pixel dimensions=1292 x 729 μm**
- Microsphere Size
  - 3 microspheres/pixel
  - **42" - 175 μm**
  - **60" - 250 μm**

Fig. 7

Table showing number of pixels, etc. for various standard display resolutions

| Acronym | Pixels HxV | Aspect | Mpixels |
|---|---|---|---|
| CIF | 352x288 | 4:3 | 0.1 |
| VGA | 640x480 | 4:3 | 0.3 |
| SVGA | 800x600 | 4:3 | 0.5 |
| XGA | 1024x768 | 4:3 | 0.8 |
| HDTV(720p) | 1280x720 | 16:9 | 0.9 |
| SXGA | 1280x1024 | 5:4 | 1.3 |
| SXGA+ | 1400x1050 | 3:4 | 1.5 |
| UXGA | 1600x1200 | 4:3 | 1.9 |
| HDTV(1080i,p) | 1920x1080 | 16:9 | 2.1 |
| WUXGA | 1920x1200 | 16:10 | 2.3 |
| QXGA | 2048x1536 | 4:3 | 3.1 |
| VXGA | 2048x2048 | 1:1 | 4.2 |
| GXGA/QSXGA | 2560x2048 | 5:4 | 5.2 |
| Photo CD (16Base) | 3072x2048 | 3:2 | 6.3 |
| Photo CD (64Base) | 6144x4096 | 3:2 | 25.0 |

Fig. 8

Fig. 9

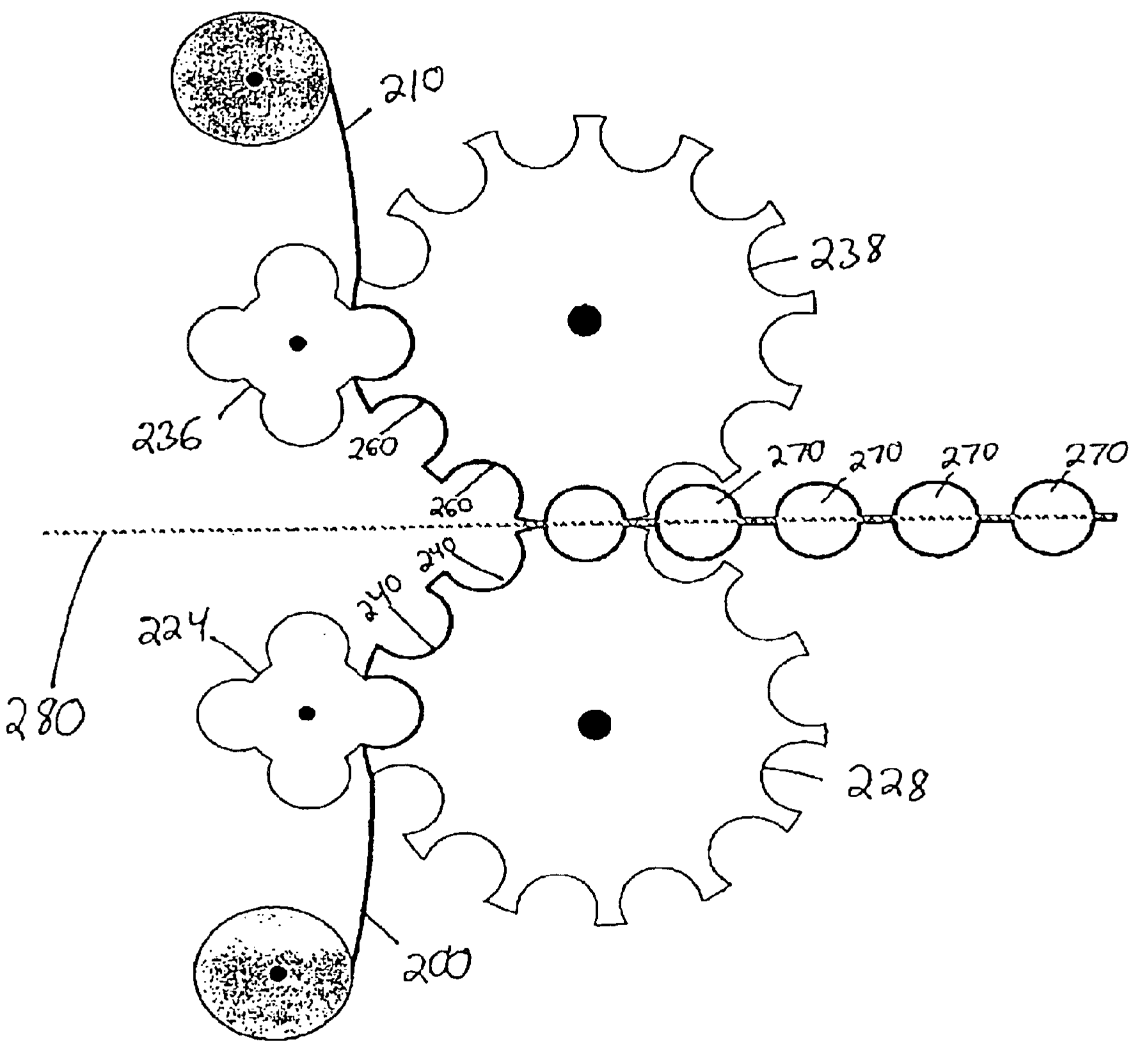
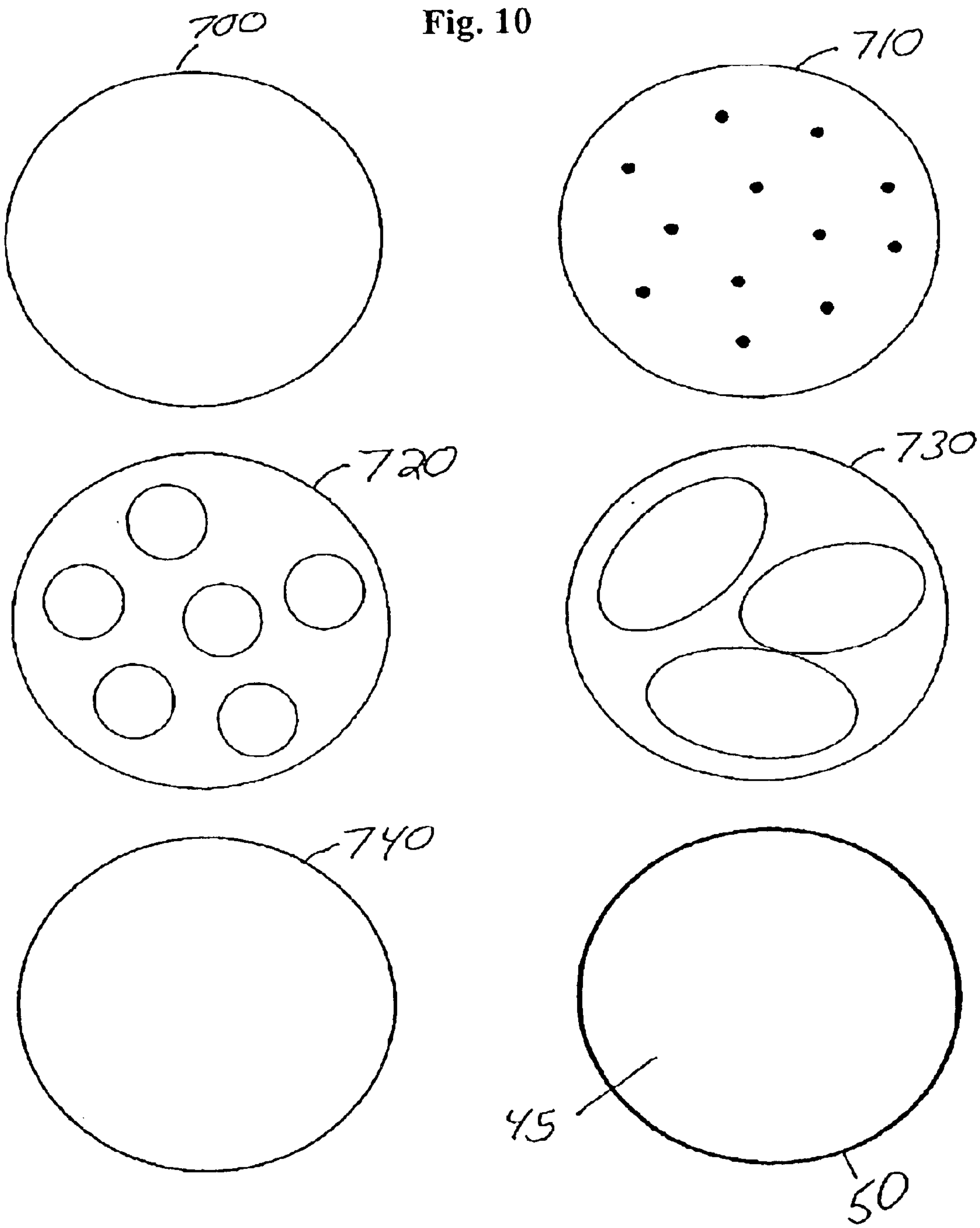


Fig. 10



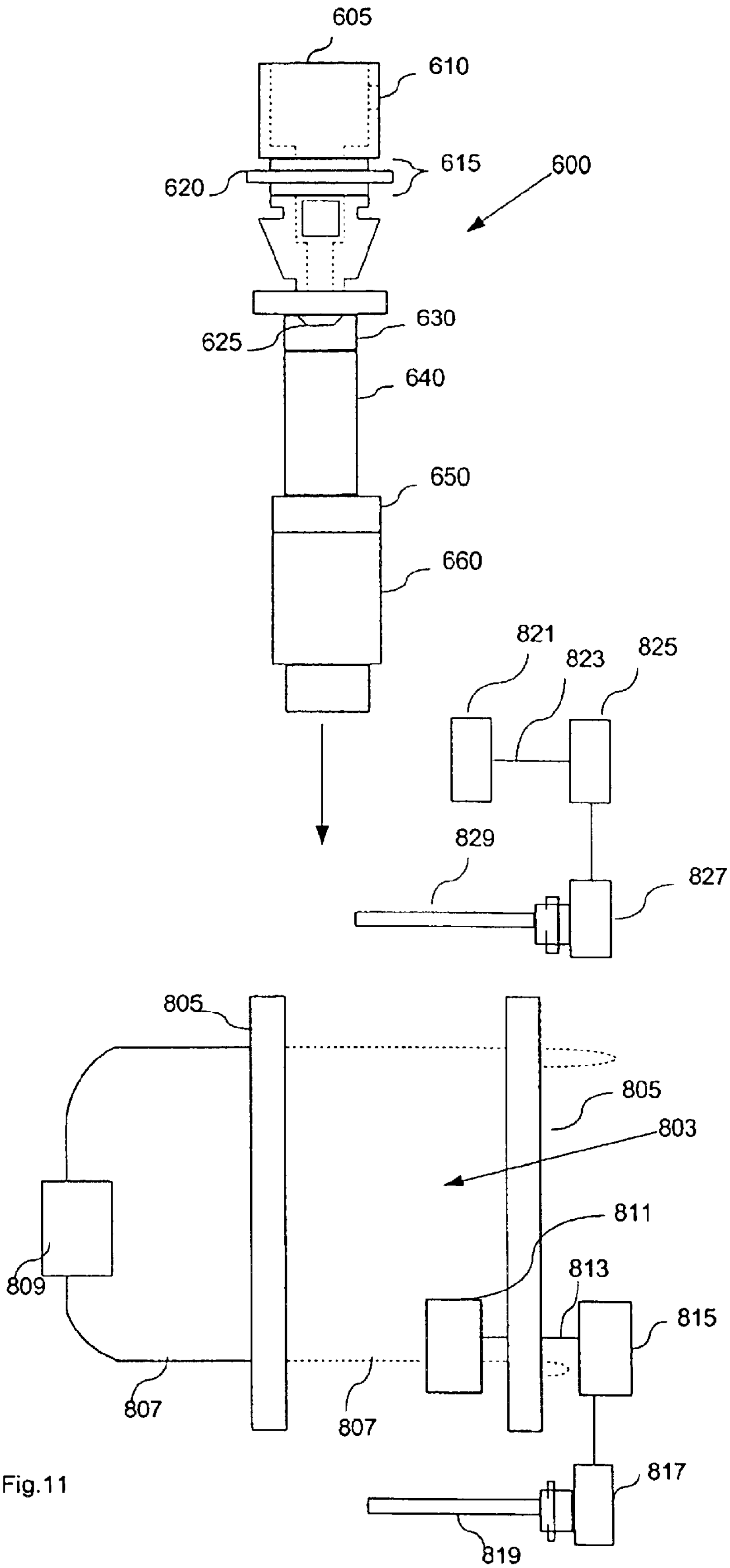

605
610
615
600
620
630
625
640
650
660
821
823
825
801
829
827
805
805
803
811
809
813
815
807
807
817
819

Fig.11

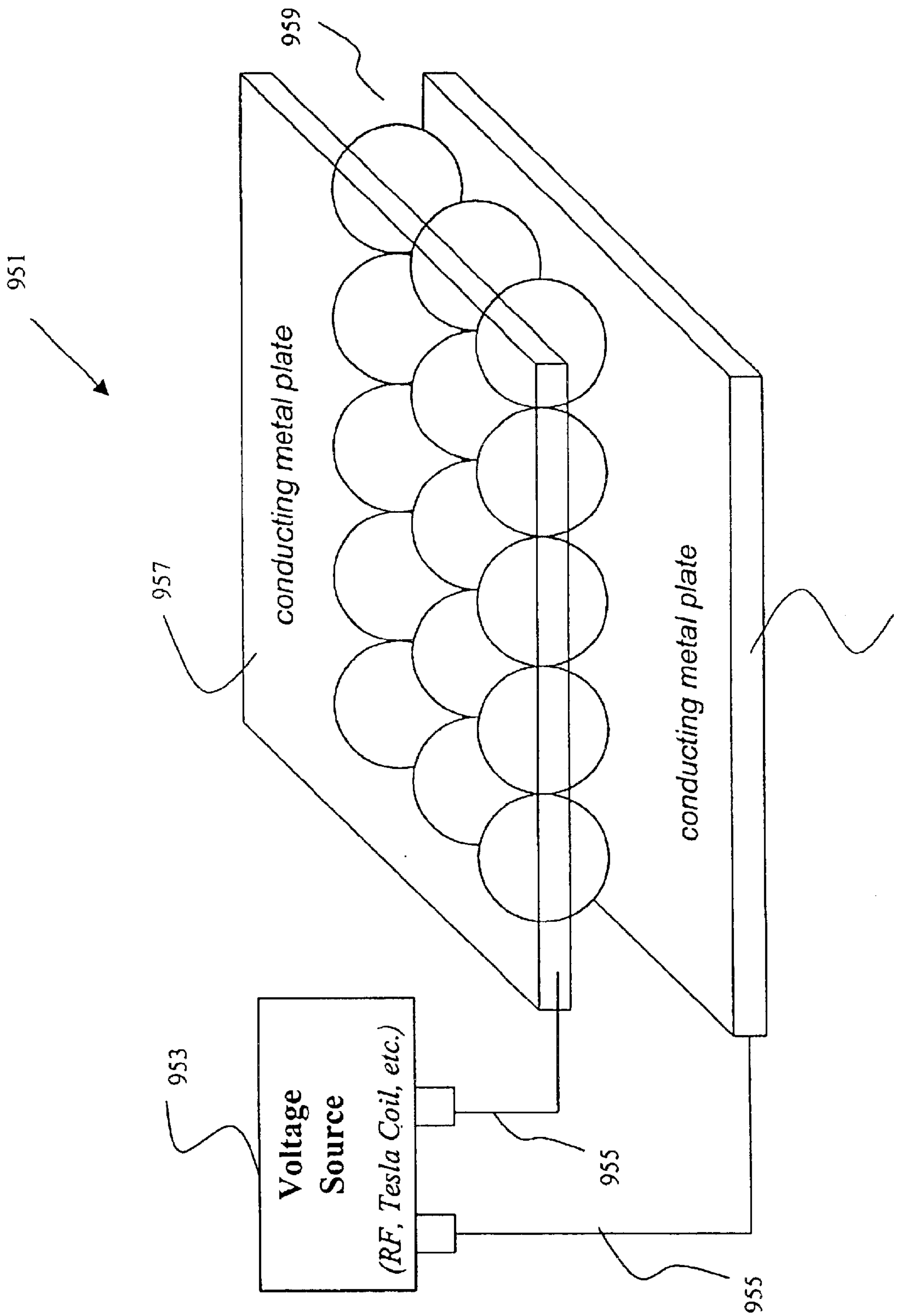

951
959
957
conducting metal plate
conducting metal plate
957
953
Voltage Source
(RF, Tesla Coil, etc.)
955
955

Fig. 12

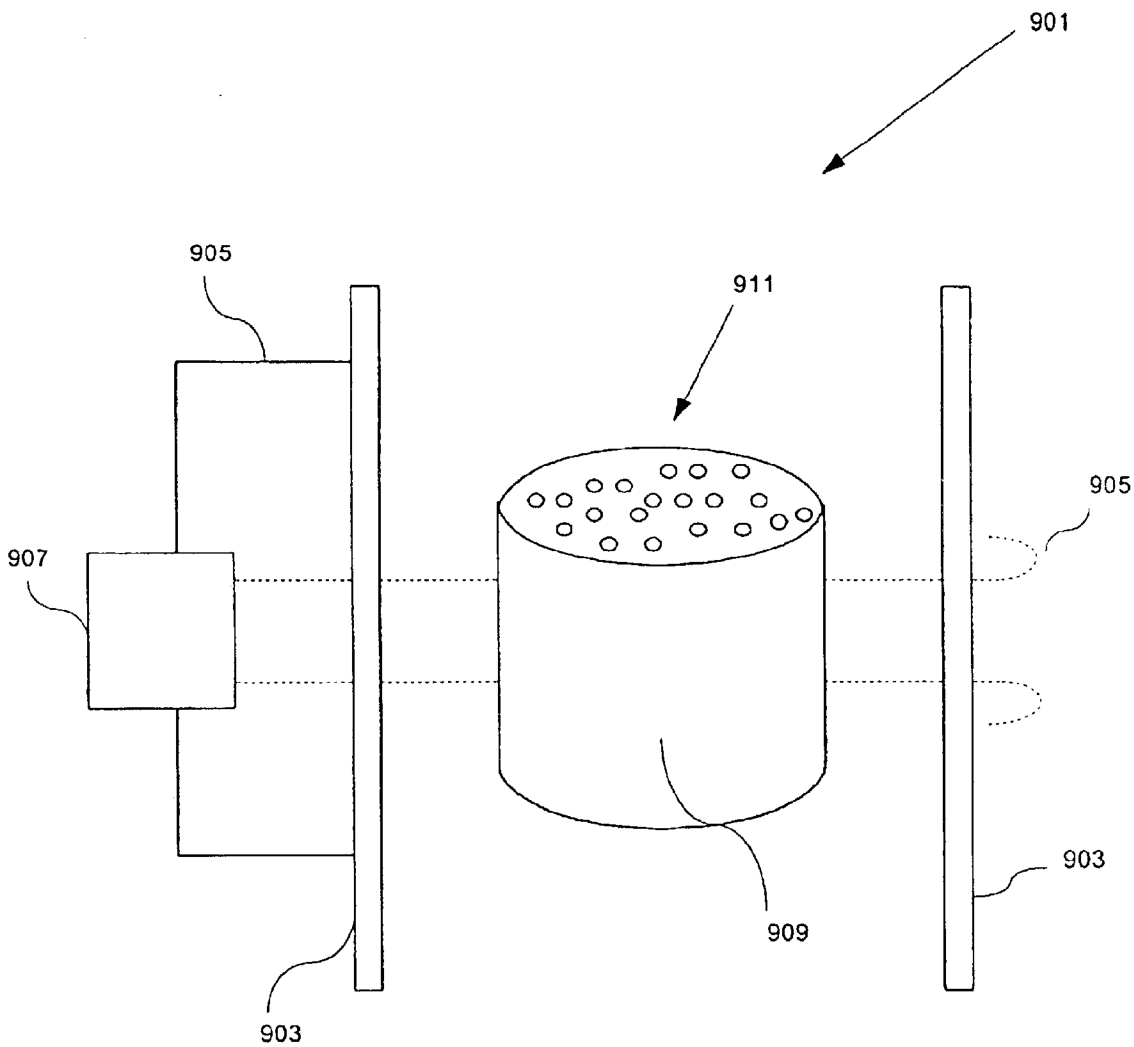



Fig. 13

# DESIGN, FABRICATION, TESTING, AND CONDITIONING OF MICRO-COMPONENTS FOR USE IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. patent application Ser. No. 09/697,358 entitled "A Micro-Component for Use in a Light-Emitting Panel," filed Oct. 27, 2000 now U.S. Pat. No. 6,762,566, and claims priority to that parent application's filing date. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties, and the filing dates thereof to which priority is also claimed: U.S. patent application Ser. No. 09/697,344 entitled "A Light-Emitting Panel and a Method for Making" filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled "A Method for Testing a Light-Emitting Panel and the Components Therein," filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled "A Method and System for Energizing a Micro-Component in a Light-Emitting Panel," filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,346 entitled "A Socket for Use in a Light-Emitting Panel," filed Oct. 27, 2000; U.S. patent application Ser. No. 10/214,769 entitled "Use of Printing and Other Technology for Micro-Component Placement," filed concurrently herewith; U.S. patent application Ser. No. 10/214,740 entitled "Liquid Manufacturing Processes for Panel Layer Fabrication," filed concurrently herewith; U.S. patent application Ser. No. 10/214,716 entitled "Method for On-Line Testing of a Light-Emitting Panel," filed concurrently herewith; and U.S. patent application Ser. No. 10/214,764 entitled "Method and Apparatus for Addressing Micro-Components in a Plasma Display Panel," filed concurrently herewith.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a micro-component for use in a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this plasma-forming discharge occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby eventually extinguish the discharge. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes may be located partially within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma-forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma-forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates, the pumping down to vacuum, the baking out under vacuum, and the introduction of the plasma-forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels without a write pulse being applied. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma-forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total physical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to pump down to vacuum, bake out under vacuum, introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma-forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing paint or other coatings, and for sterilization. With the addition of one or more phosphor coatings to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other electromagnetic wavelengths would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma-forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In one embodiment of the present invention, the micro-component is configured to emit ultra-violet (UV) light, which may be converted to visible light by at least partially coating each micro-component with phosphor. To obtain an improvement in the discharge characteristics, each micro-component may be at least partially coated with a secondary emission enhancement material.

In another embodiment, each micro-component is at least partially coated with a reflective material. An index matching material is disposed so as to be in contact with at least a portion of the reflective material. The combination of the index matching material and the reflective material permits a predetermined wavelength of light to be emitted from each micro-component at the point of contact between the index matching material and the reflective material.

Another object of the present invention is to provide a micro-component for use in a light-emitting panel. A shell at least partially filled with at least one plasma-forming gas provides the basic micro-component structure. The shell may be doped or ion implanted with a conductive material, a material that provides secondary emission enhancement, and/or a material that converts UV light to visible light. The micro-components will be made as a sphere, cylinder or any other shape. The size and shape will be determined in accordance with the desired resolution for the display panel to be assembled. Typical sizes are about hundreds of microns independent of shape.

Another preferred embodiment of the present invention is to provide a method of making a micro-component. In one embodiment, the method is part of a continuous process, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the plasma-forming gas or gas mixture.

In another embodiment, the micro-component is made by affixing a first substrate to a second substrate in the presence of at least one plasma-forming gas. In this method, either the first and/or the second substrate contains a plurality of cavities so that when the first substrate is affixed to the second substrate the plurality of cavities are filled with the plasma-forming gas or gas mixture. In a preferred embodiment, a first substrate is advanced through a first roller assembly, which includes a roller with a plurality of nodules and a roller with a plurality of depressions. Both the plurality of nodules and the plurality of depressions are in registration with each other so that when the first substrate passes through the first roller assembly, the first substrate has a plurality of cavities formed therein. A second substrate is advanced through a second roller assembly and then affixed to the first substrate in the presence of at least one gas so that when the two substrates are affixed the cavities are filled with the gas or gas mixture. In an alternate preferred embodiment, the second roller assembly includes a roller with a plurality of nodules and a roller with a plurality of depressions so that when the second substrate passes through the second roller assembly, the second substrate also has a plurality of cavities formed therein. In either of these embodiments, at least one electrode may be sandwiched between the first and second substrates prior to the substrates being affixed.

In another embodiment, at least one substrate is thermally treated in the presence of a least one plasma-forming gas so as to form shells filled with the plasma-forming gas or gas-mixture.

In a specific aspect, the micro-components, whether sphere, capillary or other shape are coated with a frequency converting coating. Phosphor is an example of such a coating. More specifically, the coating converts electromagnetic radiation generated in the plasma in the ultraviolet region of the spectrum, and converts it to the visible red, blue or green region of the spectrum.

Alternatives include putting a drop of the frequency converting material in a socket into which the micro-component is placed, or the micro-component itself can be doped with a material such as a rare earth that is a frequency converter. Examples of materials include barium fluoride or the like, yttrium aluminum garnet, or gadolinium gallium garnet. The plasma gases in the micro-component can include xenon chloride, argon chloride, etc., namely the rare gas halides.

In another aspect, the micro-components are tested as they are manufactured. The micro-components are optionally scanned for certain physical characteristics or defects, for example, in an optical field detecting shape such as sphericity and size as they drop through a tower. A micro-component displacement device can be used to remove those that are bad. At a subsequent layer, as they drop the micro-components are subjected to electron beam excitation, microwave or RF field, for example, to excite the gas. Another physical characteristic or defect is tested, such as if a certain luminous output is achieved, and if achieved, it is preliminarily accepted. Those for which a desired luminous output is not achieved are discarded, for example, through the use of a second micro-component displacement device.

In yet still another aspect, the micro-components are preconditioned by being excited for a predetermined period of time. Examples include taking the micro-components that passed the initial test, placing them in a container and exciting them, for example, for 5 to 10 hours. Alternatively, they can be placed between large parallel electrodes. After the batch run, they are dropped through a tower as they are excited, output detected and the ones that do not excite are knocked out of the stream.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** shows a socket with a micro-component disposed therein.

FIG. **2** depicts a portion of a light-emitting panel showing a plurality of micro-components disposed in sockets.

FIG. **3A** shows an example of a cavity that has a cube shape.

FIG. **3B** shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a hemicylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components.

FIG. **5** shows an apparatus used in an embodiment of the present invention as pan of another process for forming micro-components.

FIG. **6** shows an variation of the apparatus shown in FIG. **5**, which is used as part of another process for forming micro-components.

FIG. **7** illustrates an example of selection of pixel size and micro-component (micro-sphere) size for different sized high definition television (HDTV) displays, which can be manufactured according to the micro-component method hereof.

FIG. **8** is a table showing numbers of pixels for various standard display resolutions.

FIG. **9** illustrates, according to an embodiment, one way in which an electrode may be disposed between two substrates as part of a process for forming micro-components.

FIG. **10** depicts the steps of another method for forming micro-components.

FIG. **11** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components similar to that of FIG. **4**, and including a mechanism for pretesting or pre-screening of micro-components prior to assembly in a panel.

FIG. **12** shows an apparatus used for batch conditioning of micro-components.

FIG. **13** shows an alternative embodiment of an apparatus used for batch conditioning of micro-components.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a micro-component capable of being used in the light-emitting panel and at least partially disposed in at least one socket.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates,



polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A-3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. Further, rare gas halide mixtures such as xenon chloride, xenon fluoride and the like are also suitable plasma-forming gases. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed above. This description is not intended to be limiting. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. In FIG. **2**, a two electrode configuration is shown including a first sustain electrode **520** and an address electrode **530**. In FIG. **1**, a three electrode configuration is shown, wherein a first sustain electrode **520**, an address electrode **530** and a second sustain electrode **540** are disposed within a plurality of material layers **60** that form the first substrate **10**. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr or higher pressure as appropriate. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as bandpass filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may also work. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside of the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used.

To obtain an improvement in discharge characteristics, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated on the inside surface with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

Alternatively to the previously discussed phosphor which can be used to coat the micro-component, or alternatively, placed into a socket in a display panel in which the micro-components are placed, the micro-component material can be doped with a rare earth that is a frequency converter. Such dopants can include barium fluoride or similar materials such as yttrium aluminum garnet, or gadolinium gallium garnet. These types of frequency converting materials serve to convert plasma light at the UV wavelength to visible light of red, blue or green color. The gasses in the micro-component in such cases will include rare gas halide mixtures such as xenon chloride, xenon fluoride and the like. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed previously. This description is not intended to be limiting. In the case when such frequency converting materials are used, instead of using a phosphor coating, they can be integrated as a dopant in the shell of the micro-component. For example, yttrium aluminum garnet doped with cerium can serve to convert UV wavelengths from rare gas halides into green light.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material, either in two or more localized areas to provide separate electrode-like paths or in a way to produce anisotropic conductivity in the shell (high perpendicular conductivity, low in-plane conductivity), provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel. In this manner, shorting is avoided and two or more separate electrode paths are maintained to allow exciting of the gas.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

Several methods are proposed, in various embodiments, for making a micro-component for use in a light-emitting panel. It has been contemplated that each of the coatings and dopants that may be added to a micro-component **40**, as disclosed herein, may also be included in steps in forming a micro-component, as discussed herein.

In one embodiment of the present invention, a continuous inline process for making a micro-component is described, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the gas or gas mixture. In a preferred embodiment, the process takes place in a drop tower. According to FIG. **4**, and as an example of one of many possible ways to make a micro-component as part of a continuous inline process, a droplet generator **600** including a pressure transducer port **605**, a liquid inlet port **610**, a piezoelectric transducer **615**, a transducer drive signal electrode **620**, and an orifice plate **625**, produces uniform water droplets of a predetermined size. The droplets pass through an encapsulation region **630** where each water droplet is encased in a gel outer membrane formed of an aqueous solution of glass forming oxides (or any other suitable material that may be used for a micro-component shell), which is then passed through a dehydration region **640** leaving a hollow dry gel shell. This dry gel shell then travels through a transition region **650** where it is heated into a glass shell (or other type of shell depending on what aqueous solution was chosen) and then finally through a refining region **660**. While it is possible to introduce a plasma-forming gas or gas mixture into the process during any one of the steps, it is preferred in an embodiment of the present invention to perform the whole process in the presence of the plasma-forming gas or gas mixture. Thus, when the shell leaves the refining region **660**, the plasma-forming gas or gas mixture is sealed inside the shell thereby forming a micro-component.

In an embodiment of the present invention, the above process is modified so that the shell can be doped with either a secondary emission enhancement material and/or a conductive material, although other dopants may also be used. While it is contemplated that the dopants may be added to the shell by ion implantation at later stages in the process, in a preferred embodiment, the dopant is added directly in the aqueous solution so that the shell is initial formed with the dopant already present in the shell.

The above process steps may be modified or additional process steps may be added to the above process for forming a micro-component to provide a means for adding at least one coating to the micro-component. For coatings that may be disposed on the inside of the shell including, but not limited to a secondary emission enhancement material and a conductive material, it is contemplated in an embodiment of the present invention that those coating materials are added to the initial droplet solution so that when the outer membrane is formed around the initial droplet and then passed through the dehydration region **640** the coating material is left on the inside of the hollow dry gel shell. For coatings that may be disposed on the outside of the shell including, but not limited to, coatings used to convert UV light to visible light, coatings used as reflective filters and coatings used as band-gap filters, it is contemplated that after the micro-component leaves the refining region **660**, the micro-component will travel through at least one coating region. The coatings may be applied by any number of processes known to those skilled in the art as a means of applying a coating to a surface.

A further modification of the drop tower of FIG. **4** is illustrated in FIG. **11** with a continuous testing region **801**. The continuous testing region **801** includes a first optical detector **821** which detects individual micro-components as they are formed. This optical detector can detect such things as sphericity and size in a continuous process, typically operating at about 10 kilohertz sampling rate. Signals representing the micro-component detected are passed through line **823** to a control module **825**. If a micro-component does not meet certain minimum standards, a signal is sent from control module **825** to mechanical actuator **827** which activates a micro-component displacement device or arm **829** which is activated to remove the failed micro-component from the stream. A second region of the continuing testing device **801** includes, optionally, electrodes **805** which are excited through leads **807** by power supply **809** to generate a field which excites the plasma gas within the manufactured micro-components. As the micro-components are exited, a luminous output is generated and a second optical detector **811** serves to detect the luminous output and send a signal representing the luminous output for each individual micro-component through line **813** to a second control unit **815**.

If no luminous output is detected or a luminous output of less than a predetermined threshold is detected, the control unit **815** sends a signal to actuator **817** which then actuates a second micro-component displacement device or arm **819** to remove the failed micro-component from the stream.

With respect to the photo-detectors, they are conventional, and can be of the type, for example, which detect UV light. Alternatively, if the micro-component has been coated prior to the end of the fabrication process, for example, with phosphor, the detector may be of the type which is sensitive to a red light output. It should be noted that although the micro-component displacement devices or arms **819** and **829** have been described as mechanical in nature, they may also be non-mechanical, such as an intermittent fluid stream such as a gas or liquid stream or a light pulse such as a high-intensity laser pulse.

In another embodiment of the present invention, two substrates are provided, wherein at least one of two substrates contain a plurality of cavities. The two substrates are affixed together in the presence of at least one plasma-forming gas so that when affixed, the cavities are filled with the gas or gas mixture. In an embodiment of the present invention at least one electrode is disposed between the two substrates. In another embodiment, the inside, the outside, or both the inside and the outside of the cavities are coated with at least one coating. It is contemplated that any coating that may be applied to a micro-component as disclosed herein may be used. As illustrated in FIG. **5**, one method of making a micro-component in accordance with this embodiment of the present invention is to take a first substrate **200** and a second substrate **210** and then pass the first substrate **200** and the second substrate **210** through a first roller assembly and a second roller assembly, respectively. The first roller assembly includes a first roller with nodules **224** and a first roller with depressions **228**. The first roller with nodules **224** is in register with the first roller with depressions **228** so that as the first substrate **200** passes between the first roller with nodules **224** and the first roller with depressions **228**, a plurality of cavities **240** are formed in the first substrate **200**. As may be appreciated, the cavities may be in the shape desired for micro-components manufactured therewith such as hemispheres, capillaries, cylinders, etc. The second roller assembly, according to a preferred embodiment, includes two second rollers, **232** and **234**. The first substrate **200**, with a plurality of cavities **240** formed therein, is brought together with the second substrate **210** in the presence of a plasma-forming gas or gas mixture and then affixed, thereby forming a plurality of micro-components **250** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **210** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller **234**.

The nodules on the first roller with nodules **224** may be disposed in any pattern, having even or non-even spacing between adjacent nodules. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the distance between adjacent nodules is approximately equal. The nodules may also be disposed in groups such that the distance between one group of nodules and another group of nodules is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each nodule in a group of nodules may be used to form a micro-component that is configured for red, green, and blue, respectively.

While it is preferred that the second roller assembly simply include two second rollers, **232** and **234**, in an embodiment of the present invention as illustrated in FIG. **6**, the second roller assembly may also include a second roller with nodules **236** and a second roller with depressions **238** that are in registration so that when the second substrate **210** passes between the second roller with nodules **236** and the second roller with depressions **238**, a plurality of cavities **260** are also formed in the second substrate **210**. The first substrate **200** and the second substrate **210** are then brought together in the presence of at least one gas so that the plurality of cavities **240** in the first substrate **200** and the plurality of cavities **260** in the second substrate **210** are in register. The two substrates are then affixed, thereby forming a plurality of micro-components **270** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **240** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller with depressions **238**.

In an embodiment of the present invention that is applicable to the two methods discussed above, and illustrated in FIG. **9**, at least one electrode **280** is disposed on or within the first substrate **200**, the second substrate **240** or both the first substrate and the second substrate. Depending on how the electrode or electrodes are disposed, the electrode or electrodes will provide the proper structure for either an AC or DC (FIG. **7**) light-emitting panel. That is to say, if the at least one electrode **280** is at least partially disposed in a cavity **240** or **260** then there will be a direct conductive path between the at least one electrode and the plasma-forming gas or gas mixture and the panel will be configured for D.C. If, on the other hand, the at least one electrode is disposed so as not to be in direct contact with the plasma-forming gas or gas mixture, the panel will be configured for A.C.

In another embodiment of the present invention, at least one substrate is thermally treated in the presence of at least one plasma-forming gas, to form a plurality of shells **50** filled with the plasma-forming gas or gas mixture. In a preferred embodiment of the present invention, as shown in FIG. **10**, the process for making a micro-component would entail starting with a material or material mixture **700**, introducing inclusions into the material **710**, thermally treating the material so that the inclusions start forming bubbles within the material **720** and those bubbles coalesce **730** forming a porous shell **740**, and cooling the shell. The process is performed in the presence of a plasma-forming gas so that when the shell cools the plasma-forming gas **45** is sealed inside the shell **50**. This process can also be used to create a micro-component with a shell doped with a conductive material and/or a secondary emission enhancement material by combining the appropriate dopant with the initial starting material or by introducing the appropriate dopant while the shell is still porous.

In a yet still further method of manufacture, the micro-components can be manufactured using any of the above-mentioned methods, but not in the presence of a plasma-forming gas, and either in a vacuum, air or other atmosphere such as an inert atmosphere. They can be fabricated with one or two openings, and the initial gas inside can be drawn out, for example, through injection of plasma-forming gas through one opening, forcing the gas therein out the other opening. The openings can then be sealed conventionally.

In yet another alternative method, a device having one or more micro-pipettes can create the micro-components much like conventional glass blowing. The gas used to effect the glass-blowing operation can be one of the aforementioned plasma-forming gasses.

In yet still another alternative, an optical fiber extrusion device can be used to manufacture the micro-components. Like an optical fiber, which is solid, the device can be used to extrude a capillary which is hollow on the inside. The capillary can then be cut, filled with plasma-forming gas and sealed.

With respect to the selection of materials and dimensions for the micro-components manufactured in the manner described herein, they are manufactured to meet requirements for various standard display resolutions. FIG. **7** illustrates an example of calculation of pixel size and micro-component size, in the case where the micro-components are spheres, for 42-inch and 60-inch high definition television display having a 16:9 aspect ratio. FIG. **8** is a table showing numbers of pixels for various standard display resolutions, and using the process for manufacturing in accordance with the invention herein, such standards can be easily met.

In a further aspect, once the micro-components are manufactured, it is desirable to condition them prior to assembly into a plasma display panel. By conditioning is meant exciting them for a time and at an excitation sufficient to cause those micro-components which are likely to fail a short time after assembly in a plasma display panel, to fail prior to assembly. In this manner the yield relative to non-defective micro-components which are eventually assembled into a plasma display panel is significantly increased. Examples of devices for achieving said conditioning are shown in FIGS. **11** and **12**. As shown in the conditioning device **951** of FIG. **11** the manufactured and pretested micro-components **959** can be assembled between two conducting metal plates **957** which are powered through leads **955** by a voltage source **953** which can take various forms as illustrated therein. The micro-components **959** are subjected to a field sufficient to excite the plasma gas contained therein, and preferably at a level higher than any excitation level achieved when assembled in a plasma display panel. This is done for a period of time sufficient such that any micro-components which are prone to fail, will fail during the conditioning phase, typically five to ten hours.

As may be appreciated, an alternative system is illustrated by FIG. **13** which shows a conditioning device **901** which further includes a container **909** for confining and containing micro-components **911**. The container **909** may be placed between parallel plates or electrodes **903** which are powered through leads **905** by a power source **907** such as a voltage source of the type previously discussed with reference to FIG. **11**. The advantage of such a system is that by having container **909**, the micro-components are easily contained. After the conditioning period, the individual micro-components can then be dropped through a system such as pretesting device **801** shown in FIG. **11** without the presence of manufacturing drop tower **600**, and tested previously described for the method during which the micro-components are assembled. In this manner, those micro-components which failed the conditioning are eliminated and only fully-functioning micro-components can then be assembled into a plasma display panel as heretofore described.

With respect to micro-components manufactured as discussed with reference to FIGS. **5**, **6**, and **9**, once assembled, they may be cut from the sheets on which they are formed. They can be pretested with a device such as shown in the lower half of FIG. **11** at **801** and **803**. They can then be preconditioned as previously described with reference to FIGS. **12** and **13**, and then retested with the device of the lower half of FIG. **11** at **801** and **803**.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A process for forming a micro-component, comprising:

forming a shell of predetermined shape and encapsulating therein a plasma-forming gas to thereby form a micro-component;

testing the formed micro-component for certain predetermined physical characteristics;

discarding each formed micro-component that does not meet the predetermined physical characteristics.

**2**. The process of claim **1**, further comprising:

creating liquid droplets of the same shape as the micro-component to be formed, in the presence of a plasma-forming gas;

encasing said droplets with a material which forms said shell; and

dehydrating said encased droplets.

**3**. The process of claim **1**, wherein said predetermined shape is a sphere.

**4**. The process of claim **1**, wherein said predetermined shape is a capillary.

**5**. The process of claim **1**, wherein said testing comprises inspecting the formed micro-component for physical defects, and thereafter exciting the gas therein, detecting luminous output from each formed micro-component and discarding each formed micro-component that has physical defects or does not achieve a predetermined level of luminous output.

**6**. The process of claim **1**, wherein the micro-components are formed by forming a shell and thereafter injecting a plasma-forming gas therein and sealing the shell to encapsulate the plasma-forming gas in the shell.

**7**. The process of claim **1**, wherein the micro-component is formed by forming cavities in at least one of two substrates in the presence of at least one plasma-forming gas, and affixing the two substrates together.

**8**. The process of claim **1**, further comprising forming said micro-components of a size of at least about 10 microns to about several centimeters.

**9**. The process of claim **1**, further comprising coating the micro-component with a frequency converting coating.

**10**. The process of claim **9**, wherein said frequency converting coating is phosphor.

**11**. The process of claim **9**, wherein said frequency converting coating is a rare earth.

**12**. The process of claim **9**, wherein said coating is at least one of barium fluoride, yttrium aluminum garnet, yttrium aluminum garnet doped with cerium, and gadolinium gallium garnet.

**13**. The process of claim **1**, wherein said plasma-forming gas is a rare gas halide.

**14**. The method of claim **1**, wherein said plasma-forming gas contains at least one of the rare gas halides.

**15**. The process of claim **1**, wherein the micro-components are formed by glass blowing with a capillary, and with a plasma-forming gas being blown through the capillary to form the plasma-forming gas encapsulating micro-component.

**16**. A process for testing formed micro-components, comprising:

in a continuous process, optically inspecting micro-components as they are formed for structural defects; and

discarding micro-components detected to have structural defects.

**17**. The process of claim **16** further comprising applying an excitation field to the formed micro-components to cause plasma generating gas therein to become excited;

optically inspecting each micro-component to determine if it discharges radiation; and

discarding those micro-components that do not discharge radiation.

**18**. The process of claim **17**, wherein said micro-components are excited by an electron beam.

**19**. The method of claim **18**, wherein said individual testing comprises discarding micro-components which fail said individual testing.

**20**. The method of claim **18**, wherein said micro-components are excited at a level of excitation greater than any excitation to be applied when assembled in a plasma display.

**21**. The method of claim **18**, wherein said predetermined amount of time is selected to be sufficient to ensure that substantially all micro-components which are to fail, fail during said predetermined amount of time.

**22**. The process of claim **17**, wherein said micro-components are excited by a tesla coil.

**23**. The process of claim **17**, wherein said micro-components are excited by high frequency RF.

**24**. A method of conditioning micro-components for use in plasma display, comprising

assembling micro-components to be assembled into a display in a batch;

applying an excitation field to the assembled micro-components to excite a plasma generating gas in the micro-components for a predetermined amount of time; and

terminating said excitation and continuously individually testing the micro-components to ensure each one functions.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,822,626 B2 Page 1 of 1
DATED : November 23, 2004
INVENTOR(S) : E. Victor George et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Item [56], **References Cited**, OTHER PUBLICATIONS,
“Srinivasan” reference, please change “f-Assembly Using Capillary Forces,” Nournal of Microelec-” to -- f-Assembly Using Capillary Forces,” Journal of Microelec- --.

“LG Electronics Introduces” reference, please change “display.com/eng/news/e13read.as?nSeqno=22” to -- display.com/eng/news/e_read.as?nSeqno=22 --.

“Runco Plasma Wall PL” reference, please change “Internet: http://www.runco.com/Prodcuts/Plasma/” to -- Internet: http://www.runco.com/Products/Plasma/ --.

Signed and Sealed this

Twenty-second Day of November, 2005

Jon W. Dudas

JON W. DUDAS
*Director of the United States Patent and Trademark Office*

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,822,626 B2 Page 1 of 1
DATED : November 23, 2004
INVENTOR(S) : E. Victor George et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 15,
Line 32, change "conditioning device 951 in FIG. 11 the manufactured and" to -- conditioning device 951 of FIG. 12, the manufactured and --.

Signed and Sealed this

Ninth Day of May, 2006

JON W. DUDAS
*Director of the United States Patent and Trademark Office*

US006902456B2

# (12) United States Patent
George et al.

(10) Patent No.: US 6,902,456 B2
(45) Date of Patent: Jun. 7, 2005

(54) SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL

(75) Inventors: **Edward Victor George**, Lake Arrowhead, CA (US); **Roger Laverne Johnson**, Encinitas, CA (US); **Albert Myron Green**, Springfield, VA (US); **Newell Convers Wyeth**, Oakton, VA (US)

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/643,608**

(22) Filed: **Aug. 20, 2003**

(65) **Prior Publication Data**

US 2004/0051450 A1 Mar. 18, 2004

**Related U.S. Application Data**

(63) Continuation of application No. 10/318,150, filed on Dec. 13, 2002, now Pat. No. 6,646,388, which is a continuation of application No. 09/697,346, filed on Oct. 27, 2000, now Pat. No. 6,545,422.

(51) **Int. Cl.**[7] .................................................. **H01J 9/00**

(52) **U.S. Cl.** .......................................... **445/24**; 445/25

(58) **Field of Search** ............................ 445/24, 25, 50, 445/51; 313/484, 485, 491

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 | A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 | A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 | A | 11/1972 | Coleman | 316/17 |
| 3,755,027 | A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 | A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 | A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 | A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 | A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 | A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 | A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | 7/1983 | Kamegaya et al. | 313/582 |

(Continued)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).*

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

(Continued)

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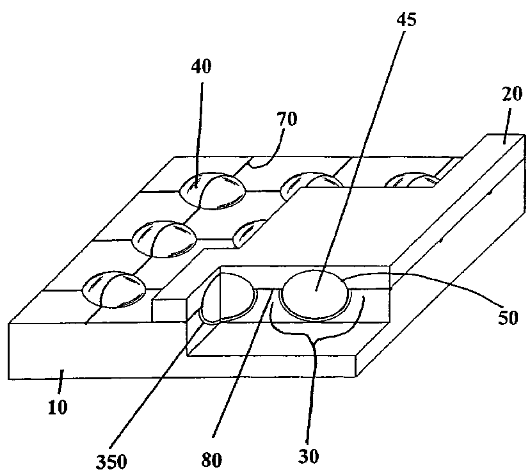
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components at least partially disposed in a socket and sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes.

**11 Claims, 18 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,429,303 | A | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 | A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | 3/1990 | Hollóet al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Salavin et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 2001/0008825 | A1 | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

Sheats, James, "Introduction to Organic Light–Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll–to–Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www– star.stanford.edu/~vlf/plasma_display/index.htm.

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose,* Washington, DC, 8 pp., Apr. 21–25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self–Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems,* vol. 10, No. 1, Mar. 2001, pp. 17–17–24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs," *The American Physical Society,* vol. 62, No. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42–Inch Digital PDP TV"[online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First In Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco Plasma Wall PL–42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco Plasma Wall P1–50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco Plasma Wall™ PL–61 cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

Alien Technology Corporation's Technology Overview; copyright ® 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.

Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly,* Alien Technology Corp., Oct. 1999, pp. 1–7.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science,* vol. 27, No. 1, Feb., 1999, pp. 14–15.

Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell," IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10–11.

Kurihara, M., Makabe, T., "Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science,* vol. 27, No. 5, Oct., 1999, pp. 1372–1378.

Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20$_{13}$ 98/bob2.htm.

"Transparent Conductive Coatings," Copyright 1998, 4 pp.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters,* vol. 9, No. 9, Sep., 1997, pp. 1241–.

Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.

"Flat Panel Displays in Perspective," 44 pp., Sep., 1995.

Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

* cited by examiner

Fig. 1

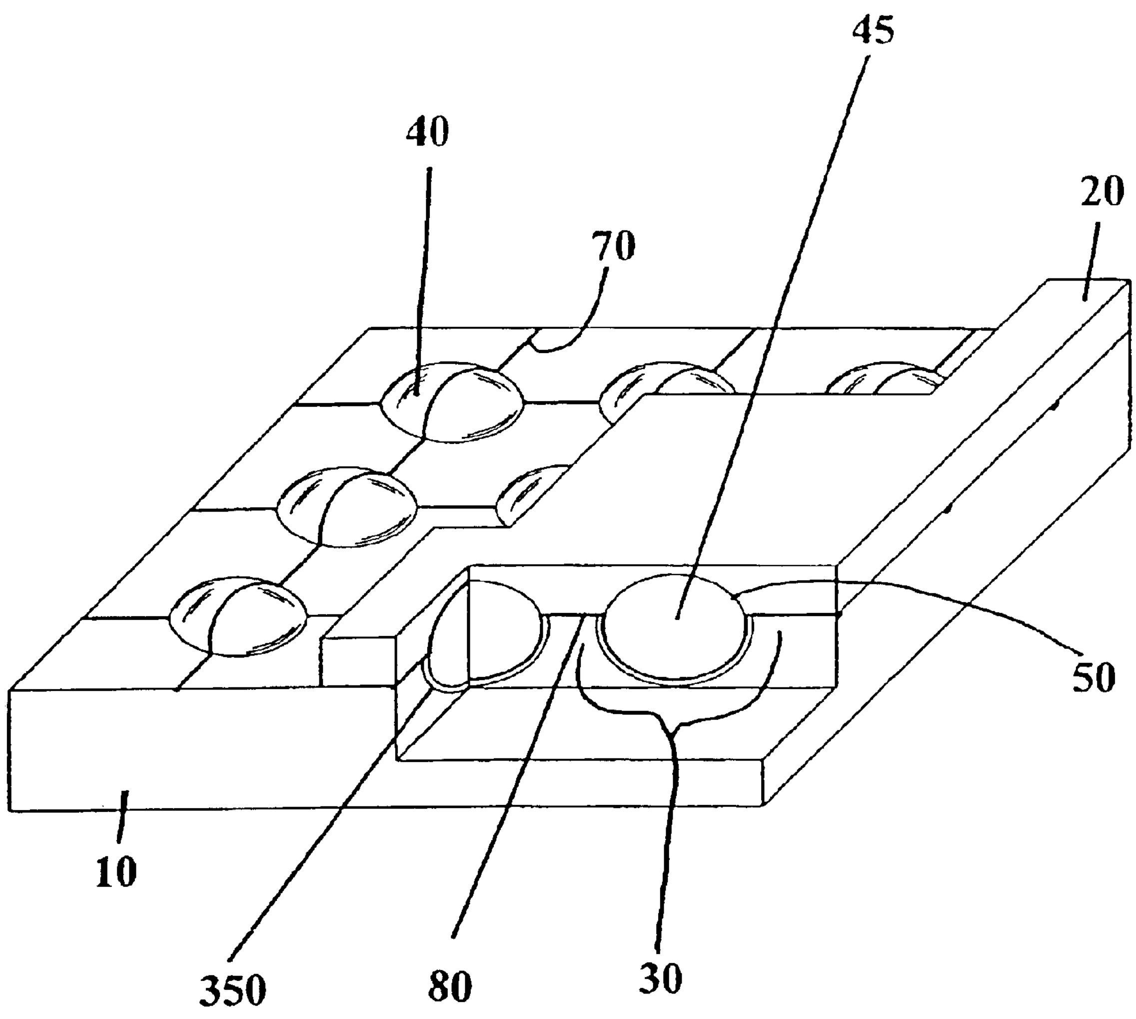
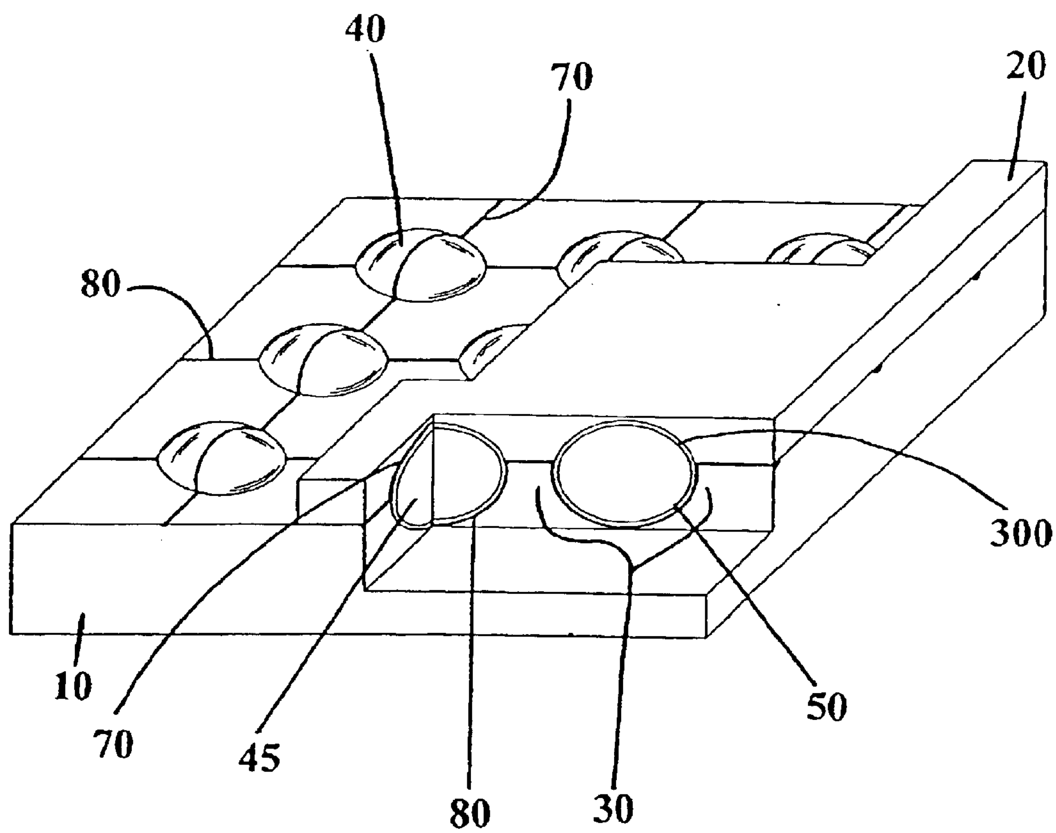


Fig. 2



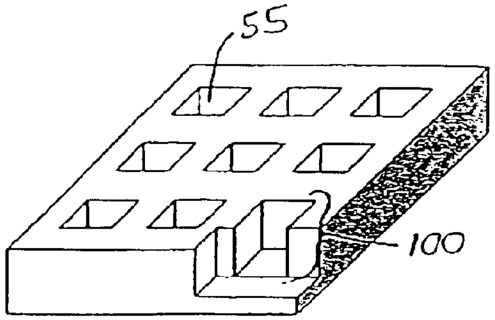



Fig. 3A

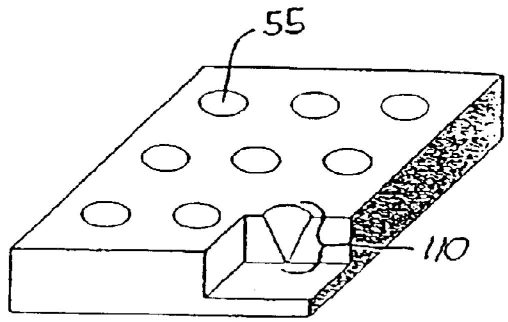



Fig. 3B

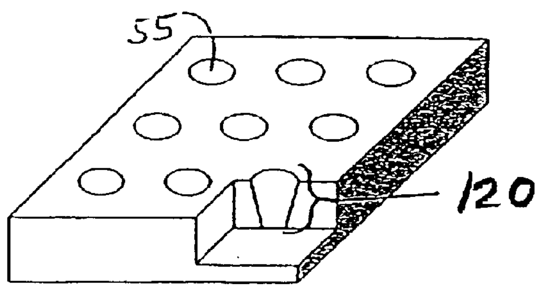



Fig. 3C

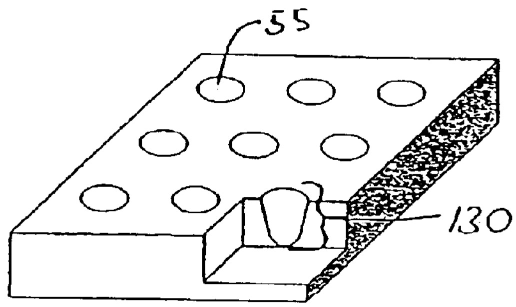



Fig 3D

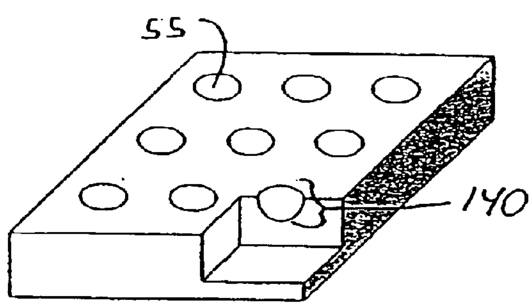



Fig 3E

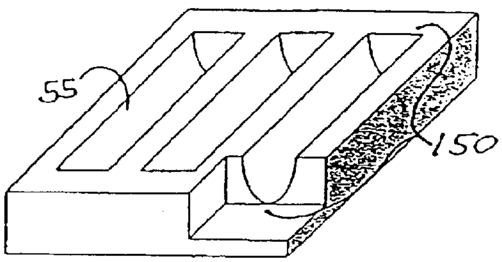



Fig. 3F

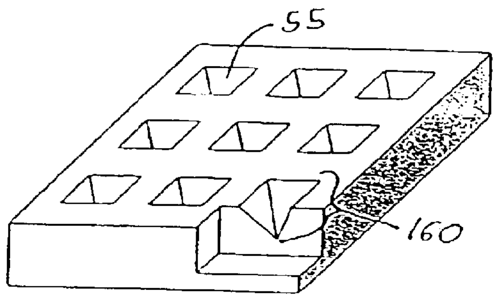



Fig. 3G

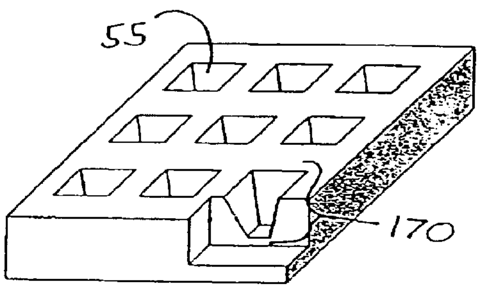



Fig. 3H

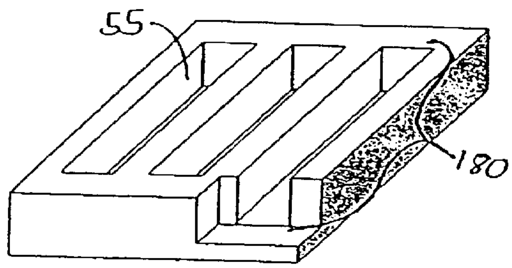



Fig. 3I

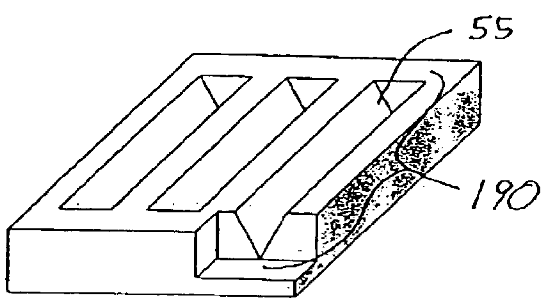



Fig. 3J

Fig. 4

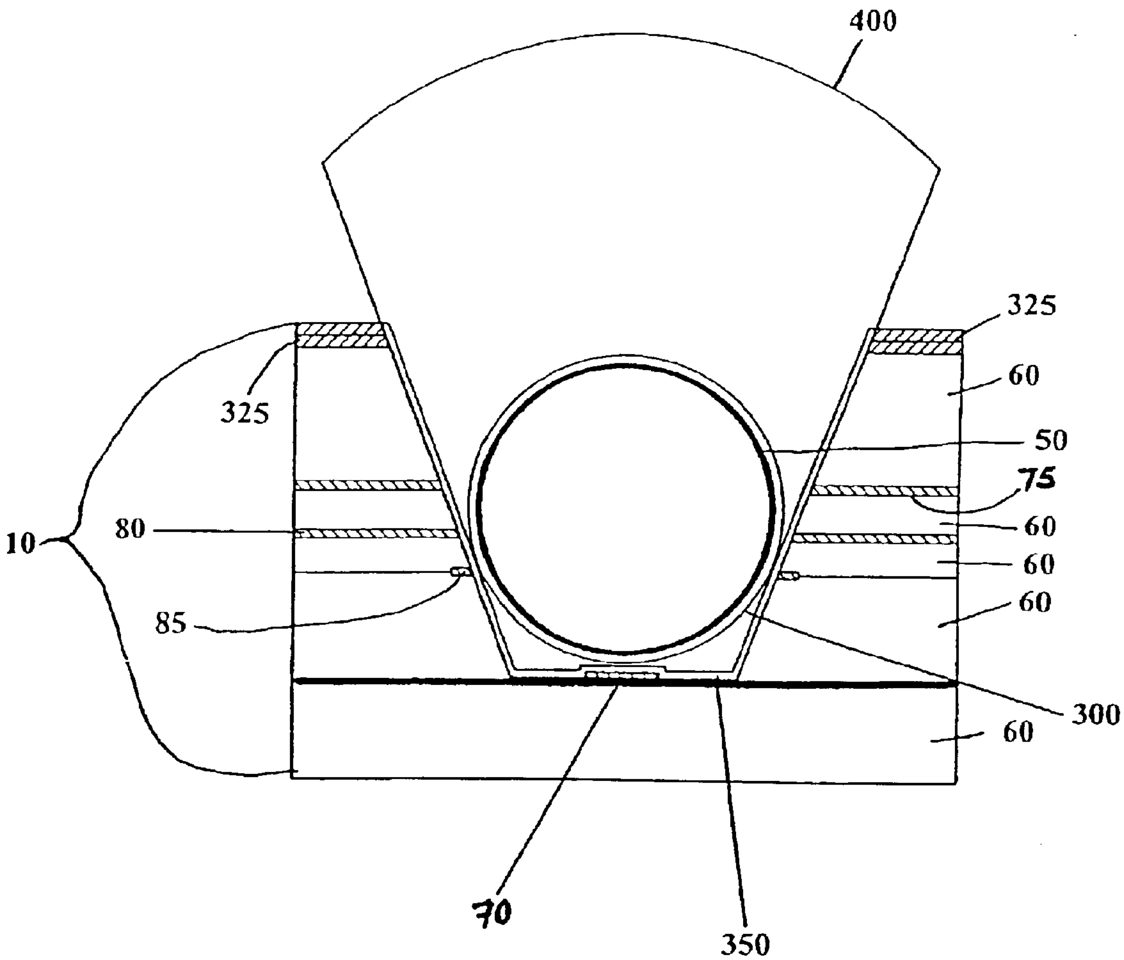


Fig. 5

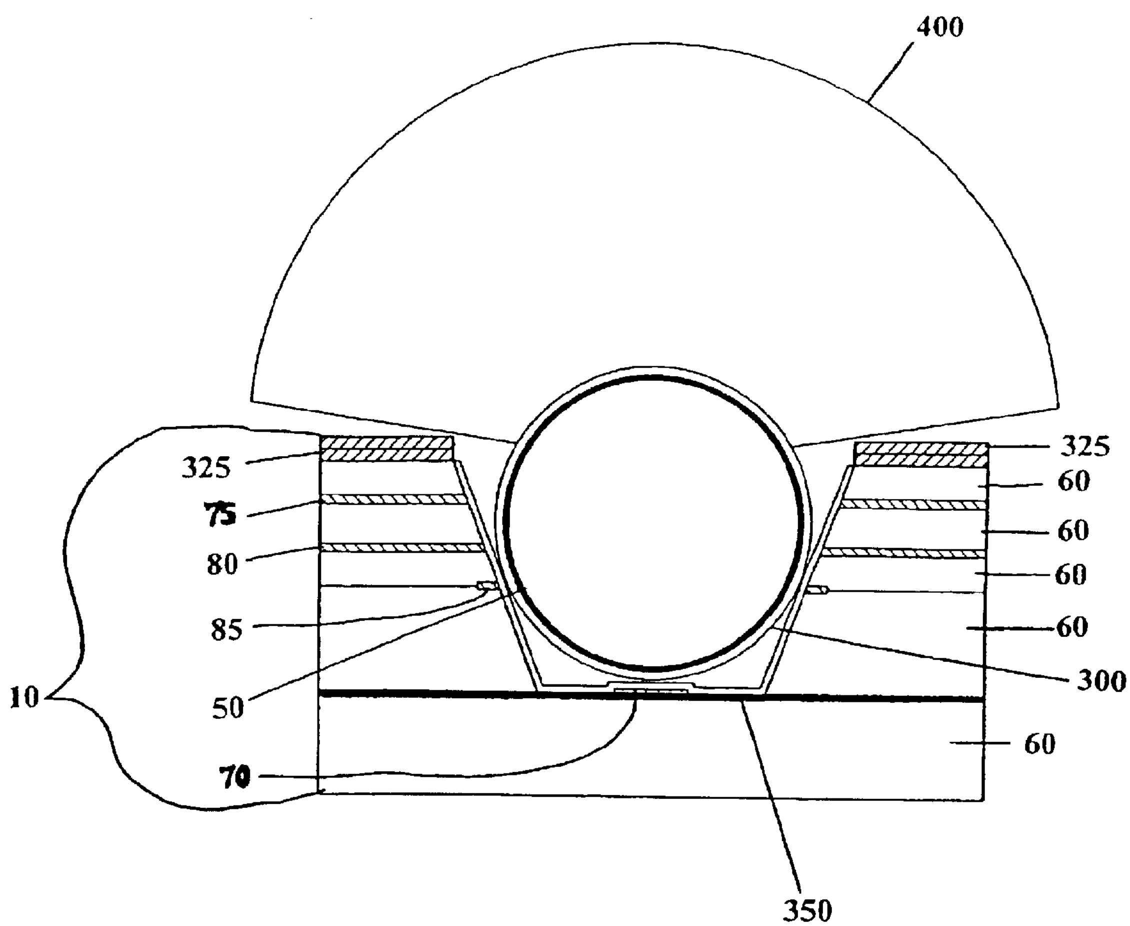


Fig. 6A

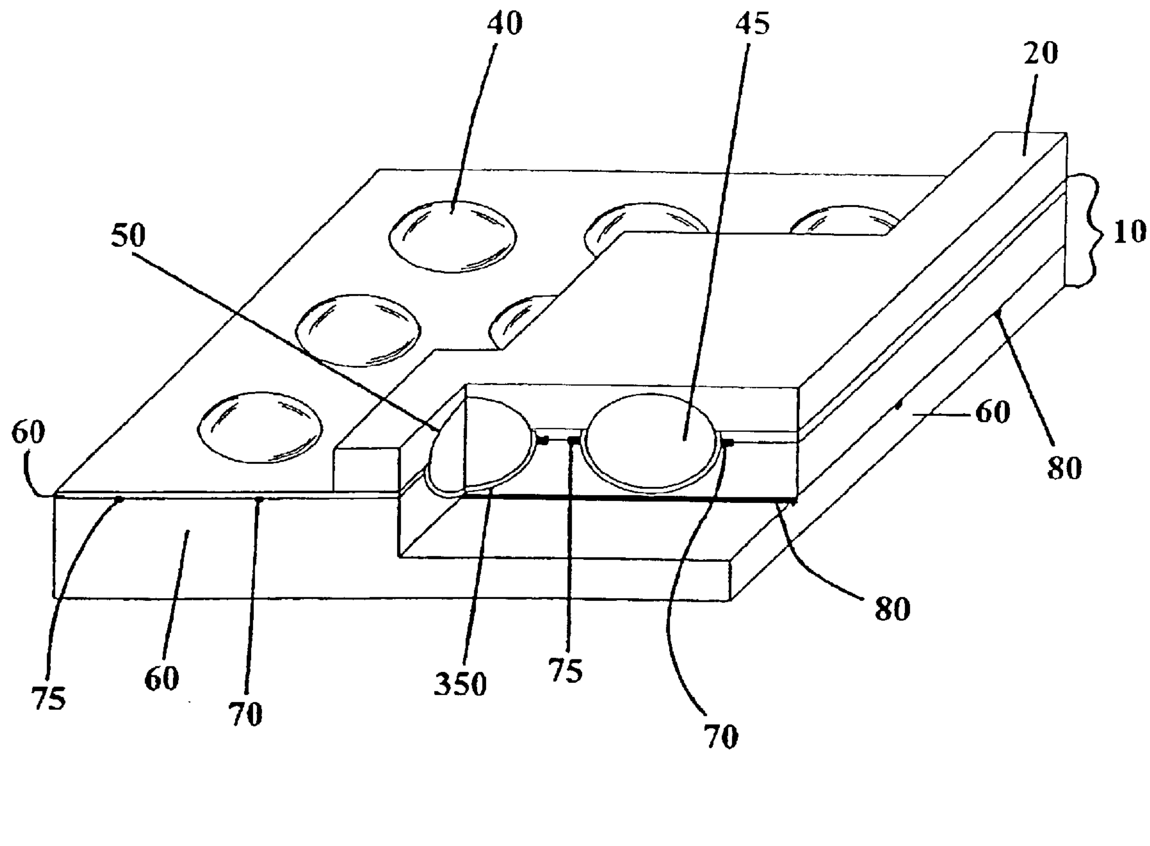


Fig. 6B

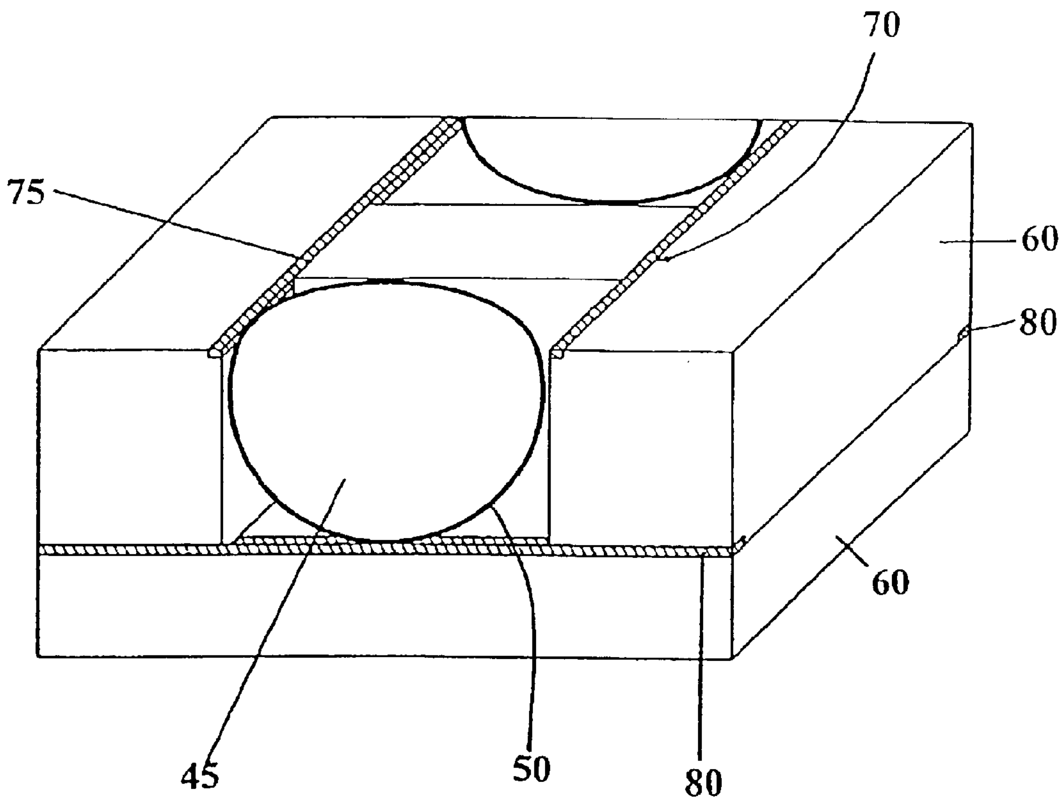


Fig. 7A

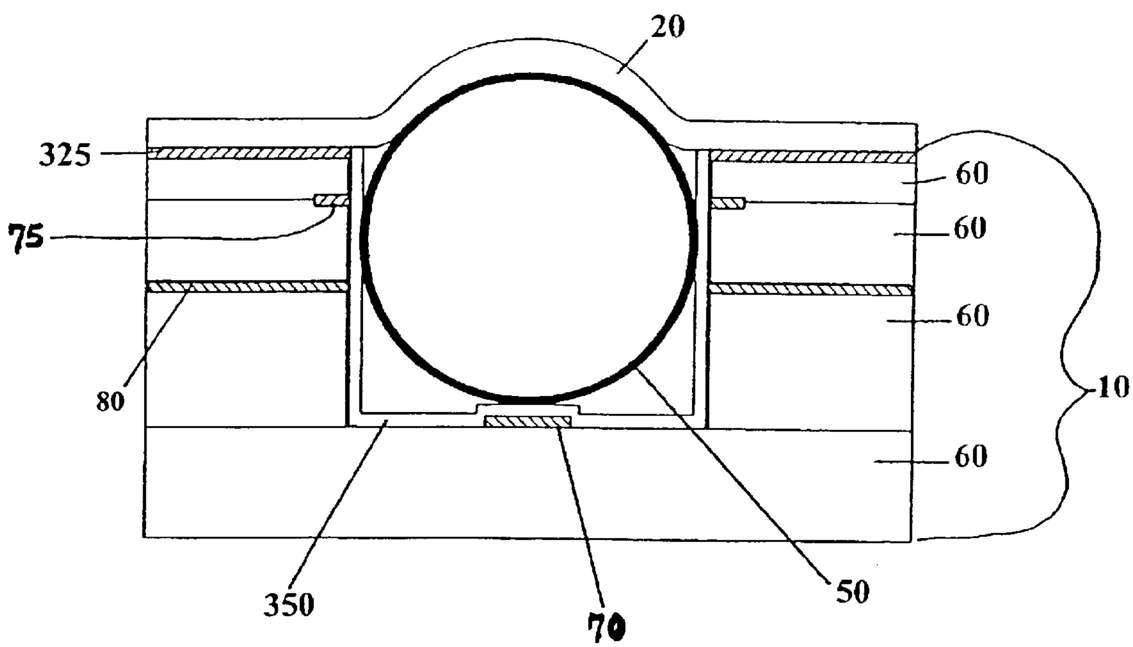


Fig. 7B

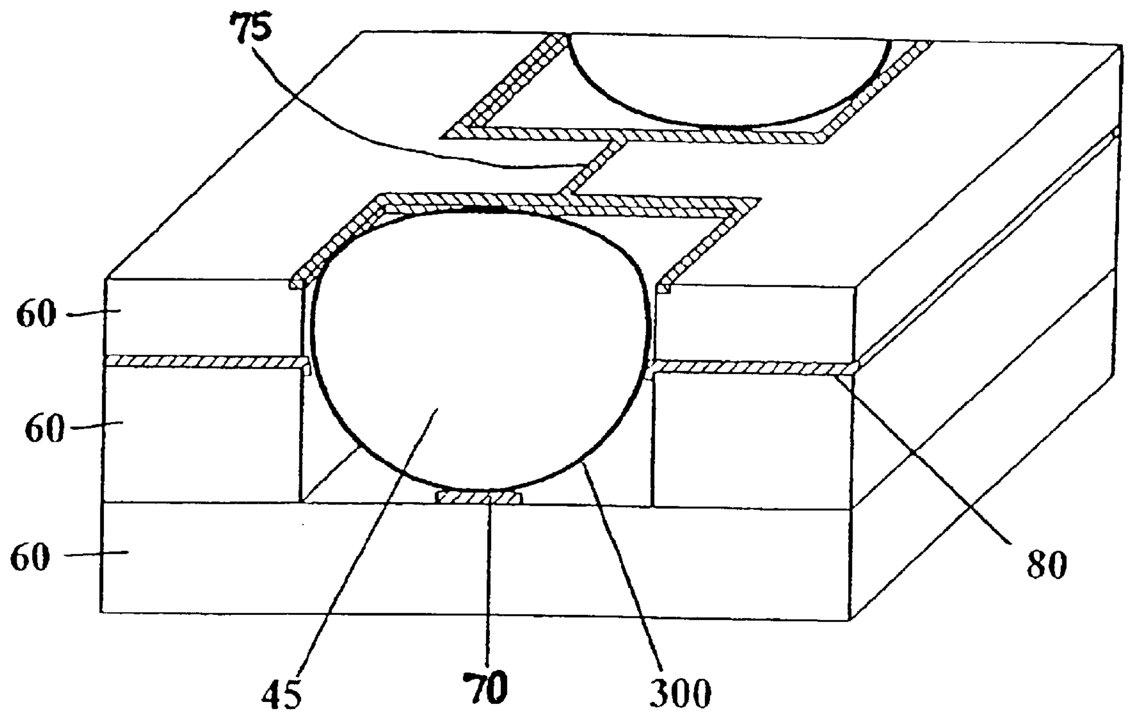


Fig. 8

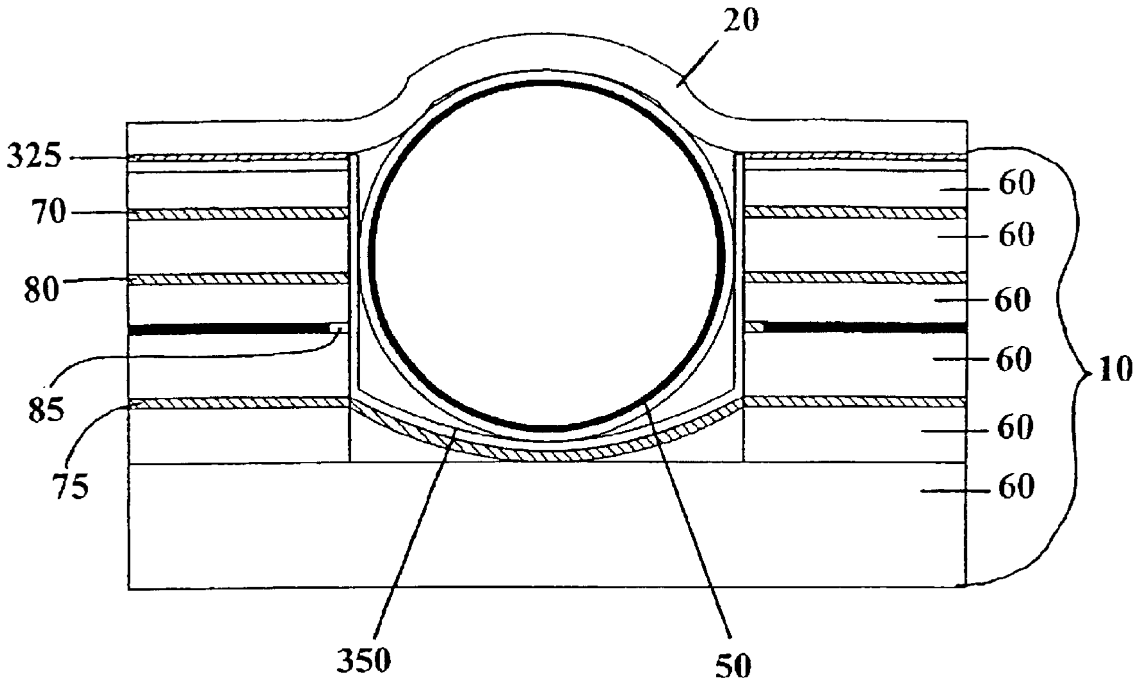


Fig. 9

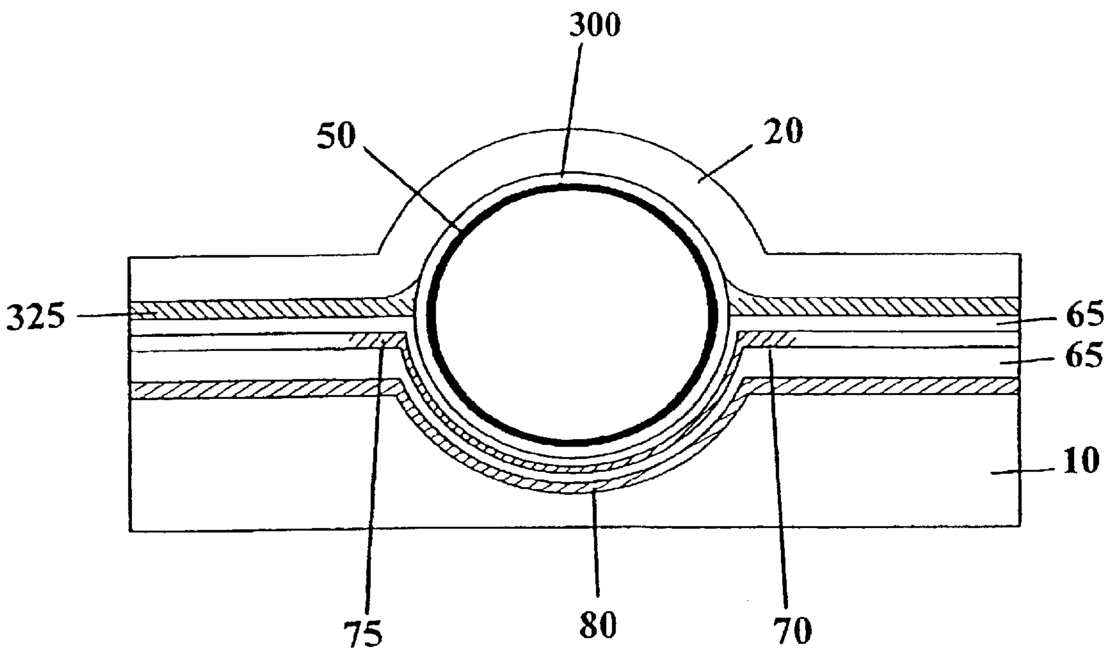


Fig. 10

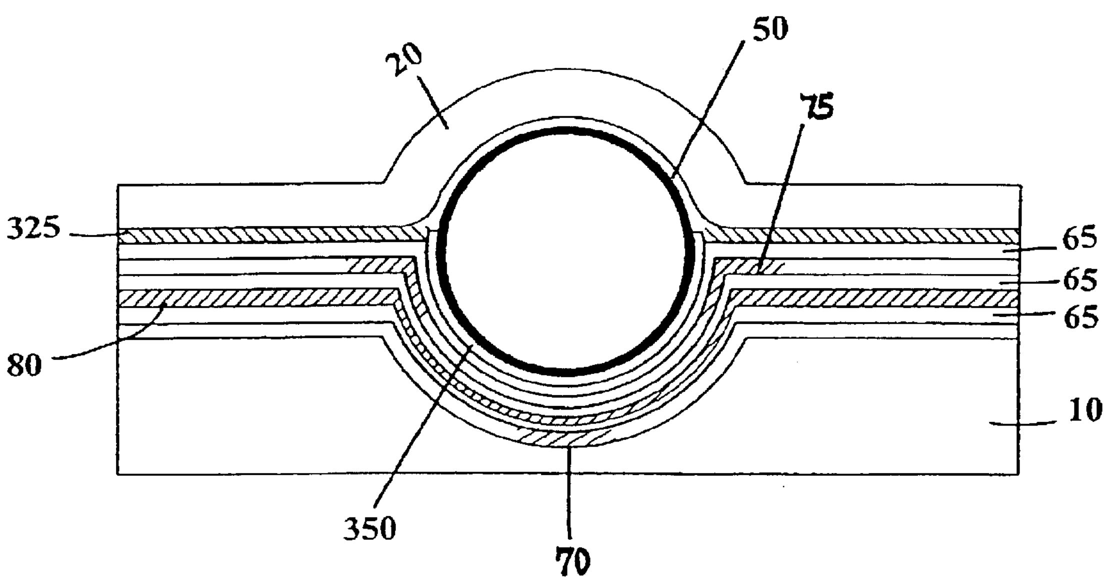


Fig. 11

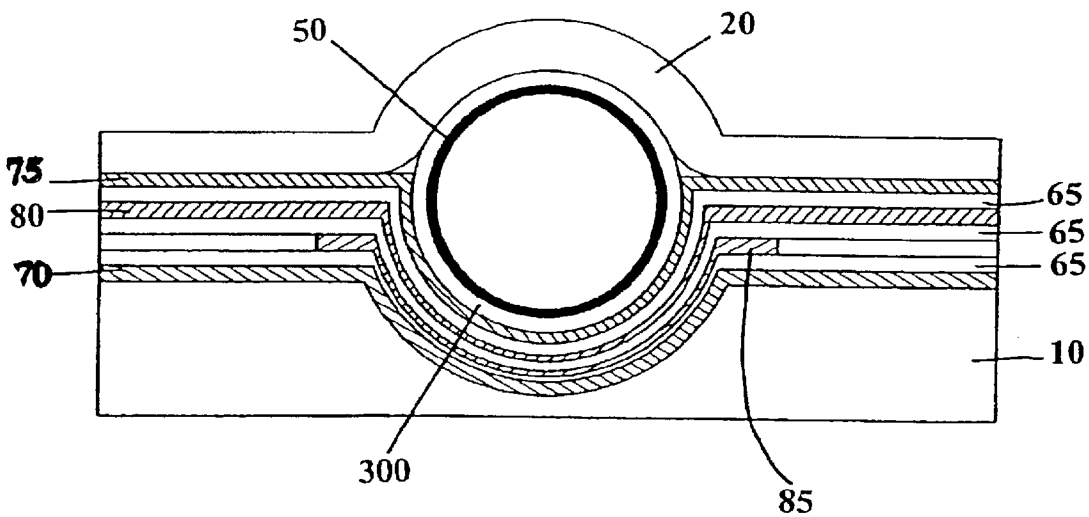


**Fig. 12**

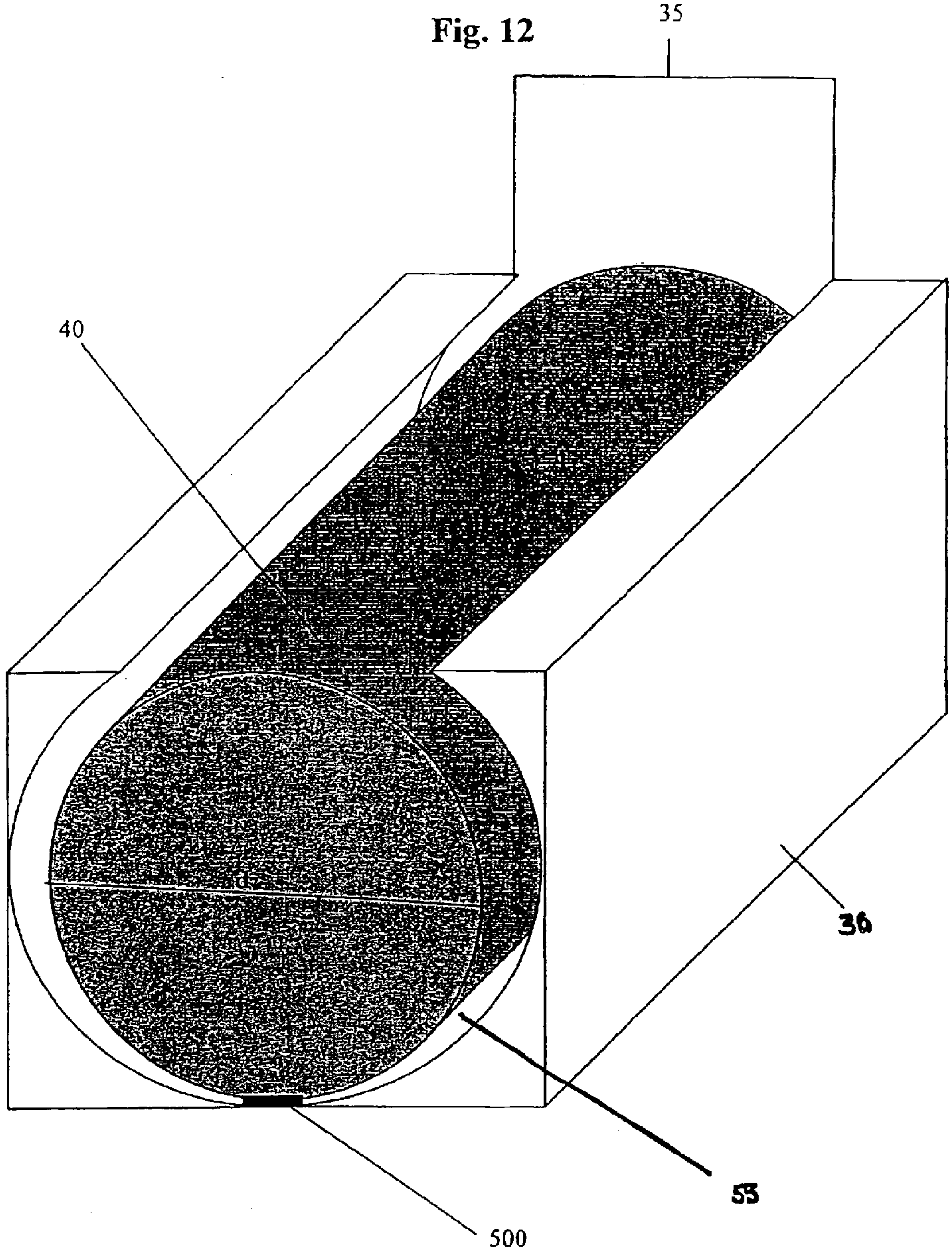


Fig. 13

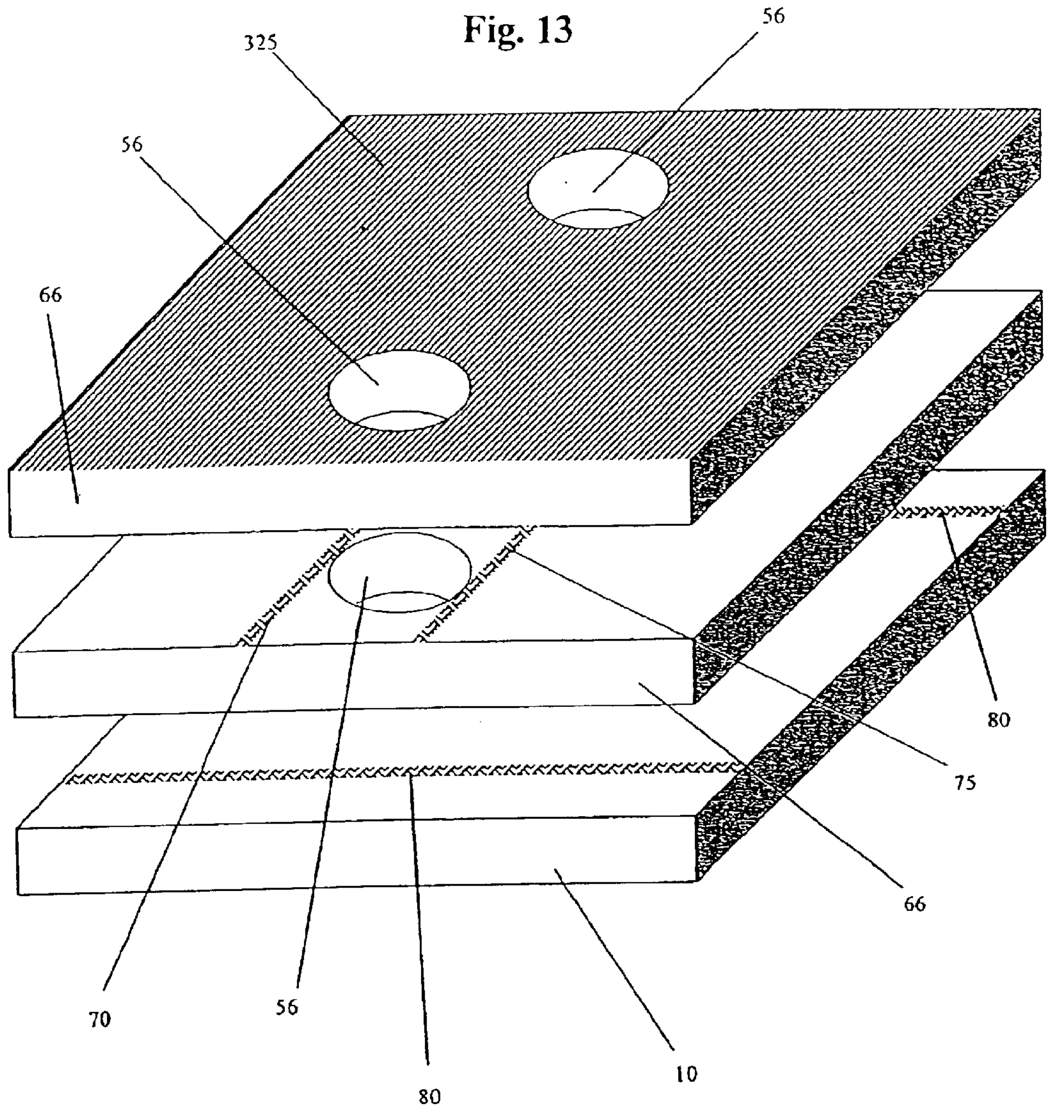


Fig. 14

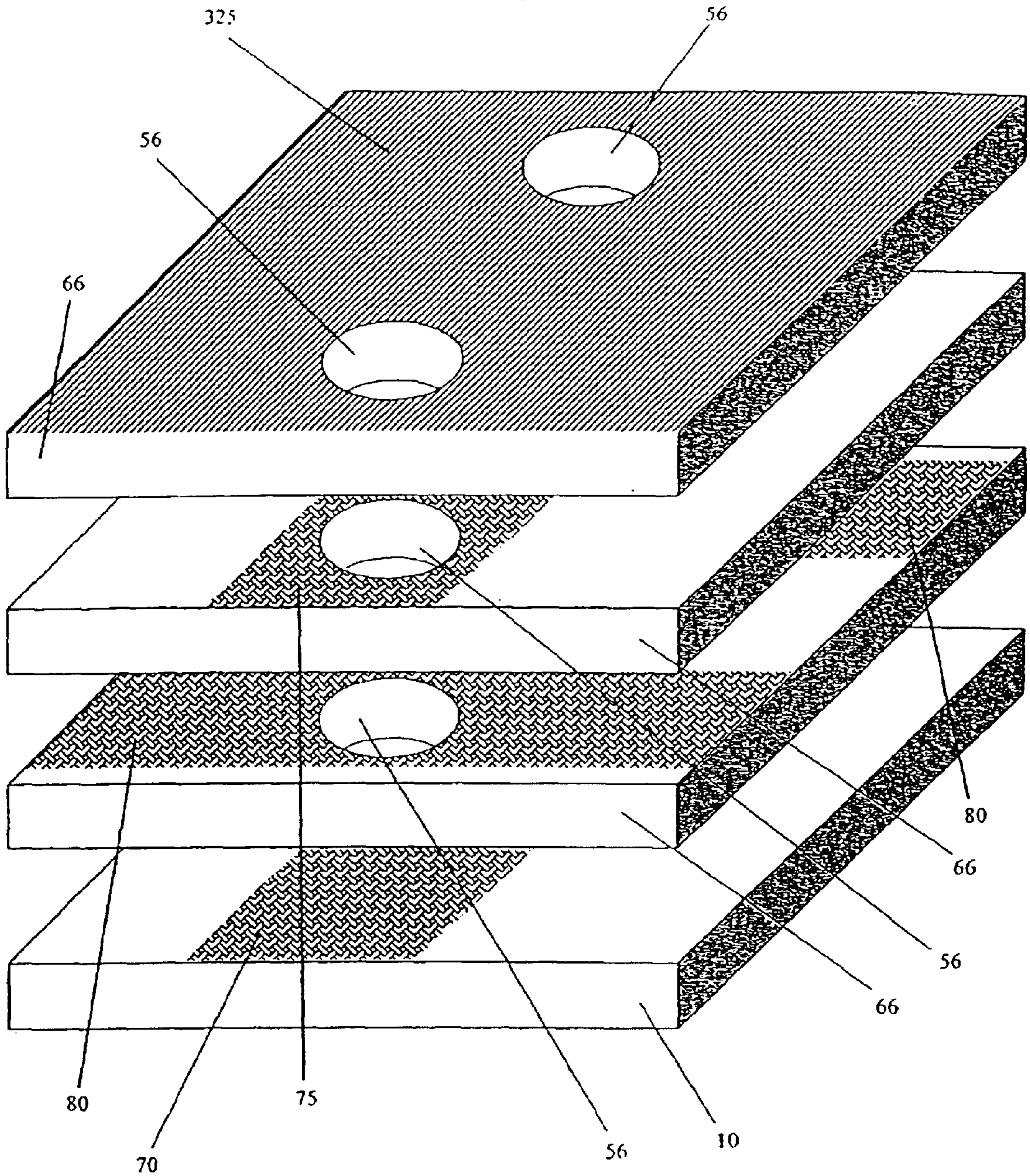
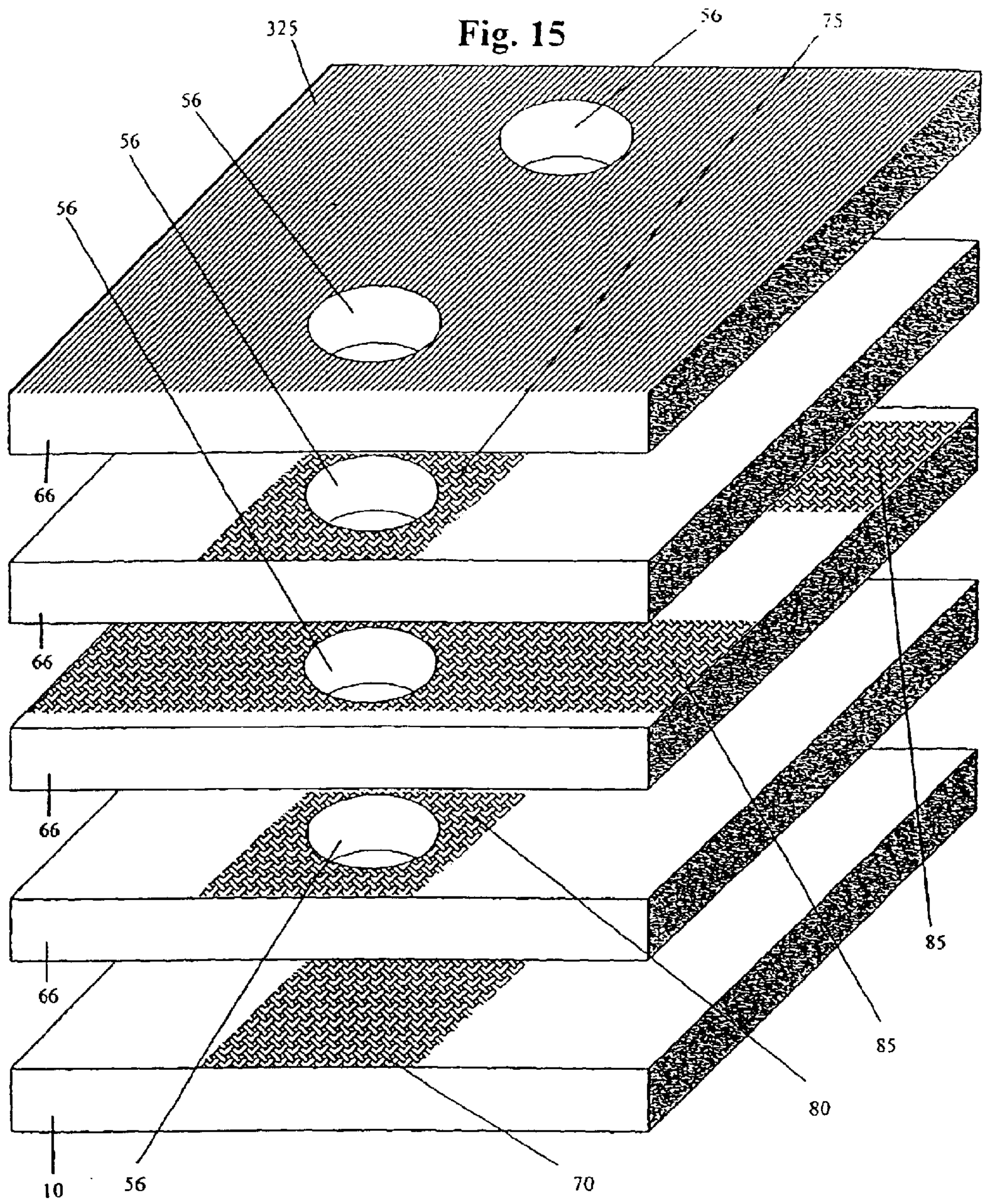


Fig. 15



# SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The current application is a continuation application of U.S. application Ser. No. 10/318,150, filed Dec. 13, 2002 now U.S. Pat. No. 6,646,388 and titled Socket for Use with a Micro-Component in a Light-Emitting Panel which is a continuation of Ser. No. 09/697,346 similarly titled U.S. Pat. No. 6,545,422 filed Oct. 27, 2000. The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a socket, for use in a light-emitting panel, in which a micro-component is at least partially disposed.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.



Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. Various embodiments of the present invention are drawn to different socket structures.

In one embodiment of the present invention, a cavity is patterned on a substrate such that it is formed in the substrate. In another embodiment, a plurality of material layers form a substrate and a portion of the material layers is selectively removed to form a cavity. In another embodiment, a cavity is patterned on a substrate so that the cavity is formed in the substrate and a plurality of material layers are disposed on the substrate such that the material layers conform to the shape of the cavity. In another embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity. Other embodiments are directed to methods for forming the sockets described above.

Each socket includes at least two electrodes that are arranged so voltage applied to the two electrodes causes one or more micro-components to emit radiation. In an embodiment of the present invention, the at least two electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to the first substrate and at least one electrode is adhered to the second substrate. In another embodiment, the at least two electrodes are arranged so that the radiation emitted from the micro-component when energized is emitted throughout the field of view of the light-emitting panel such that the radiation does not cross the two electrodes. In another embodiment, at least one electrode is disposed within the material layers.

A cavity can be any shape or size. In an embodiment, the shape of the cavity is selected from a group consisting of a cube, a cone, a conical frustum, a paraboloid, spherical, cylindrical, a pyramid, a pyramidal frustum, a parallelepiped, and a prism. In another embodiment, a socket and a micro-component are described with a male-female connector type configuration. In this embodiment, the micro-component and the cavity have complimentary shapes, wherein the opening of the cavity is smaller than the diameter of the micro-component so that when the micro-component is disposed in the cavity the micro-component is held in place by the cavity.

The size and shape of the socket influences the performance and characteristics of the display and may be chosen, for example, to optimize the panel's efficiency of operation. In addition, the size and shape of the socket may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. Further, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. In an embodiment, the inside of a socket is coated with a reflective material, which provides an increase in luminosity.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a socket capable of being used in the light-emitting panel and supporting at least one micro-component.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components **40** may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel, each cylindrical-shaped structure may hold micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

A cavity **55** formed within and/or on a substrate provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. In addition, in another embodiment of the present invention as shown in FIG. **12**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

The size and shape of the socket **30** influences the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and the electrodes disposed on or within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component that is deposited within a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

There are a variety of coatings **350** that may be at least partially added to a socket that also influence the performance and characteristics of the light-emitting panel. Types of coatings **350** include, but are not limited to, adhesives, bonding agents, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters. One skilled in the art will recognize that other coatings may also be used. The coatings **350** may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used. Alternatively, or in conjunction with the variety of socket coatings **350**, a micro-component **40** may also be coated with a variety of coatings **300**. These micro-component coatings **300** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may readily hold a micro-component or plurality of micro-components in a socket or may require additional activation energy to secure the micro-components or plurality of micro-components in a socket. In an embodiment of the present invention, where the micro-component is configured to emit UV light, the inside of each of the sockets **30** is at least partially coated with phosphor in order to convert the UV light to visible light. In a color light-emitting panel, in accordance with another embodiment, red, green, and blue phosphors are used to create alternating red, green, and blue, pixels/subpixels, respectively. By combining these colors at varying intensities all colors can be formed. In another embodiment, the phosphor coating may be combined with an adhesive so that the adhesive acts as a binder for the phosphor and also binds the micro-component **40** to the socket **30** when it is cured. In addition, the socket **30** may be coated with a reflective material, including, but not limited to, optical dielectric stacks, to provide an increase in luminosity, by directing radiation traveling in the direction of the substrate in which the sockets are formed out through the field of view **400** of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **65** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **65** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the cavities **55** are patterned on the first substrate **10** so that the cavities are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the cavities **55** are formed by selectively removing a portion of the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where the cavities **55** are patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **13**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **14**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **15**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A method for forming an emission unit for use in a light emitting panel comprising:

forming a first conductive layer of material on a substrate;

forming a second non-conductive layer of material on the first conductive layer of material;

forming a third conductive layer of material on the second non-conductive layer of material;

forming a fourth non-conductive layer of material on the third conductive layer of material;

removing portions of the first conductive layer, the second non-conductive layer, the third conductive layer and the fourth non-conductive layer, forming a cavity therein;

forming a fifth conductive layer in the cavity; and

inserting at least one micro-component into the cavity, wherein the micro-component is electrically contacted to the first conductive layer, the third conductive layer, and the fifth conductive layer.

**2**. The method according to claim **1**, further comprising coating the cavity with a sixth enhancement layer prior to inserting the at least one micro-component therein.

**3**. The method according to claim **1**, wherein the sixth enhancement layer is selected from the group consisting of an adhesive, a bonding agent, and a reflection filter.

**4**. The method according to claim **2**, further comprising forming a seventh transparent layer on the fourth conductive layer and the micro-component.

**5**. The method according to claim **1**, wherein the first conductive layer is a sustain electrode.

**6**. The method according to claim **1**, wherein the third conductive layer is an address electrode.

**7**. The method according to claim **1**, wherein the fifth conductive layer is a sustain electrode.

**8**. A method for forming an emission unit for use in a light emitting panel comprising:

forming a cavity in a substrate;

forming a first mechanically flexible conductive layer of material in the cavity;

forming a second mechanically flexible non-conductive layer of material on the first mechanically flexible conductive layer of material;

forming a third mechanically flexible conductive layer of material on the second mechanically flexible non-conductive layer of material;

forming a fourth mechanically flexible non-conductive layer of material on the third mechanically flexible conductive layer of material; and

inserting at least one micro-component into the cavity by flexing the first mechanically flexible conductive layer, the second mechanically flexible non-conductive layer, the third mechanically flexible conductive layer and the fourth mechanically flexible non-conductive layer.

**9**. The method according to claim **8**, wherein the first mechanically flexible conductive layer is an address electrode.

**10**. The method according to claim **8**, wherein the third mechanically flexible conductive layer is a sustain electrode.

**11**. The method according to claim **8**, wherein a fifth enhancement material layer is applied to the micro-component and is selected from the group consisting of an anti-glare coating, a touch sensitive surface, a contrast enhancement coating and a protective coating.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,902,456 B2 Page 1 of 1
DATED : June 7, 2005
INVENTOR(S) : Edward Victor George et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

<u>Title page,</u>
Item [56], **References Cited**, OTHER PUBLICATIONS,
"Srinivasan" reference, please change "Nournal of Microelec-" to -- Journal of Microelec- --; and
"Peterson" reference, please change "sn_arc98/6_201398/bob2.htm" to
-- sn_arc98/6_20_98/bob2.htm --.

Signed and Sealed this

Eighth Day of November, 2005

Jon W. Dudas

JON W. DUDAS
*Director of the United States Patent and Trademark Office*

US006975068B2

(12) **United States Patent**
**Green et al.**

(10) **Patent No.: US 6,975,068 B2**
(45) **Date of Patent: Dec. 13, 2005**

(54) **LIGHT-EMITTING PANEL AND A METHOD FOR MAKING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/303,924**

(22) Filed: **Nov. 26, 2002**

(65) **Prior Publication Data**

US 2003/0164684 A1 Sep. 4, 2003

**Related U.S. Application Data**

(62) Division of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**[7] ................................................ **H01J 17/49**

(52) **U.S. Cl.** ...................... **313/582**; 313/584; 313/583; 313/585

(58) **Field of Search** ................................ 313/582, 586, 313/587

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,559,190 A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | 11/1972 | Coleman | 316/17 |
| 3,704,386 A | 11/1972 | Cola | 313/108 R |
| 3,755,027 A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | 5/1977 | Caccoma et al. | 235/151.1 |

(Continued)

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| JP | 4-287397 | 10/1992 | H05K/9/00 |
| JP | 10-3869 | 1/1998 | H01J/31/12 |
| WO | WO 00/36465 | 6/2000 | G02F/1/167 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42805, dated Apr. 2, 2004 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003.

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

(Continued)

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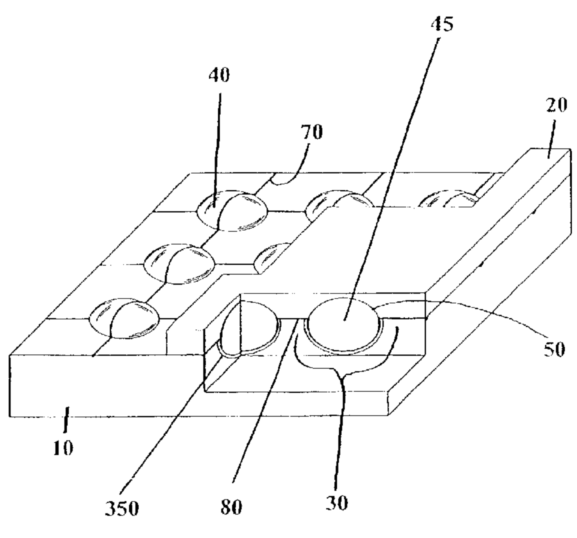
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous incline process.

**14 Claims, 22 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 4,035,690 | A | | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 | A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | * | 1/1986 | Davidson | 313/513 |
| 4,591,847 | A | | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | | 12/1991 | Dechamps | 315/169.4 |
| 5,126,632 | A | | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | | 7/1999 | Jones | 257/40 |
| 5,939,826 | A | | 8/1999 | Ohsawa et al. | 313/582 |
| 5,945,174 | A | | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | | 3/2000 | Song | 349/43 |
| 6,039,619 | A | | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | | 11/2001 | Sasaki et al. | 239/568 |
| 6,545,422 | B1 | | 4/2003 | George et al. | 315/169.3 |
| 6,570,335 | B1 | | 5/2003 | George et al. | 315/169.3 |
| 6,612,889 | B1 | | 9/2003 | Green et al. | 445/24 |
| 2001/0008825 | A1 | | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | | 2/2002 | Peng et al. | 438/700 |

| | | | | |
|---|---|---|---|---|
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |
| 2003/0094891 | A1 | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1 | 9/2003 | Green et al. | 313/582 |

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).
Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
Sheats, James, "Introduction to Organic Light–Emitting Diodes (OLEDs)" [online]. [retrieved on May 9, 2002]. 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled. htm.
Sauvante, Michael, "Roll–to–Roll Manufacturing" [online]. [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.
Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online]. [retrieved on Mar. 13, 2002]. 8 pp., Retrieved from the Internet: http://wwwstar.stanford.edu/~vlf/plasma_display/index.htm, no month.
Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose.* Washington, DC. 8 pp., Apr. 21–25, 2001.
Srinivasan, Uthara, et al., "Microstructure to Substrate Self–Assembly Using Capillary Forces." *Nournal of Microelectromechanical Systems,* vol. 10, No. 1, Mar., 2001, pp. 17–17–24.
Chutinan. Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two–Dimensional Photonic Crystal Slabs." *The American Physical Society.* vol. 62, No. 7, 5 pp., Aug. 15, 2000.
"Rolltronics" [online]. Feb. 20, 2000 [retrieved on Mar. 12, 2000]. 13 pp., Retrieved from the Internet: http://www.rolltronics.com.
"Electronics & Telecommunications" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3, no month.
"New Product" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 1 p.. Retrieved from the Internet: http://www.lge.com, no month.
"Monitor " [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp, no month.
"LG Electronics Introduces 42–Inch Digital PDP TV" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22, no month.
"LG PDP Now Available at World Renowned Harrods Department Store" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet:http://www.pdpdisplay.com/eng/news/e_readasp?nSeqno21, no month.
"LG Electronics Becomes First in Korea to Export PDP Module" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=, no month.
"LG Electronics—To The Top in PDP Business" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=, no month.
"LG Electronics Becomes the First in Korea to Export PDP" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=, no month.
"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word=, no month.
"Runco Plasma Wall Systems with Vivex Processing" [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm, no month.
"Runco Plasma Wall PL–42ex" [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42ex.htm, no month.
"Runco Plasma Wall Pl–50c" [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50chtm, no month.
"Runco Plasma Wall™PL–61cx" [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm, no month.
Alien Technology Corporation'Technology Overview: copyright © 2000. Alien Technology™; http://www alien-technology.com/d/technology/overview.html, no month.
Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly,* Alien Technology Corp., Oct. 1999, pp. 1–7.
Shin, Y. K., Lee, J. K., Shon, C. H., "Two–Dimensional Breakdown Characteristics of PDP Cells fo Varying Geometry." *IEEE Transactions on Plasma Science,* vol. 27, No. 1, Feb., 1999, pp. 14–15.
Raulf, S., Kushner, M. J., "Operation of a Coplanar–Electrode Plasma Display Panel Cell." *IEEE Transactions on Plasma Science.* vol. 27. No. 1. Feb. 1999. pp. 10–11.
Kurihara, M., Makabe, T., "Two–Dimensional Modeling of a Micro–Cell Plasma in Xe Driven by High Frequency." *IEEE Transactions on Plasma Science,* vol. 27, No. 5, Oct., 1999, pp. 1372–1378.
Peterson, "Rethinking Ink" [online]. Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002]. 7 pp.. Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.
"Transparent Conductive Coatings," Copyright 1998. 4 pp., no month.

Lin, Yi–Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides." *IEEE Photonics Technology Letters.* vol. 9. No. 9. No. 9. Sep. 1997. pp. 1241–.

Jacobson, et al., "The Last Book" [online]. IBM Systems Journal, vol. 36. No. 3. 1997 [retrieved on Dec. 4, 2002]. 6 pp.. Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html, no month.

Stearns, Thomas H.. "Flexible Printed Circuitry." 6 pp.. 1996, no month.

"Flat Panel Displays in Perspective." 44 pp.. Sep., 1995.

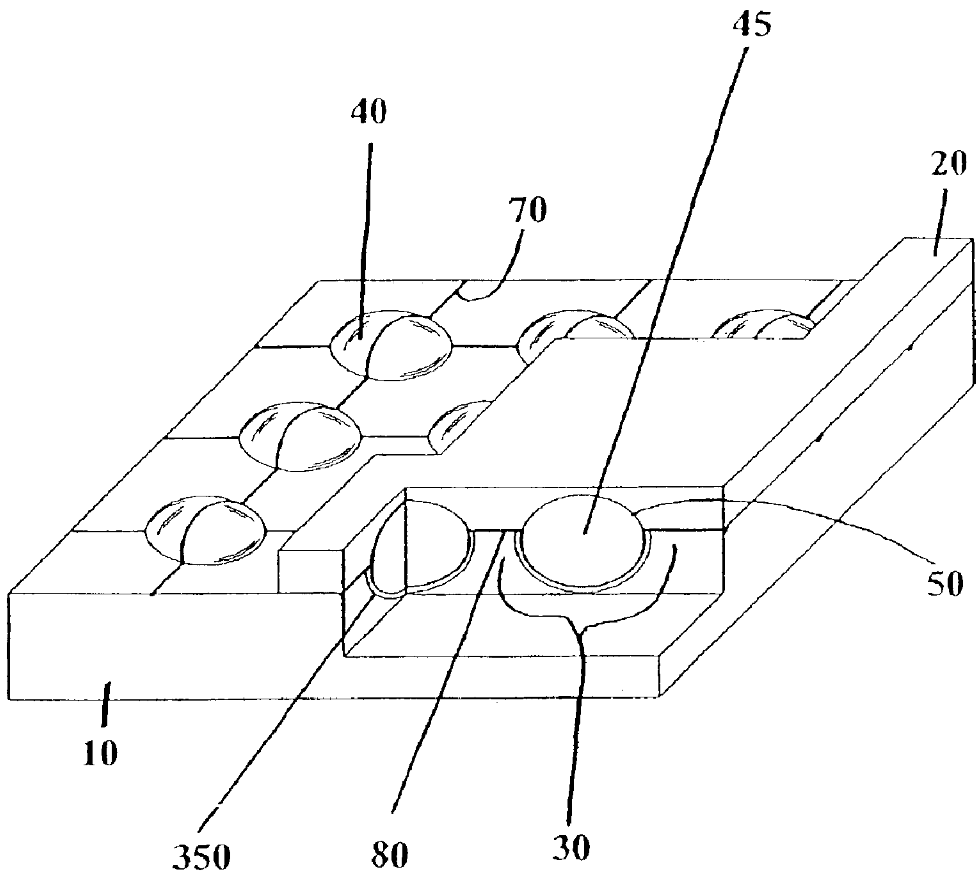
Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today. Summer. 1995 [retrieved on Dec. 4, 2002]. 10 pp.. Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

Preliminary Examination Report for Application No. PCT/US03/22868, dated Sep. 27, 2004 (mailing date).

International Search Report for Application No. PCT/US03/22868, dated Jun. 1, 2004 (mailing date).

* cited by examiner

Fig. 1



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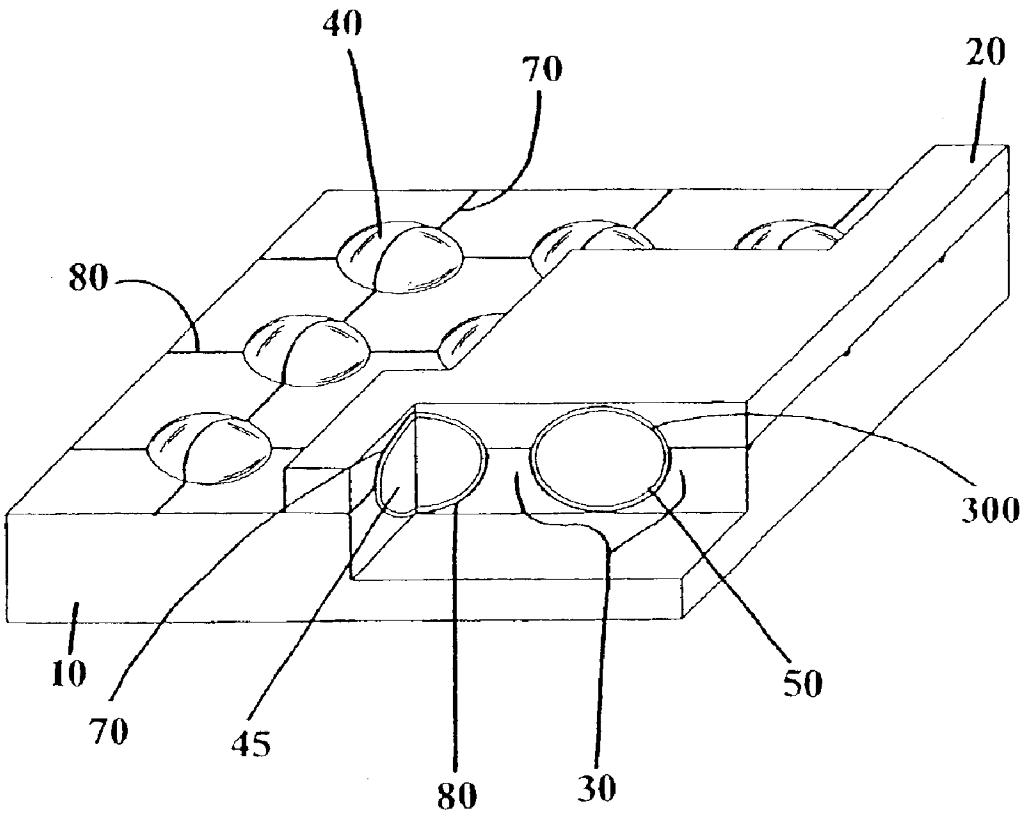

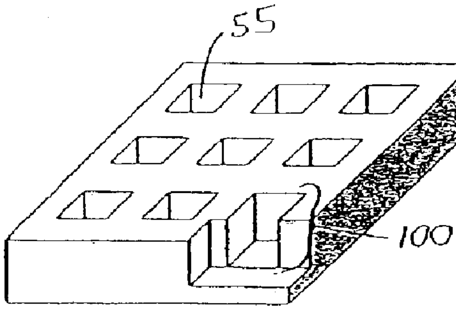


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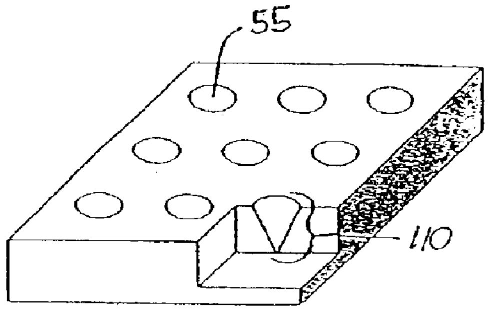


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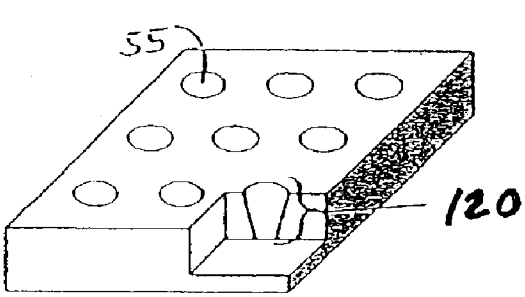


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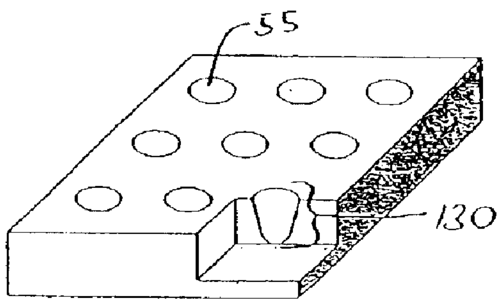


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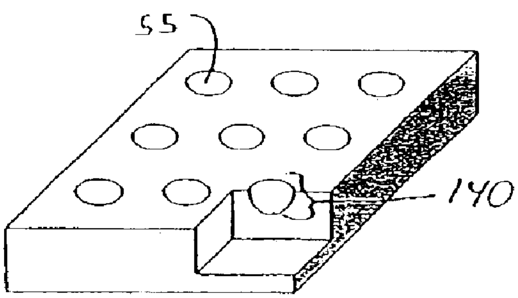


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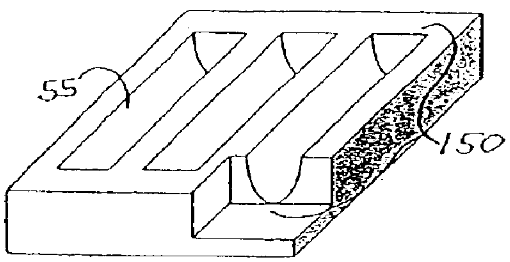


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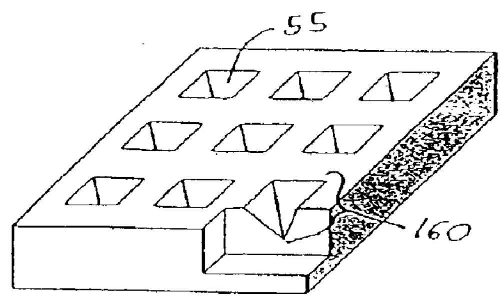


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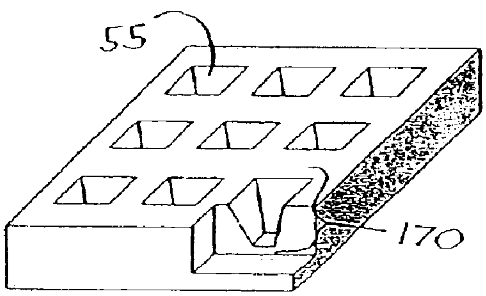


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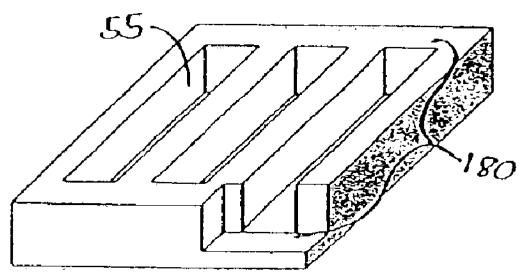


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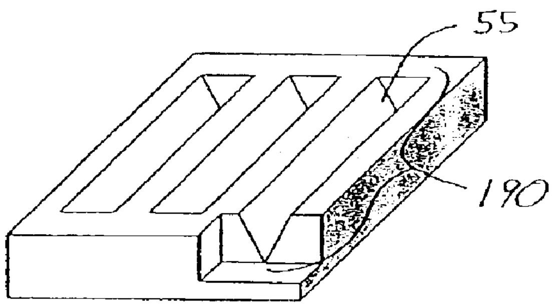
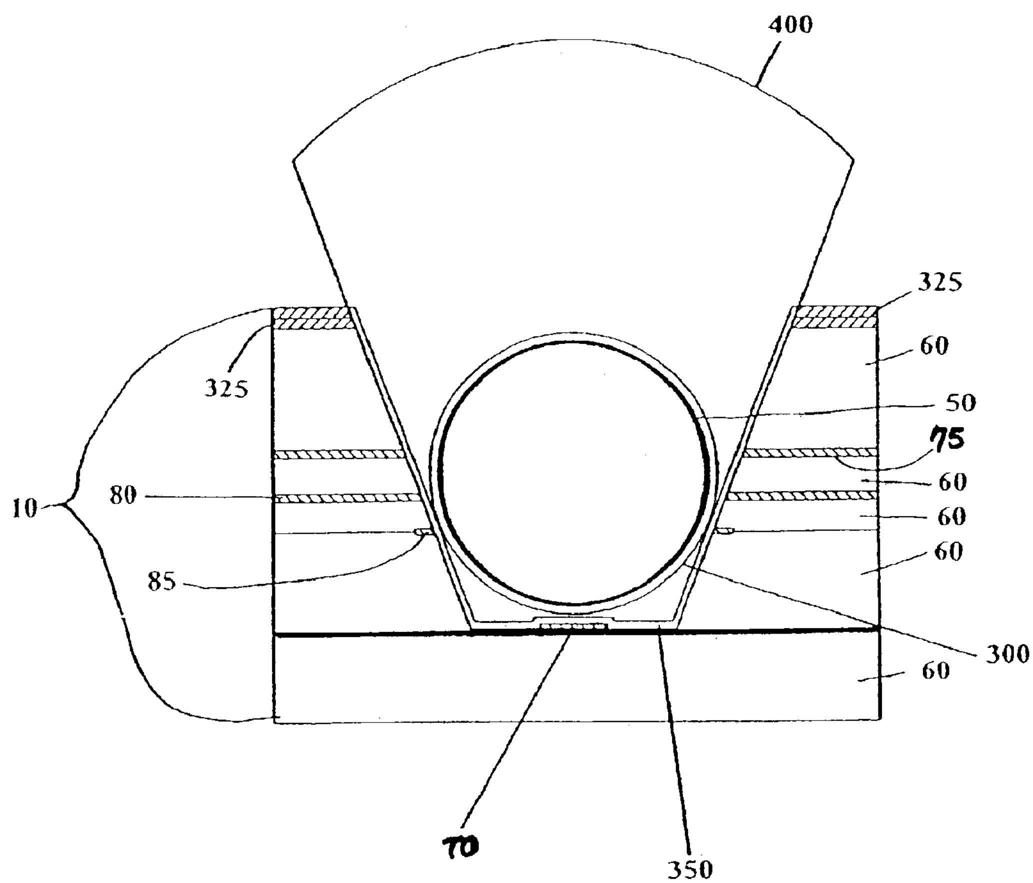



Fig. 3J

Fig. 4



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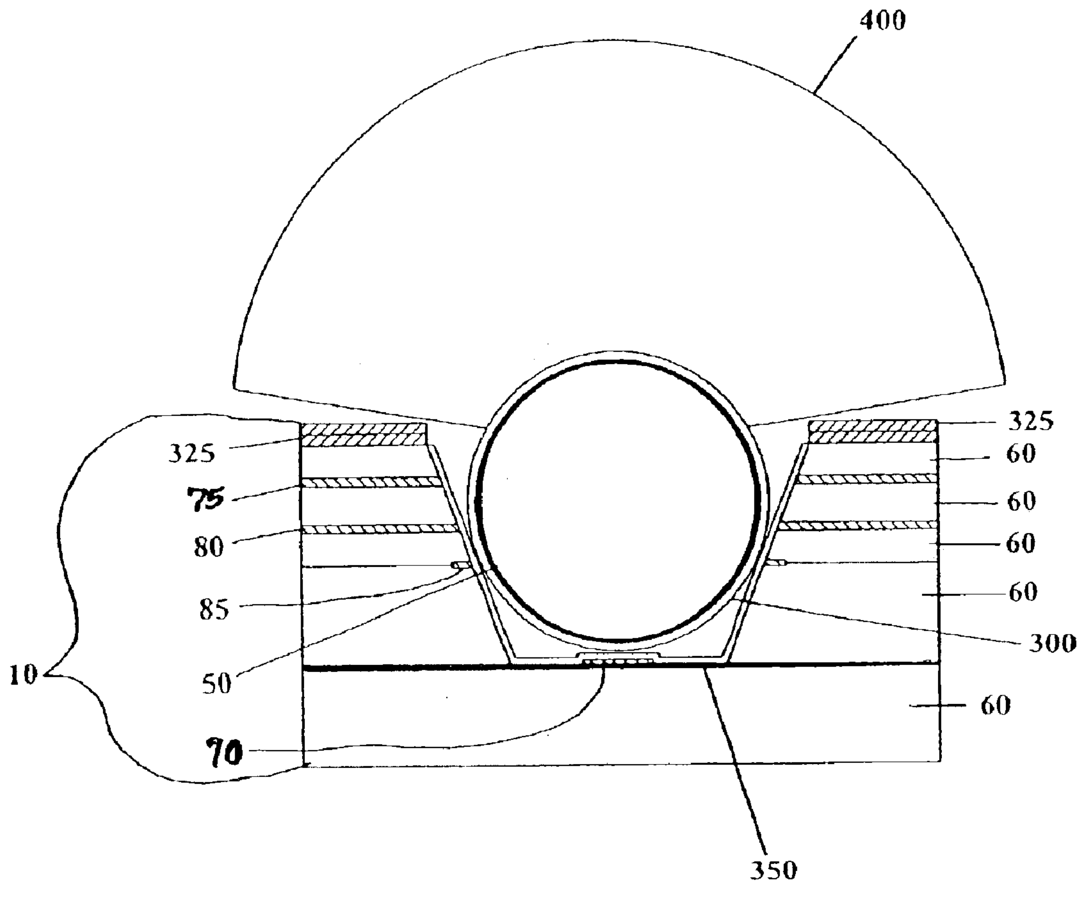


Fig. 6A

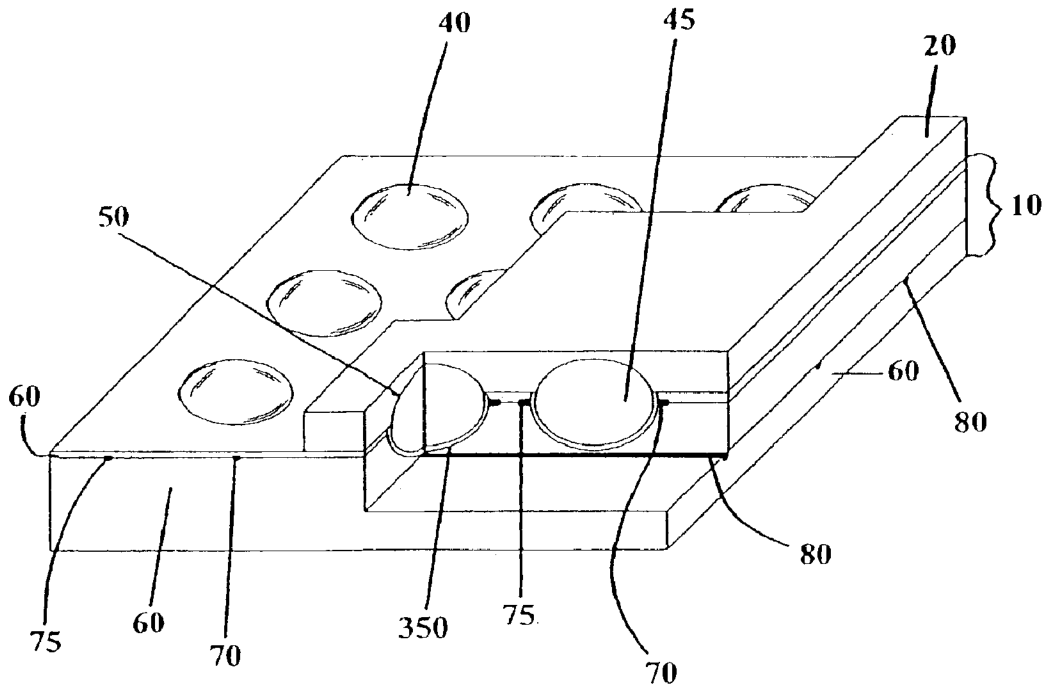


Fig. 6B

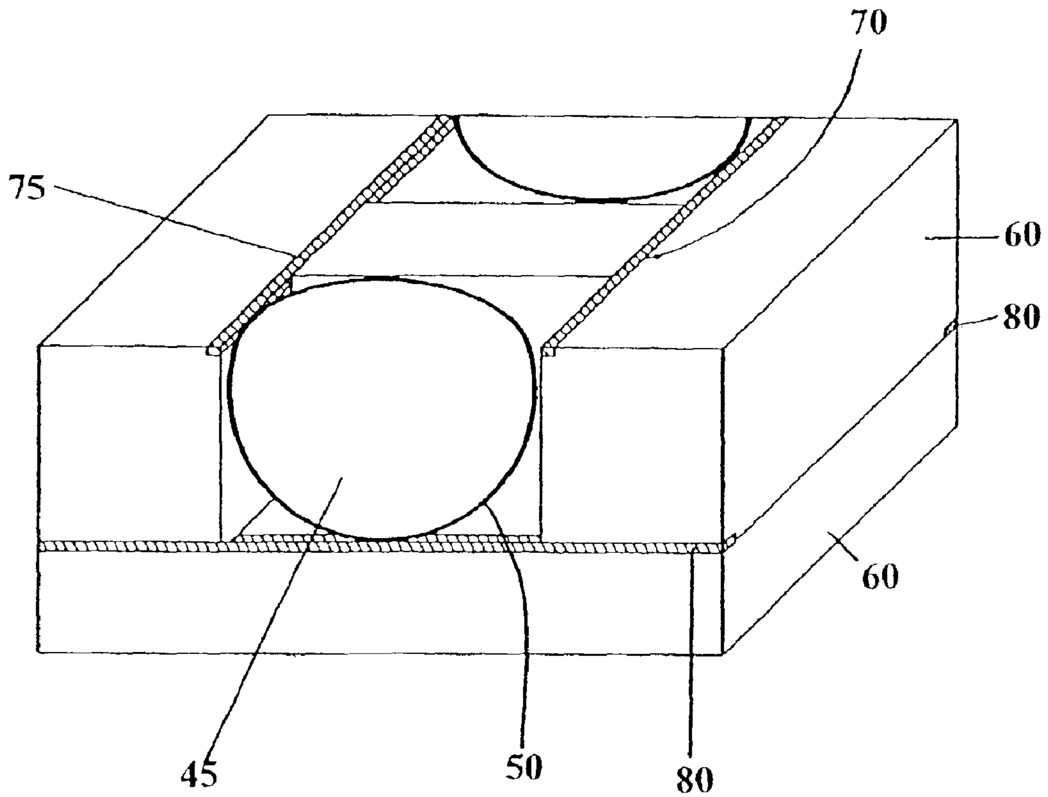


Fig. 7A

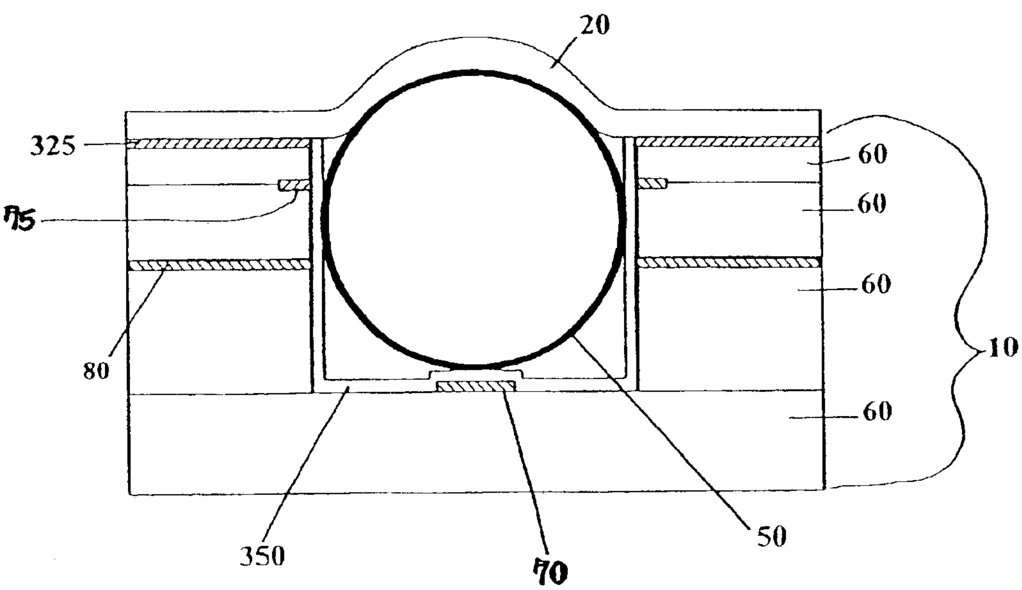


Fig. 7B

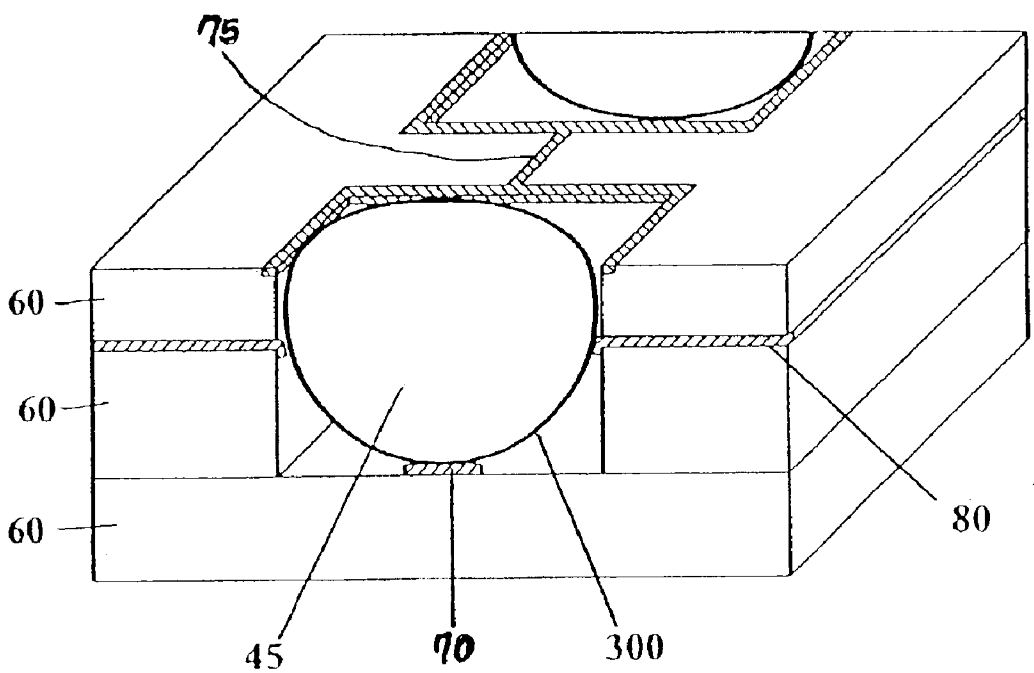


Fig. 8

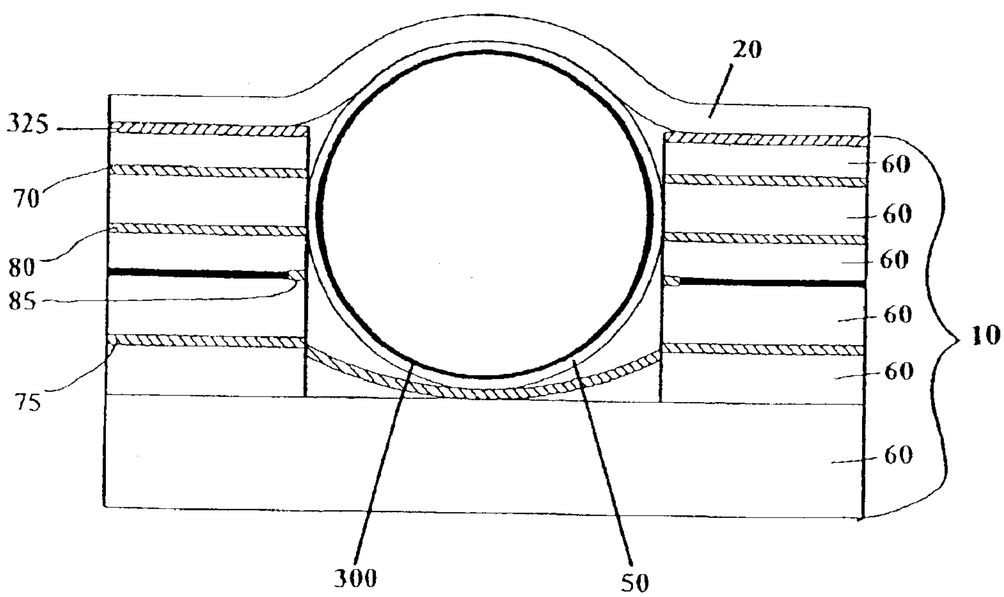


Fig. 9

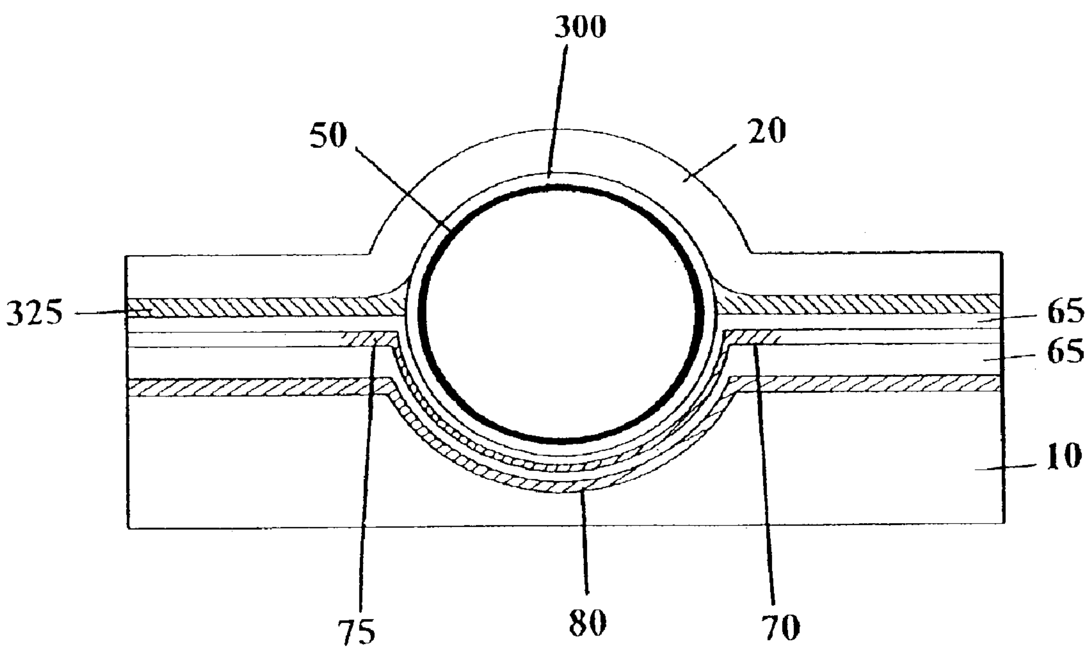


Fig. 10

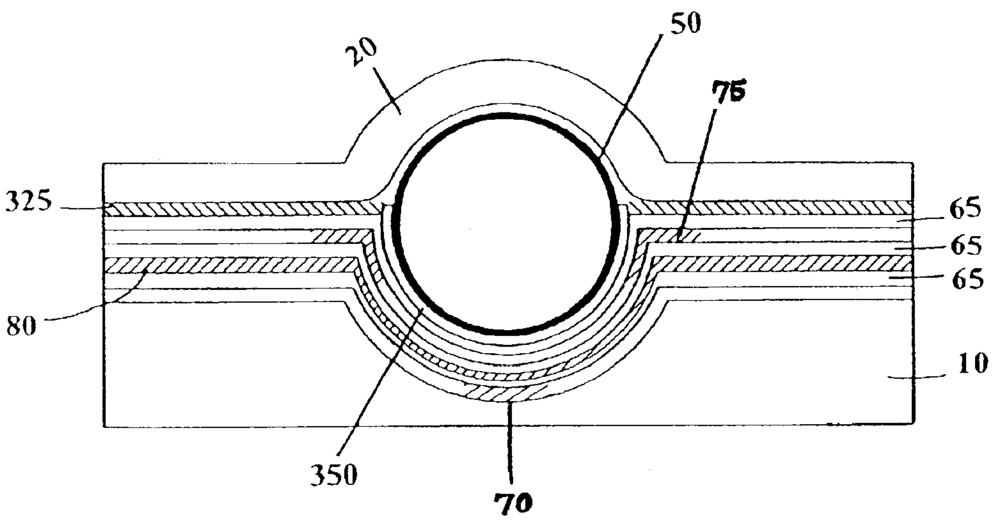
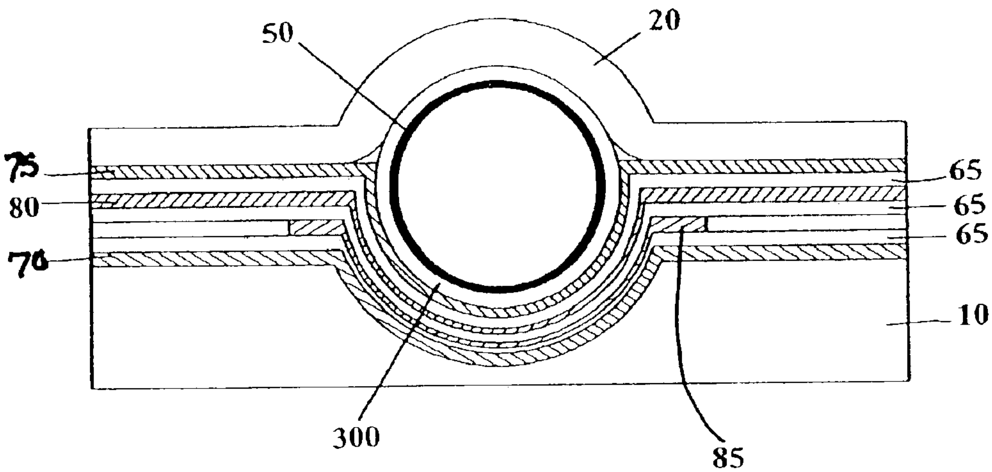
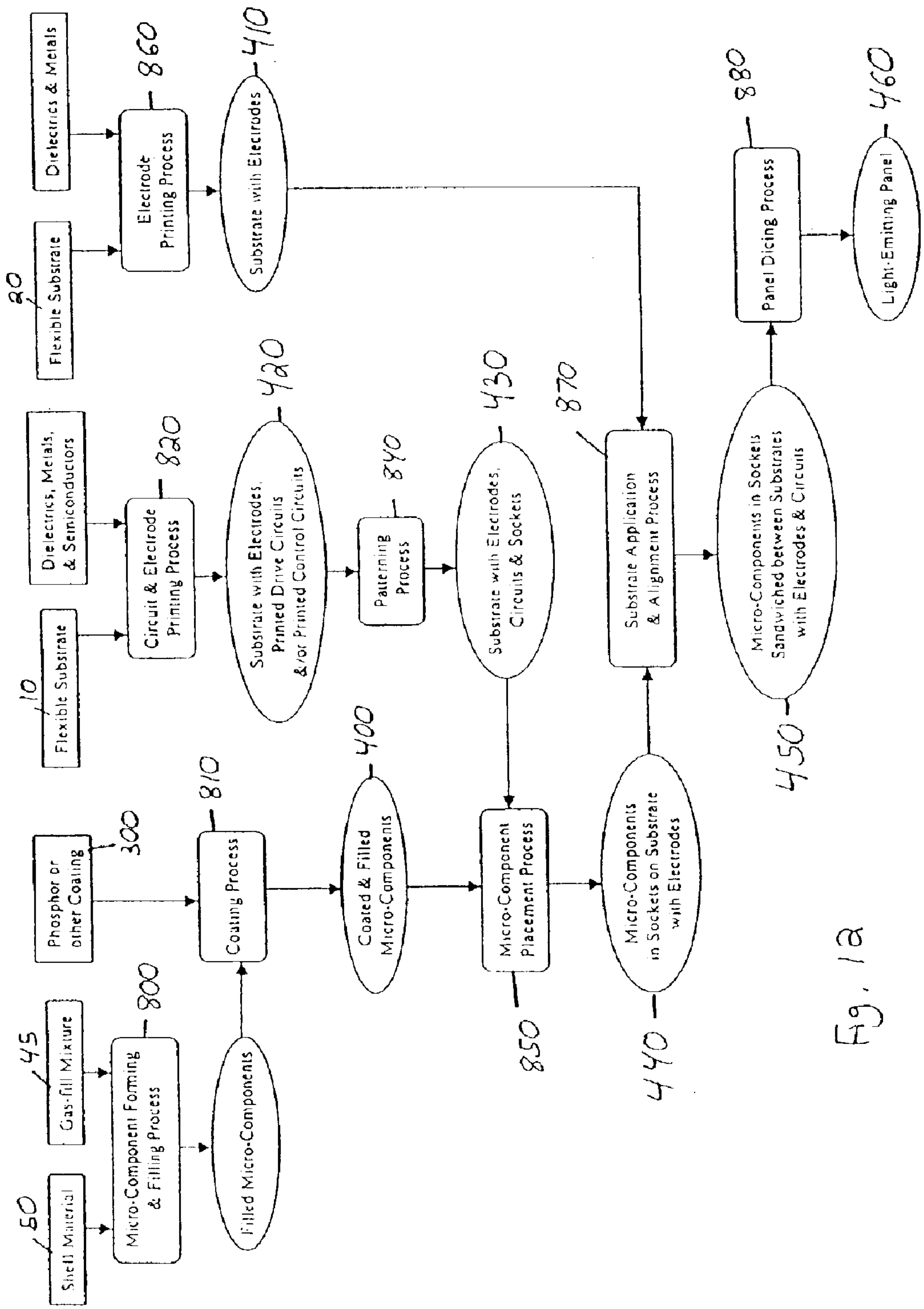


Fig. 11

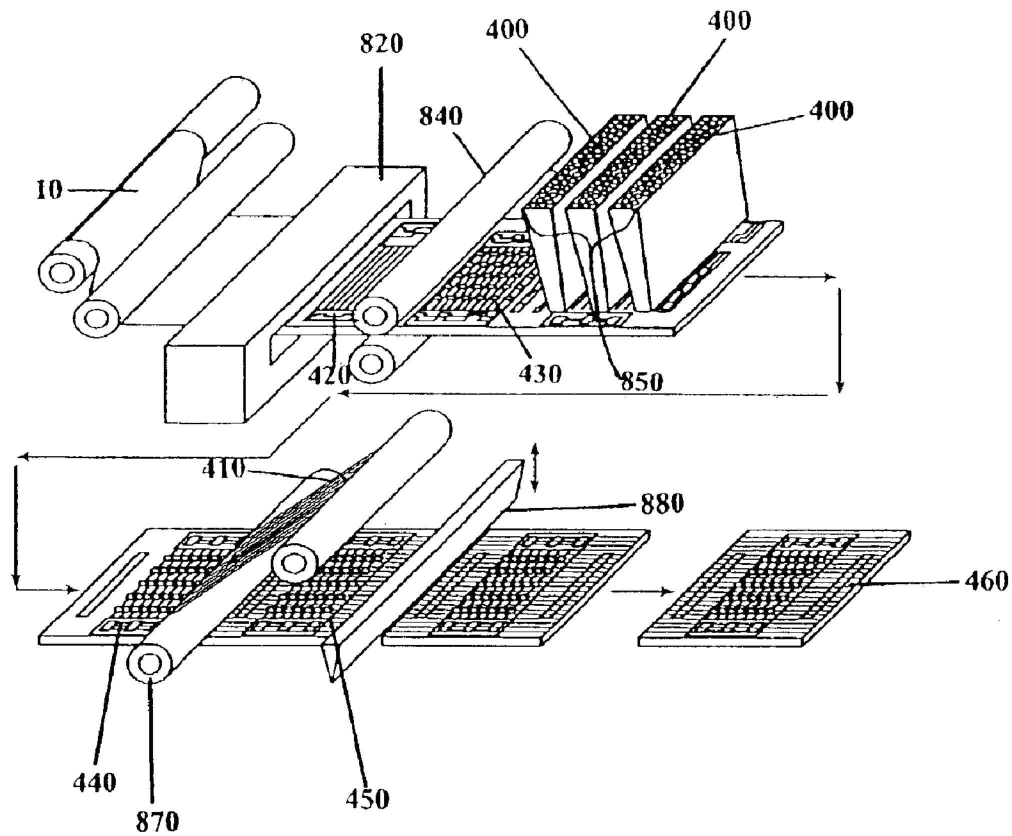




Shell Material
50
Gas-fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits &/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched between Substrates with Electrodes & Circuits
450
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Panel Dicing Process
880
Light-Emitting Panel
460


Fig. 18

Fig. 13



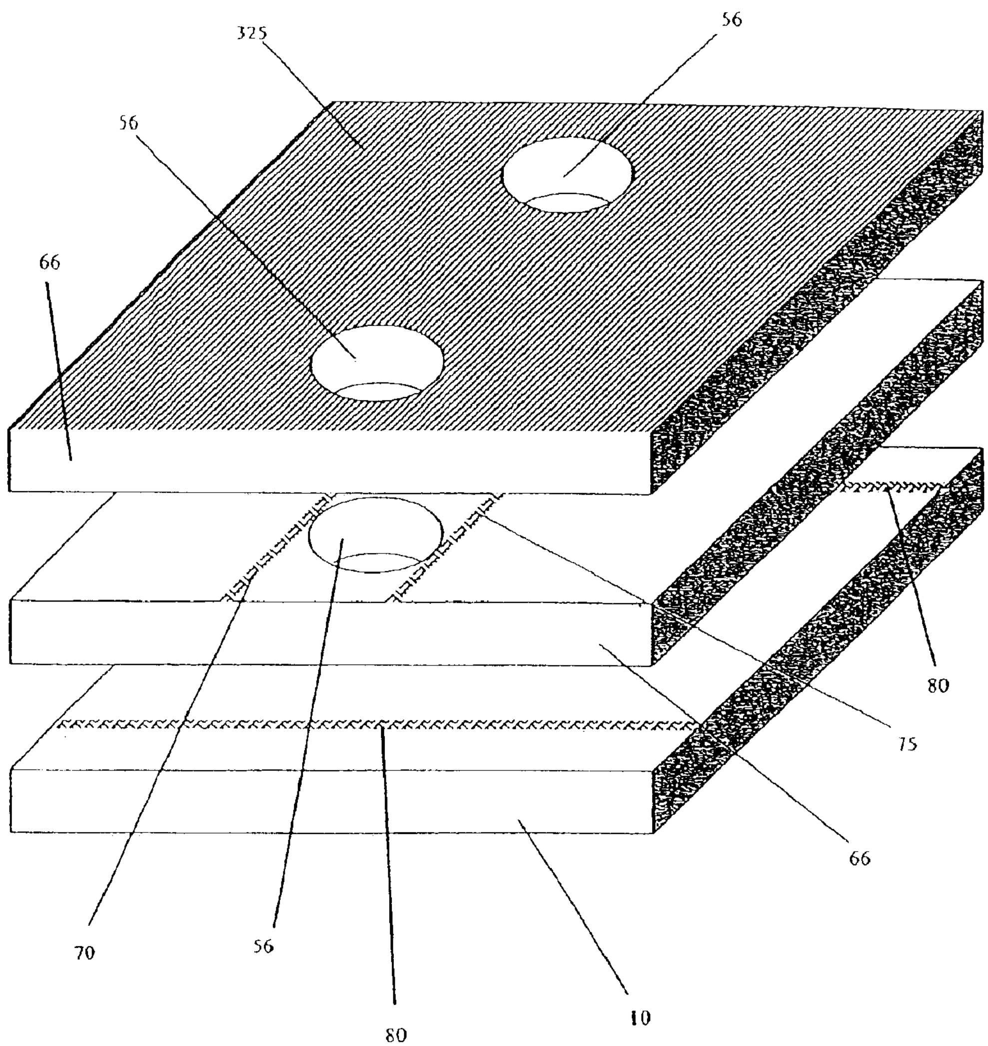



Fig. 14

Fig. 15

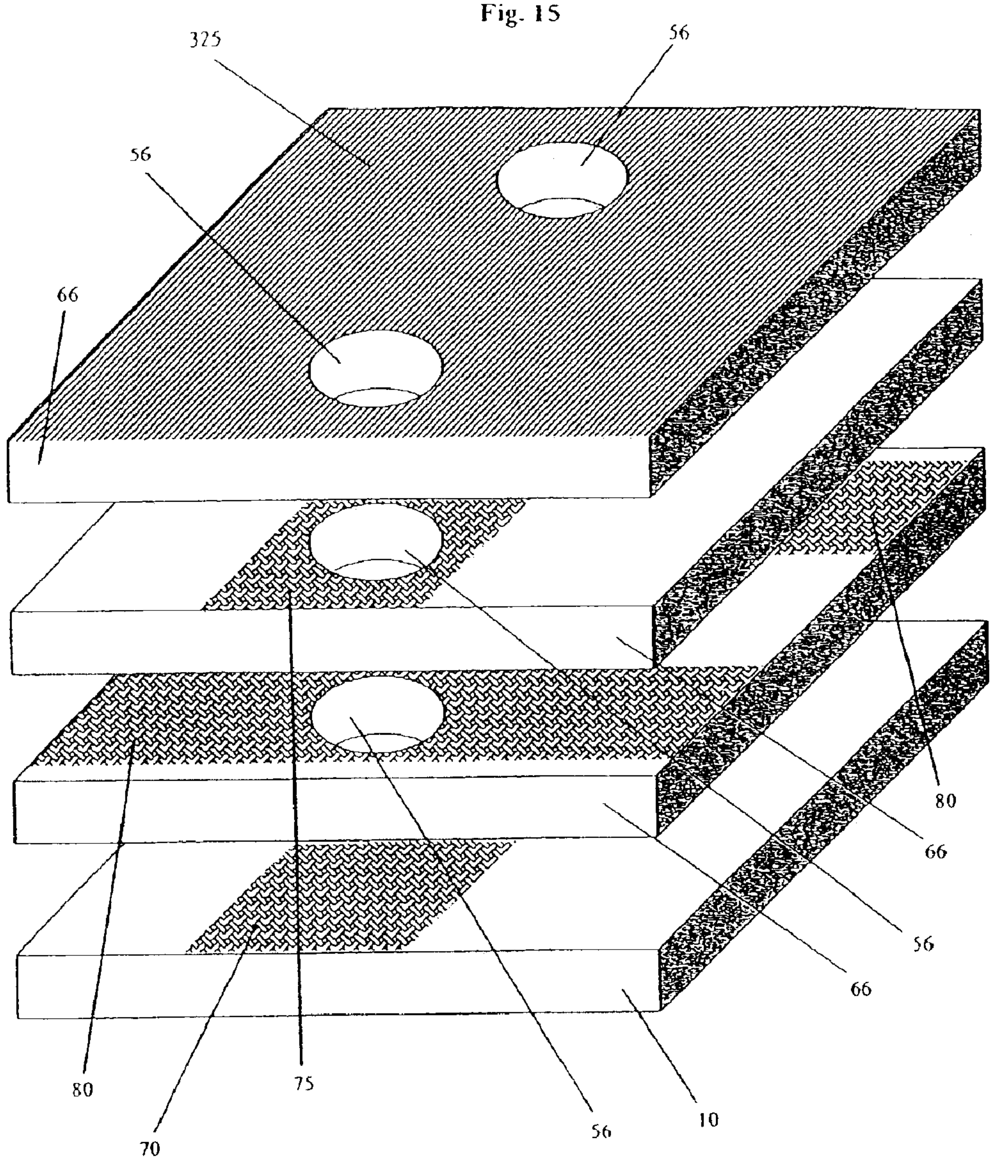


Fig. 16

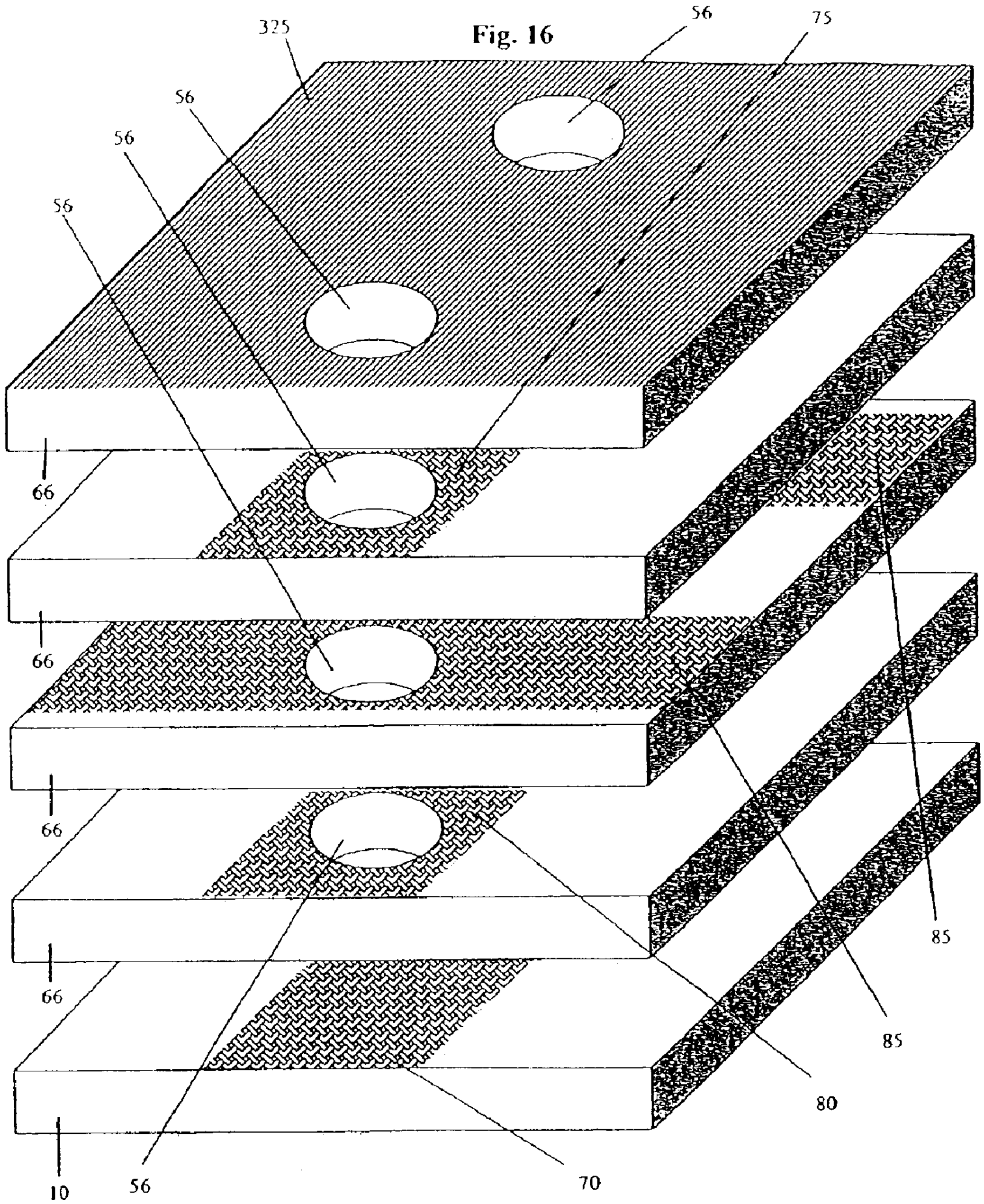


Fig. 17

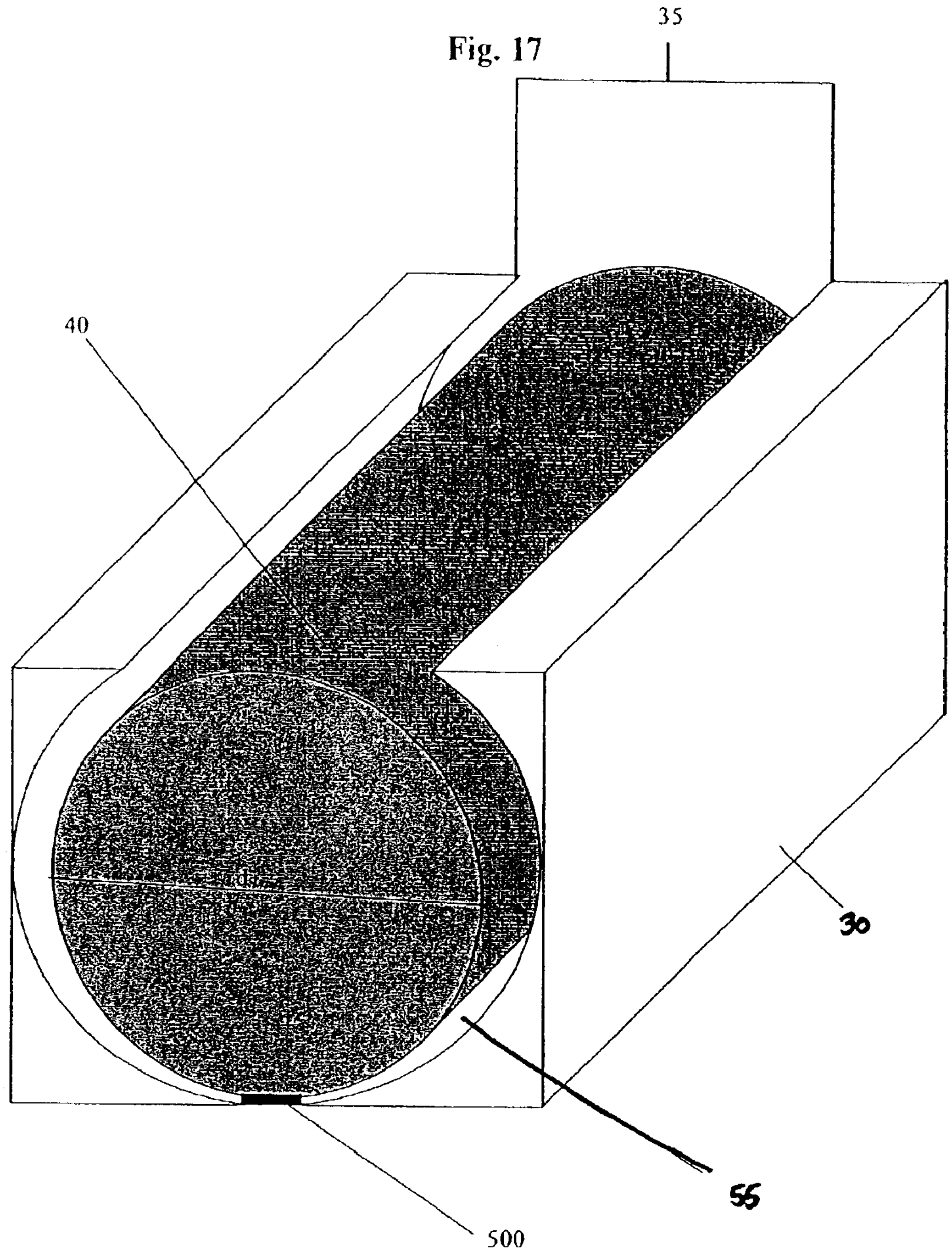


Fig. 18

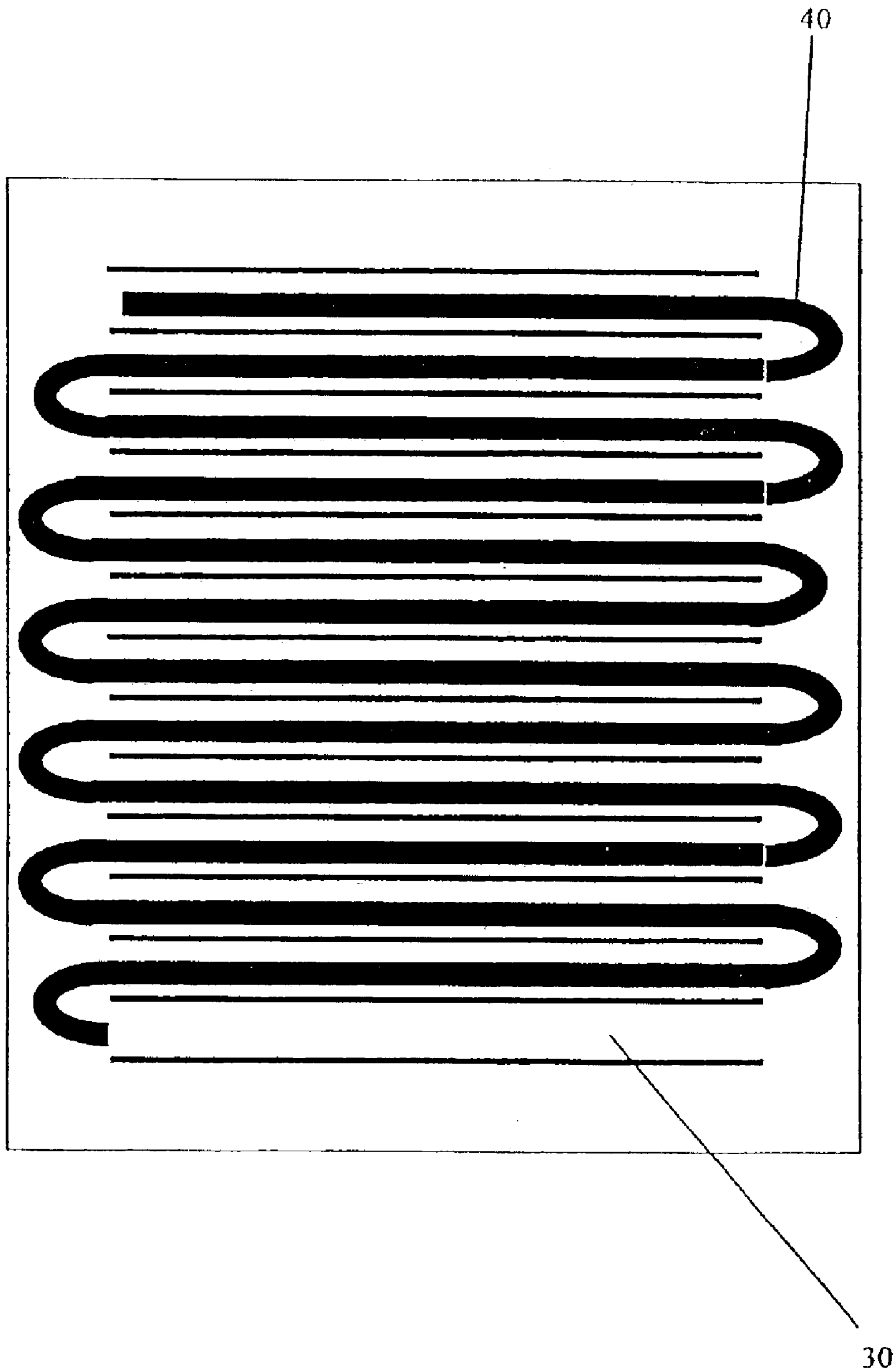
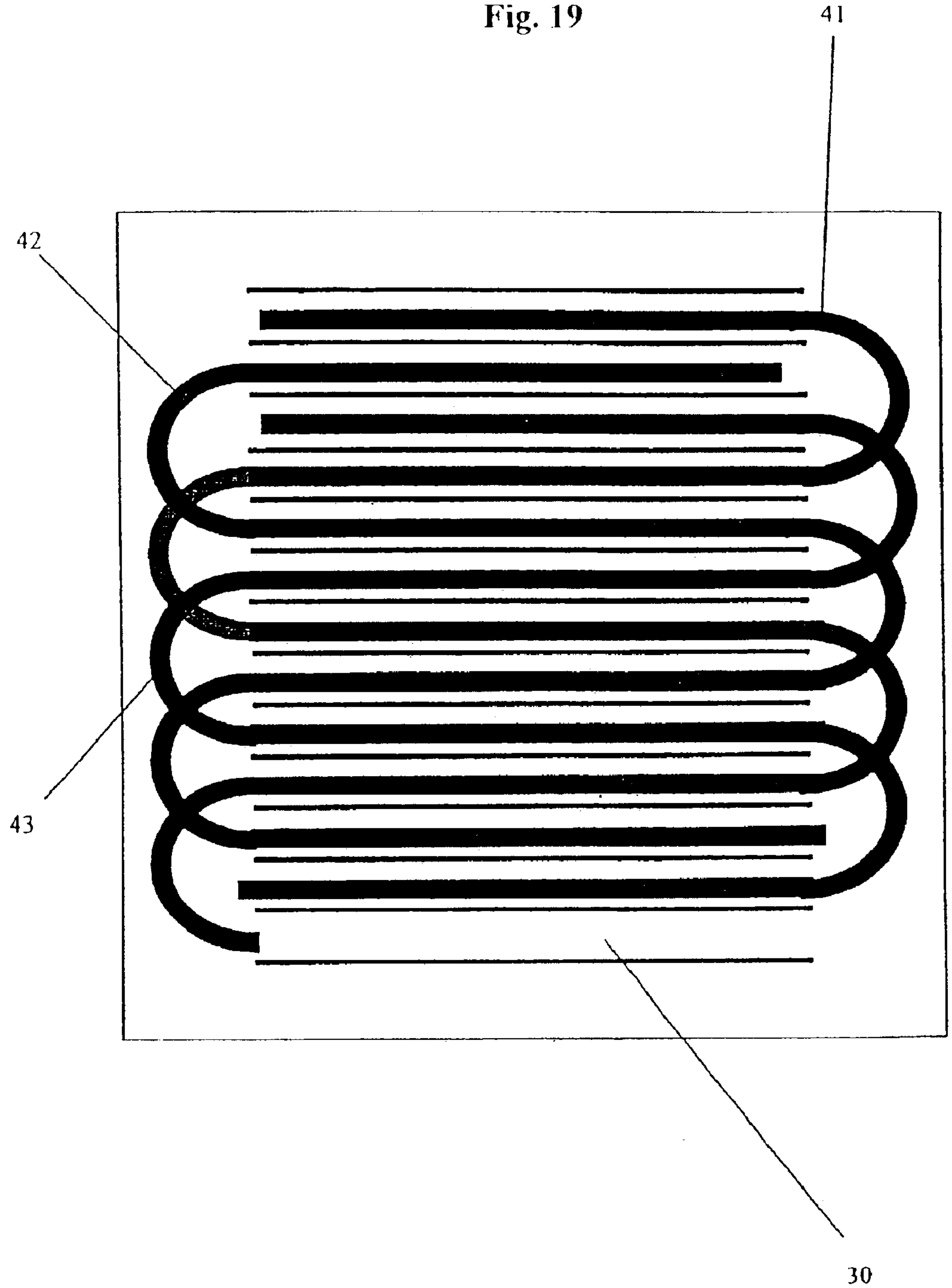


Fig. 19



# LIGHT-EMITTING PANEL AND A METHOD FOR MAKING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of and claims priority to and incorporates by reference in its entirety, application Ser. No. 09/697,344, filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use in a Light-Emitting Panel filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates.

This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In another embodiment of the present invention, at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, at least two electrodes are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In yet another embodiment, disposed in, or proximate to, each socket is at least one enhancement material.

Another preferred embodiment of the present invention is drawn to a web fabrication method for manufacturing light-emitting panels. In an embodiment, the web fabrication process includes providing a first substrate, disposing a plurality of micro-components on the first substrate, disposing a second substrate on the first substrate so the at the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrates to form individual light-emitting panels. In another embodiment, the web fabrication method includes the following process steps: a micro-component forming process; a micro-component coating process; a circuit and electrode printing process; a patterning process; a micro-component placement process; an electrode printing process; a second substrate application and alignment process; and a panel dicing process.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate.

As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the fust substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the fist substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed incline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17**, and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

1. A curing or sterilization device comprising a light-emitting panel, wherein the light-emitting panel comprises:
- a first substrate, wherein the first substrate comprises a plurality of sockets;
- a plurality of micro-components, wherein each micro-component comprises a shell at least partially filled

with a plasma-forming gas, wherein the micro-component is configured to emit ultraviolet light, and wherein at least one micro-component of the plurality of micro-components is at least partially disposed in each socket;

a second substrate, wherein the second substrate is opposed to the first substrate such that at least one micro-component is sandwiched between the first substrate and the second substrate; and

a plurality of electrodes, wherein at least two electrodes of the plurality of electrodes are adhered to only the first substrate or only the second substrate so that voltage supplied to the at least two electrodes causes one or more micro-components to emit the ultra-violet light.

**2**. The curing or sterilization device of claim **1**, wherein the ultraviolet light is emitted throughout the filed of view of the light-emitting panel without crossing the at least two electrodes.

**3**. A device for curing or sterilizing using ultraviolet radiation comprising:

a plurality of micro-components for emitting ultraviolet radiation, wherein each of the plurality of micro-components comprises a shell that is at least partially filled with an ionizable gas;

means for ionizing the ionizable gas and causing the plurality of micro-components to emit ultraviolet radiation; and

means for directing the emitted ultraviolet radiation through a field of view, wherein the means for ionizing the ionizable gas is not located within the field of view.

**4**. The device according to claim **3**, wherein the means for directing the emitted ultraviolet radiation comprises a first substrate having a plurality of sockets formed therein, wherein at least one of the plurality of micro-components is at least partially disposed in each of the plurality of sockets.

**5**. The device according to claim **4**, wherein each of the plurality of sockets contains a material that reflects ultraviolet radiation.

**6**. The device according to claim **4**, wherein there are at least two micro-components at least partially disposed in each of the plurality of sockets.

**7**. The device according to claim **3**, wherein the means for ionizing the ionizable gas comprises at least two electrodes configured so as to provide a potential across the ionizable gas.

**8**. The device according to claim **3**, wherein the means for ionizing the ionizable gas is formed of a material that is transparent to ultraviolet radiation.

**9**. The device according to claim **3**, wherein the ionizable gas has a pressure within the range of approximately 100 ton to 700 ton.

**10**. The device according to claim **3**, wherein the ionizable gas is comprised at least in part of at least one noble gas.

**11**. The device according to claim **4**, wherein the shell of each of the plurality of micro-components is at least partially coated with a secondary emission enhancement material.

**12**. The device according to claim **11**, wherein the secondary emission enhancement material is a low affinity material.

**13**. The device according to claim **3**, wherein the shell of each of the plurality of micro-components is doped with a secondary emission enhancement material.

**14**. The device according to claim **13**, wherein the secondary emission enhancement material is a low affinity material.

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UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,975,068 B2
APPLICATION NO. : 10/303924
DATED : December 13, 2005
INVENTOR(S) : Albert Myron Green et al.



It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, item [56]:
UNDER REFERENCES CITED - OTHER PUBLICATIONS -

On Page 3, Column 1, Lines 4 and 5 of the Tenth Reference under “Other Publications,” please change “8 pp., Retrieved from the Internet: http://wwwstar.stanford.edu/~vlf/plasma_display/index.htm, no month.” to -- 8 pp., Retrieved from the Internet: http://www.star.stanford.edu/~vlf/plasma_display/index.htm. --.

On Page 3, Column 1, Line 3 of the Eleventh Reference under “Other Publications,” please change “2001 Solar Energy: The Power to Choose. Washington, DC.” to -- 2001 Solar Energy: The Power to Choose, Washington, DC, --

On Page 3, Column 1, Line 1 of the Thirteenth Reference under “Other Publications,” please change “Chutinan. Alongkarn and Noda, Susumu, “Waveguides and” to -- Chutinan, Alongkam and Noda, Susumu, “Waveguides and --

On Page 3, Column 1, Line 3 of the Thirteenth Reference under “Other Publications,” please change “Slabs.” The American Physical Society. Vol. 62, No. 7, 5 pp.,” to --Slabs,” The American Physical Society, vol. 61, No. 7, 5 pp.,--

On Page 3, Column 1, Line 2 of the Fourteenth Reference under “Other Publcations,” please change “2000[. 13 pp., Retrieved from the Internet: http:.//www.roll-” to -- 2000], 13 pp., Retrieved from the Internet: http://www.roll- --

On Page 3, Column 1, Lines 1 and 2 of the Fifteenth Reference under “Other Publications,” please change “Electronics & Telecommunications” [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 1 p.,” to -- “Electronics & Telecommunications” [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., --

On Page 3, Column 1, Line 4 of the Fifteenth Reference under “Other Publications,” please change “company/electronic/index.jsp?code=A3, no month.” to -- company/electronic/index.jsp?code=A3. --

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On the title page, item [56]:
UNDER REFERENCES CITED - OTHER PUBLICATIONS -

On Page 3, Column 1, Lines 1-3 of the Sixteenth Reference under "Other Publications," please change ""New Product" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 1 p.. Retrieved from the Internet: http://www.lge.com, no month." to -- "New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com. --

On Page 3, Column 1, Lines 1-4 of the Seventeenth Reference under "Other Publications," please change ""Monitor "[online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp, no month." to -- "Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp. --

On Page 3, Column 1, Lines 2-4 of the Eighteenth Reference under "Other Publications," please change "line]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdp-display.com/eng/news/e_read.as?nSeqno=22, no month." to -- line], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2pp., Retrieved from the Internet: http://www.pdp-display.com/eng/news/e_read.as?nSeqno=22. --

On Page 3, Column 2, Lines 2-5 of the First Reference, please change "Department Store" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrived from the Internet:http://www.pdpdisplay.com/eng/news/e_readasp?nSeqno21, no month." to -- Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21. --

On Page 3, Column 2, Lines 2-3 of the Second Reference, please change "Module" [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet:" to -- Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: --

On Page 3, Column 2, Line 5 of the Second Reference, please change "qNo=19&type=&word=, no month." to --qNo=19&type=&word=. --

# UNITED STATES PATENT AND TRADEMARK OFFICE
# CERTIFICATE OF CORRECTION

PATENT NO. : 6,975,068 B2

APPLICATION NO. : 10/303924
DATED : December 13, 2005
INVENTOR(S) : Albert Myron Green et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, item [56]:
UNDER REFERENCES CITED - OTHER PUBLICATIONS -

On Page 3, Column 2, Lines 1-5 of the Third Reference, please change "“LG Electronics - To The Top in PDP Business” [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno=16&type=&word=, no month.” to -- “LG Electronics - To The Top in PDP Business” [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno=16&type=&word=. --

On Page 3, Column 2, Lines 2-3 of the Fourth Reference, please change “[online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the Internet: http://www.p-” to -- [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.p- --

On Page 3, Column 2, Line 5 of the Fourth Reference, please change “&word=, no month.” to -- & word=. --

On Page 3, Column 2, Lines 2-3 of the Fifth Reference, please change “the PDP Factory” [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001]. 2 pp.. Retrieved from the” to -- the PDP Factory” [online]. LG Electronics. Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the --

On Page 3, Column 2, Line 5 of the Fifth Reference, please change “nSeqno=13&type=&word=, no month.” to -- nSeqno=13&type=&word=. --

On Page 3, Column 2, Line 2 of the Sixth Reference, please change “line]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2pp..” to -- line], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., --

On Page 3, Column 2, Line 4 of the Sixth Reference, please change “ucts/Plasma/Default.htm, no month.” to -- ucts/Plasma/Default.htm. --

On Page 3, Column 2, Lines 1-2 of the Seventh Reference, please change "“Runco Plasma Wall PL-42ex” [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the” to -- “Runco Plasma Wall PL-42cx” [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the --

UNITED STATES PATENT AND TRADEMARK OFFICE

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INVENTOR(S) : Albert Myron Green et al.



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On the title page, item [56]:
UNDER REFERENCES CITED - OTHER PUBLICATIONS -

On Page 3, Column 2, Line 4 of the Seventh Reference, please change "PL42ex.htm, no month." to -- PL42cx.htm. --

On Page 3, Column 2, Lines 1-2 of the Eighth Reference, please change ""Runco Plasma Wall Pl-50c" [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the" to -- "Runco Plasma Wall PL-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the --

On Page 3, Column 2, Line 4 of the Eighth Reference, please change "PL50c.htm, no month." to -- PL50c.htm. --

On Page 3, Column 2, Lines 1-2 of the Ninth Reference, please change ""Runco Plasma WallTMPL-61cx" [online]. Copyright 2001 [retrieved on Jan. 17, 2002]. 2 pp.. Retrieved from the" to -- "Runco Plasma WallTM PL-61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the --

On Page 3, Column 2, Line 4 of the Ninth Reference, please change "PL61.htm, no month." to -- PL61.htm. --

On Page 3, Column 2, Lines 1-3 of the Tenth Reference, please change "Alien Technology Corporation' Technology Overview. Copyright 2000, Alien TechnologyTM; http://wwwalien-technology.com/d/technology/overview.html, no month." to -- Alien Technology Corporation's Technology Overview; Copyright 2000, Alien Technology TM; http://www.alien-technology.com/d/technology/overview.html. --

On Page 3, Column 2, Lines 2-3 of the Twelfth Reference, please change "Breakdown Characteristics of PDP Cells fo Varying Geom-etry." IEEE Transactions on Plasma Science, vol. 27, No. 1," to -- Breakdown Characteristics of PDP Cells for Varying Geom-etry," IEEE Transactions on Plasma Science, vol. 27, No. 1, --

On Page 3, Column 2, Lines 2-3 of the Thirteenth Reference, please change "trode Plasma Display Panel Cell." IEEE Transactions on Plasma Science. vol. 27. No. 1. Feb. 1999. pp. 10-11." to -- trode Plasma Display Panel Cell," IEEE Transactions on Plasma Science, vol. 27, No. 1, Feb. 1999, pp. 10-11. --

# UNITED STATES PATENT AND TRADEMARK OFFICE
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PATENT NO. : 6,975,068 B2 
APPLICATION NO. : 10/303924
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INVENTOR(S) : Albert Myron Green et al.

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On the title page, item [56]:
UNDER REFERENCES CITED - OTHER PUBLICATIONS -

On Page 3, Column 2, Line 2 of the Fourteenth Reference, please change "a Micro-Cell Plasma in Xe Driven by High Frequency."" to -- a Micro-Cell Plasma in Xe Driven by High Frequency," --

On Page 3, Column 2, Lines 1-2 of the Fifteenth Reference, please change "Peterson, "Rethinking Ink" [online]. Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002]. 7 pp.." to -- Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., --

On Page 3, Column 2, Lines 1-2 of the Sixteenth Reference, please change ""Transparent Conductive Coatings," Copyright 1998. 4 pp., no month." to -- "Transparent Conductive Coatings," Copyright 1998, 4 pp. --

On Page 4, Column 1, Lines 2-4 of the First Reference, please change "Transmission in Leaky and Absorbing Planar Waveguides." IEEE Photonics Technology Letters. vol. 9. No. 9. No. 9. Sep. 1997. pp. 1241-." to -- Transmission in Leaky and Absorbing Planar Waveguides," IEEE Photonics Technology Letters, vol. 9, No. 9, Sep. 1997, pp. 1241-. --

On Page 4, Column 1, Lines 1-4 of the Second Reference, please change "Jacobson, et al., "The Last Book" [online]. IBM Systems Journal, vol. 36. No. 3. 1997 [retrieved on Dec. 4, 2002]. 6 pp.. Retrieved from the Internet: http://www.resesarch.ibm.com/journal/sj/363/Jacobson.html, no month." to --Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html. --

On Page 4, Column 1, Lines 1-2 of the Third Reference, please change "Stearns, Thomas H.. "Flexible Printed Circuitry." 6 pp.. 1996, no month." to -- Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996. --

On Page 4, Column 1, Line 1 of the Fourth Reference, please change ""Flat Panel Displays in Perspective." 44 pp.. Sep., 1995." to -- "Flat Panel Displays in Perspective," 44 pp., Sep., 1995. --

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 6,975,068 B2
APPLICATION NO. : 10/303924
DATED : December 13, 2005
INVENTOR(S) : Albert Myron Green et al.



It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, item [56]:
UNDER REFERENCES CITED - OTHER PUBLICATIONS -

On Page 4, Column 2, Lines 2-3 of the First Reference, please change "tion" [online] Technology Today. Summer. 1995 [retrieved on Dec. 4, 2002]. 10 pp.. Retrieved from the Internet:" to --tion" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: --

IN THE CLAIMS -

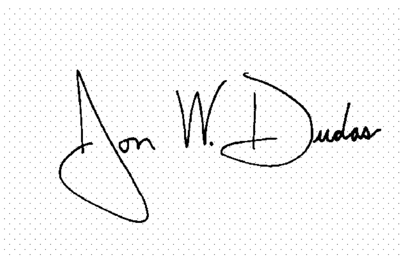
Column 17:
In Claim 2, line 2, please change "the ultraviolet light is emitted throughout the filed of view of" to -- the ultraviolet light is emitted throughout the field of view of --

Column 18: lines 16-17
In Claim 9, please change "has a pressure within the range of approximately 100 ton to 700 ton." to -- gas has a pressure within the range of approximately 100 torr to 700 torr. --

Column 18:
In Claim 11, Line 1, please change "The device according to claim 4, wherein the shell of" to -- The deivce according to claim 3, wherein the shell of --

Signed and Sealed this

Fifth Day of September, 2006



JON W. DUDAS
*Director of the United States Patent and Trademark Office*

US007005793B2

(12) **United States Patent**
**George et al.**

(10) **Patent No.: US 7,005,793 B2**
(45) **Date of Patent: Feb. 28, 2006**

(54) **SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL**


(75) Inventors: **Edward Victor George**, Lake Arrowhead, CA (US); **Roger Laverne Johnson**, Encinitas, CA (US); **Albert Myron Green**, Springfield, VA (US); **Newell Convers Wyeth**, Oakton, VA (US)

(73) Assignee: **Science Applications International Corporation**, San Diego, CA (US)


(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.


(21) Appl. No.: **11/135,538**

(22) Filed: **May 24, 2005**

(65) **Prior Publication Data**

US 2005/0206317 A1 Sep. 22, 2005


**Related U.S. Application Data**

(60) Division of application No. 10/643,608, filed on Aug. 20, 2003, now Pat. No. 6,902,456, which is a continuation of application No. 10/318,150, filed on Dec. 13, 2002, now Pat. No. 6,646,388, which is a continuation of application No. 09/697,346, filed on Oct. 27, 2000, now Pat. No. 6,545,422.

(51) **Int. Cl.**
***H01J 1/62*** (2006.01)

(52) **U.S. Cl.** ...................................... **313/484**; 313/582

(58) **Field of Classification Search** ........ 313/483–484, 313/582–587, 491–493

See application file for complete search history.

(56) **References Cited**


U.S. PATENT DOCUMENTS

3,559,190 A 1/1971 Blitzer et al. ............... 340/173
3,646,384 A 2/1972 Lay ......................... 313/109.5
3,704,052 A 11/1972 Coleman ..................... 316/17
3,755,027 A 8/1973 Gilsing ........................ 156/67
3,848,248 A 11/1974 MacIntyre, Jr. ........ 340/324 M
3,969,651 A 7/1976 Greeson, Jr. .......... 315/169 TV
3,990,068 A 11/1976 Mayer et al. .......... 340/324 M
3,998,618 A 12/1976 Kreick et al. ................. 65/105
4,027,246 A 5/1977 Caccoma et al. ........ 235/151.1
4,035,690 A 7/1977 Roeber ................. 315/169 TV
4,303,433 A 12/1981 Torobin ...................... 65/21.4
4,379,301 A 4/1983 Fischbeck ................... 346/1.1
4,386,358 A 5/1983 Fischbeck ................... 346/1.1
4,393,326 A 7/1983 Kamegaya et al. ......... 313/582
4,429,303 A 1/1984 Aboelfotoh ................. 340/701
4,534,743 A 8/1985 D'Onofrio et, al. ........... 445/24
4,554,537 A 11/1985 Dick .......................... 340/775
4,563,617 A 1/1986 Davidson .................... 315/312
4,591,847 A 5/1986 Criscimagna et al. ....... 340/776
4,654,561 A 3/1987 Shelton ................ 315/111.71

(Continued)

FOREIGN PATENT DOCUMENTS

JP 4-287397 10/1992

(Continued)

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).

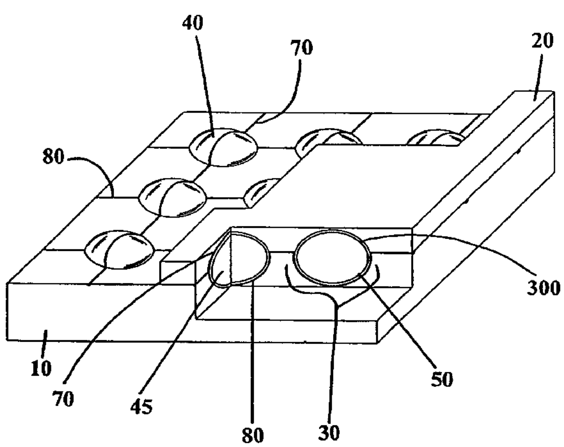
(Continued)


*Primary Examiner*—Joseph Williams
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**


An improved light-emitting panel having a plurality of micro-components at least partially disposed in a socket and sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes.


**6 Claims, 18 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | 3/1990 | Hollo et al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Deschamps, et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 6,459,201 | B1 * | 10/2002 | Schermerhorn et al. | 313/586 |
| 2001/0008825 | A1 | 7/2001 | Toyoda, et al. | 445/24 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki, et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi, et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng, et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe, et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram, et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita, et al. | 313/495 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| JP | 10-3869 | 1/1998 |
| WO | WO 00/36465 | 6/2000 |

OTHER PUBLICATIONS

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
Sheats, James, "Introduction to Organic Light Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.
Sauvante, Michael, "Roll-to-Roll Manufacturing" [online], [retrieved on May, 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.
Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www.star.stanford.edu/~vlf/plasma _display/index.htm.
Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose,* Washington DC, 8 pp., Apr. 21-25, 2001.
Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems,* vol. 10, No. 1, Mar., 2001, pp. 17-17-24.
Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," *The American Physical Society,* vol. 62, No. 7, 5 pp., Aug. 15, 2000.
"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.
"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.
"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.
"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.
"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.
"LG PDP Now Available at World Renowned Harrods Department Store"[online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.
"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.
"LG Electronics —To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.
"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.
"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.
"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.
"Runco PlasmaWall PL-42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.
"Runco PlasmaWall Pl-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.
"Runco PlasmaWall™ PL-61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.
Alien Technology Corporation's Technology Overview; copyright© 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.
Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly,* Alien Technology Corp., Oct. 1999, pp. 1-7.
Shin, Y.K., Lee, J. K., Shon, C. H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry" , *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb., 1999, pp. 14-15.
Raulf, S., Kushner, M. J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell" , *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10-11.
Kurihara, M., Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency" , *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372-1378.
Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.
"Transparent Conductive Coatings" , Copyright 1998, 4 pp.
Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides" , *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep. 1997, pp. 1241.
Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.
Stearns, Thomas H., "Flexible Printed Circuitry" , 6 pp., 1996.
"Flat Panel Displays in Perspective" , 44 pp., Sep., 1995.
Franjione, et al., "The Art and Science of Microencapsulation" [online]Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

* cited by examiner

Fig. 1

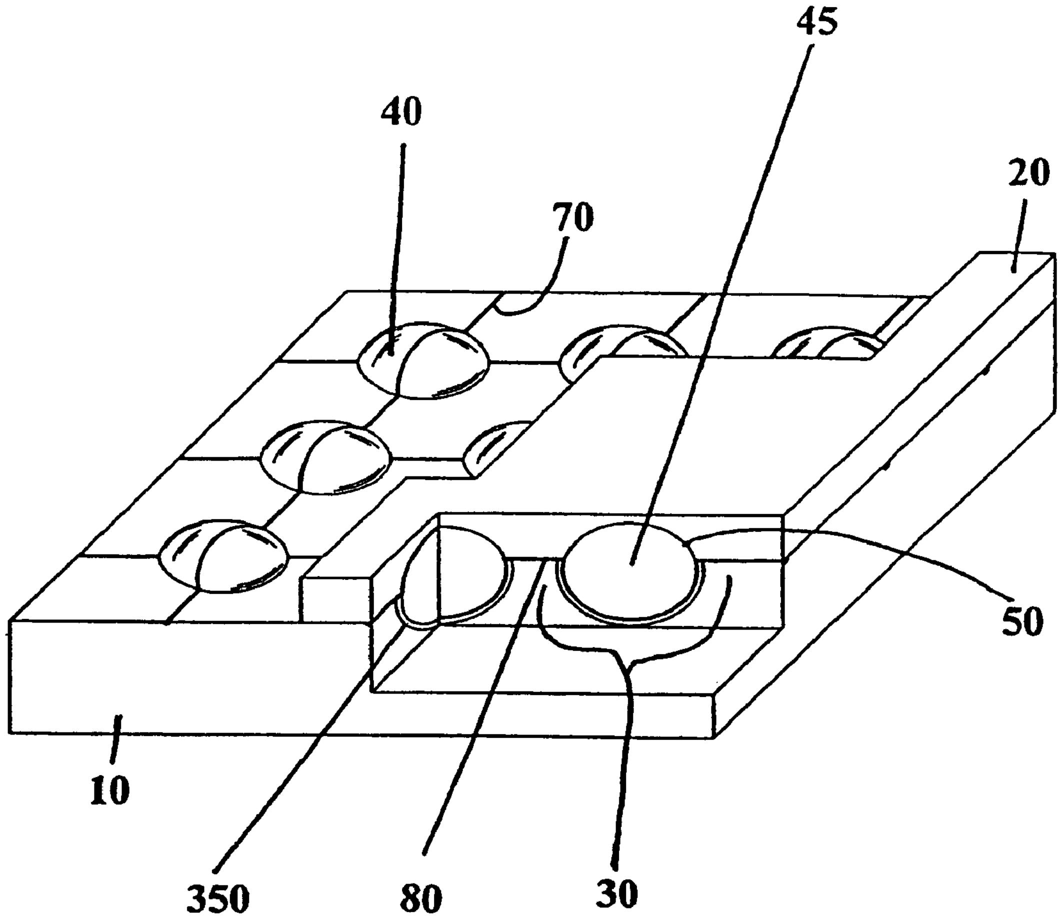
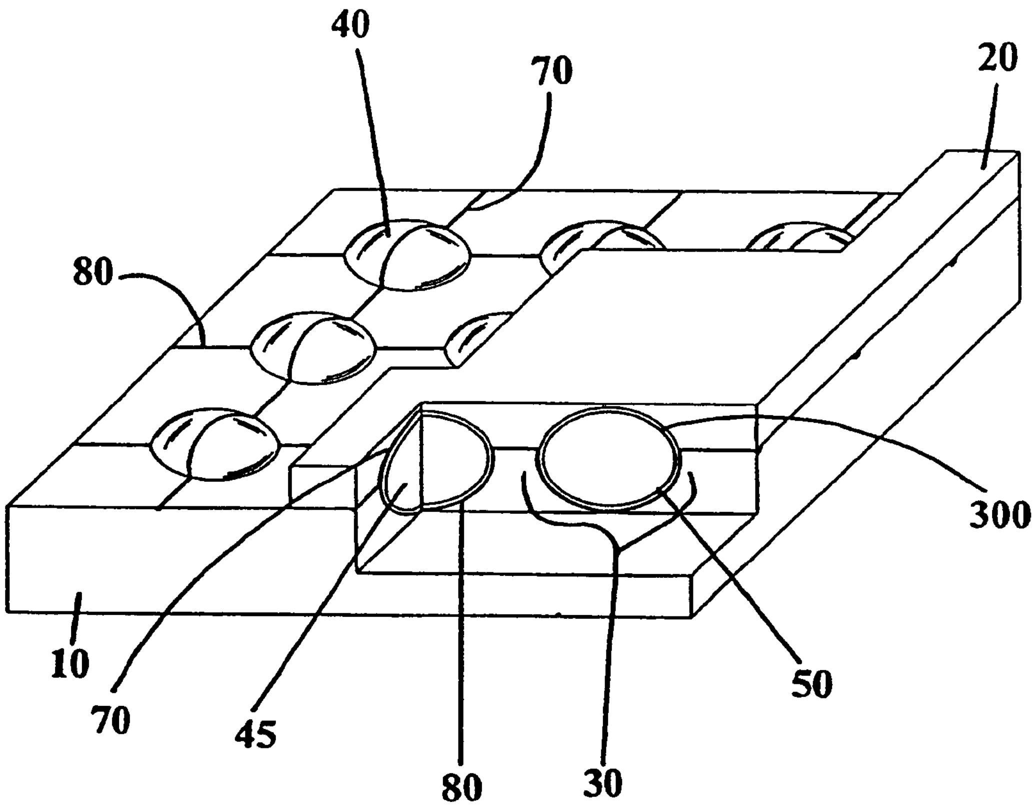


Fig. 2



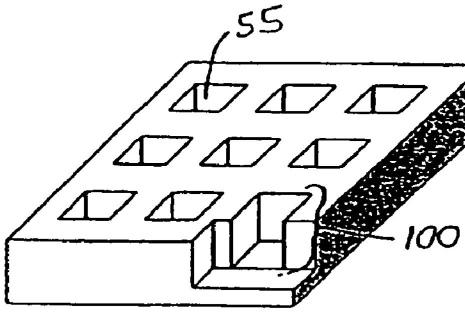



Fig. 3A

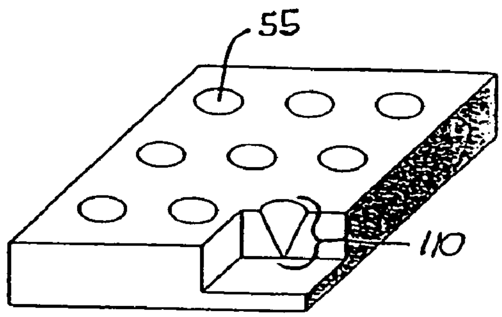



Fig. 3B

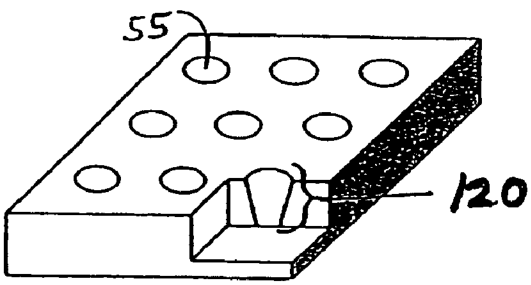



Fig. 3C

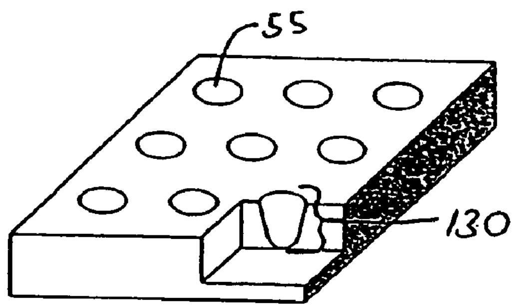



Fig 3D

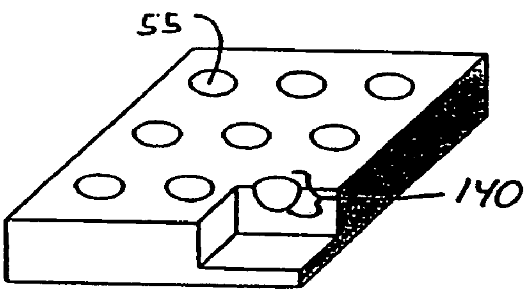



Fig 3E

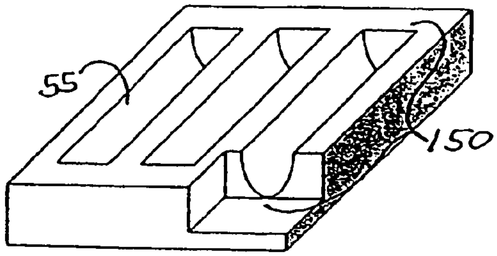


Fig. 3F

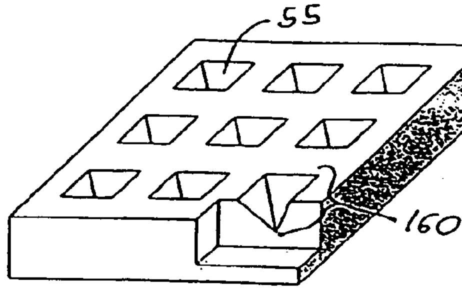


Fig. 3G

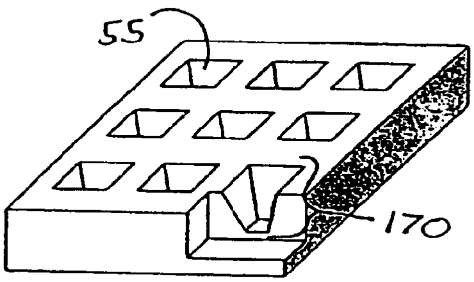


Fig. 3H

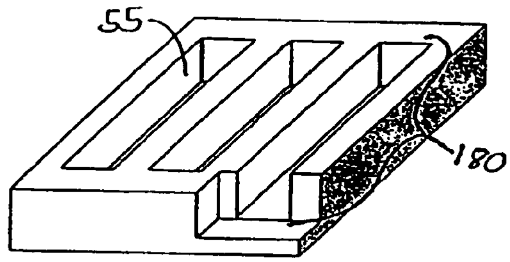


Fig. 3I

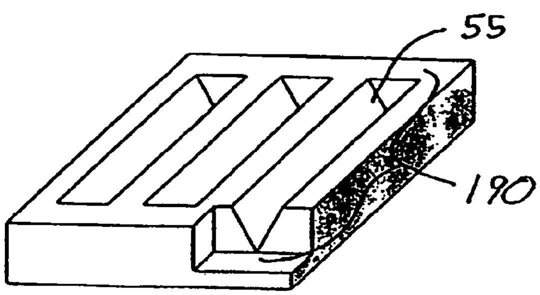


Fig. 3J

Fig. 4

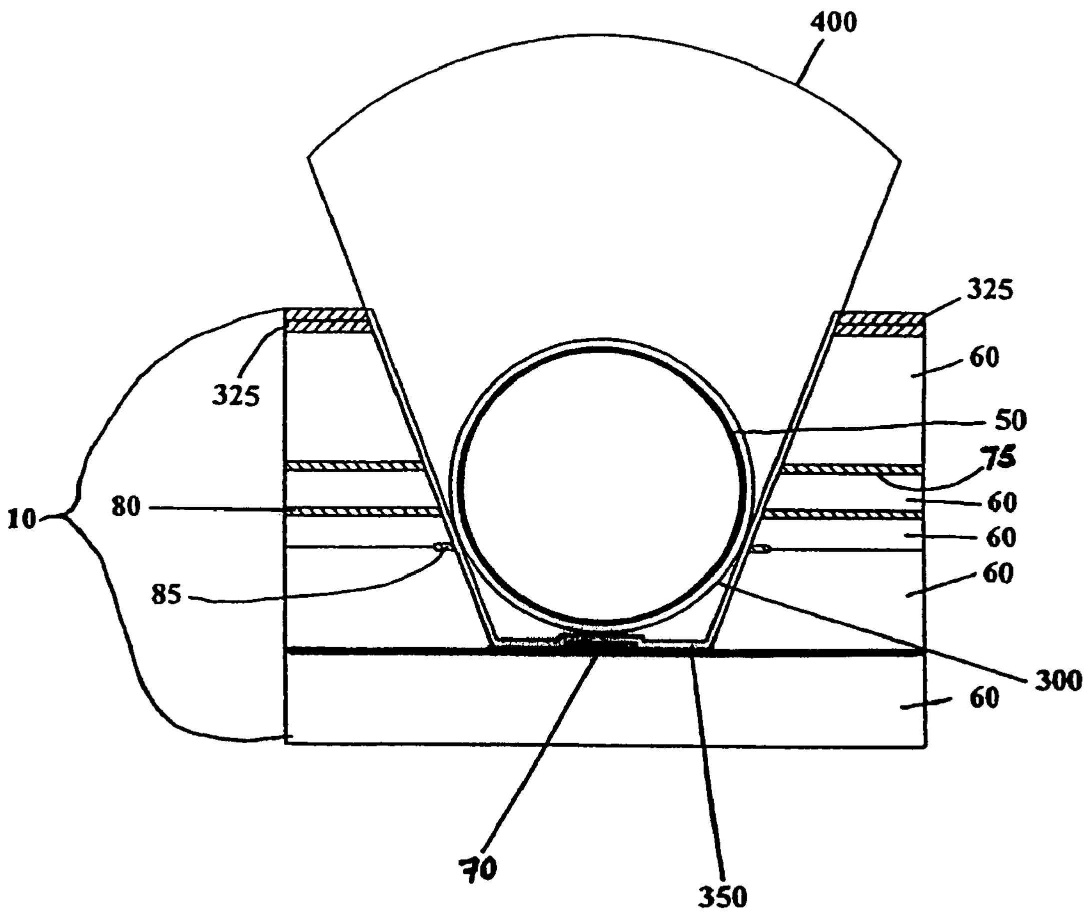


Fig. 5

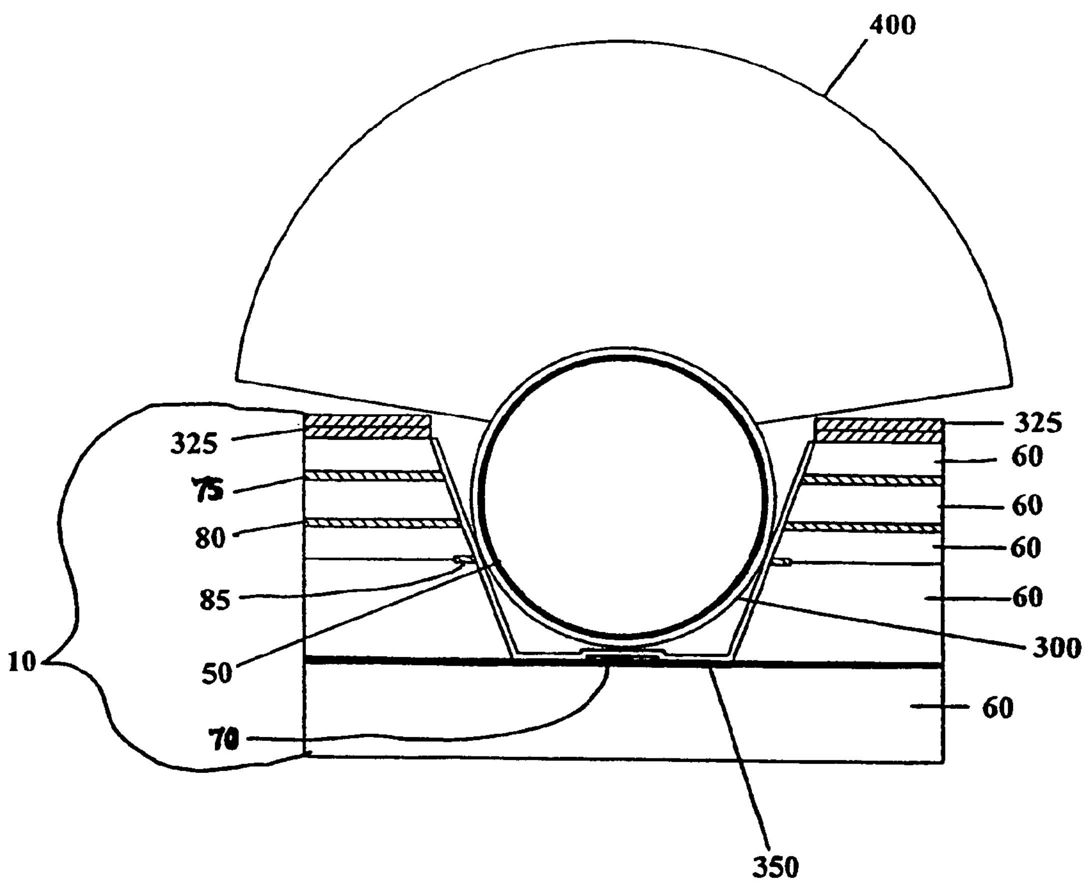


Fig. 6A

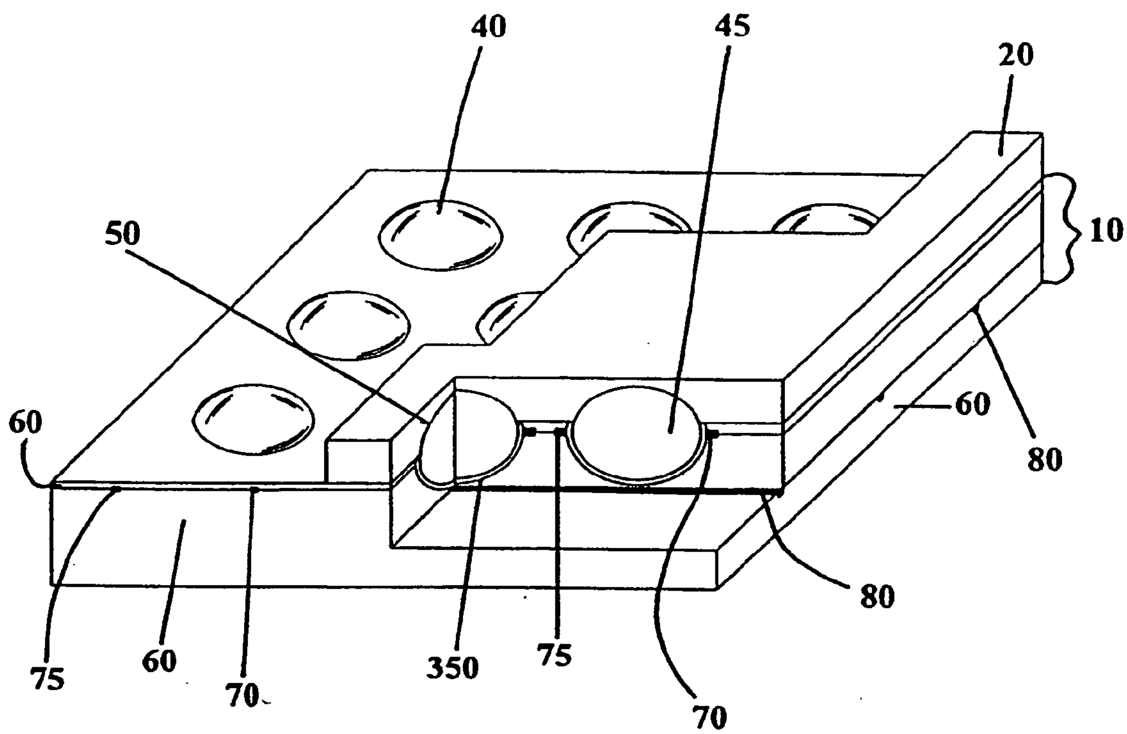


Fig. 6B

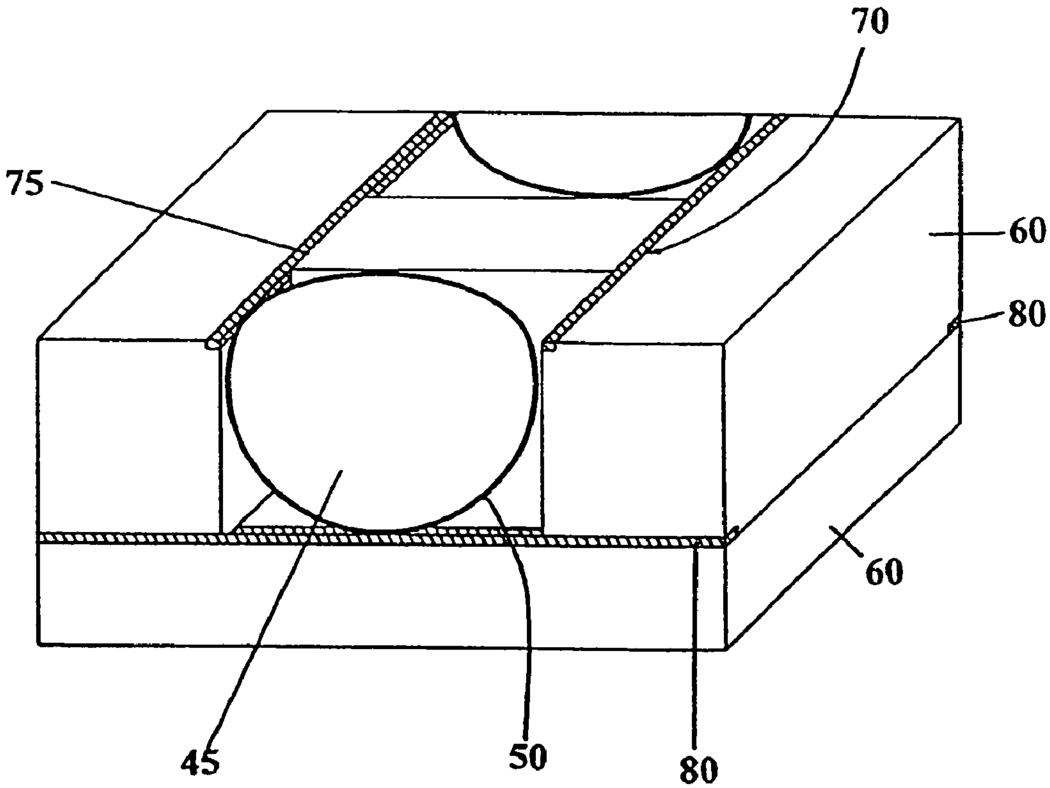


Fig. 7A

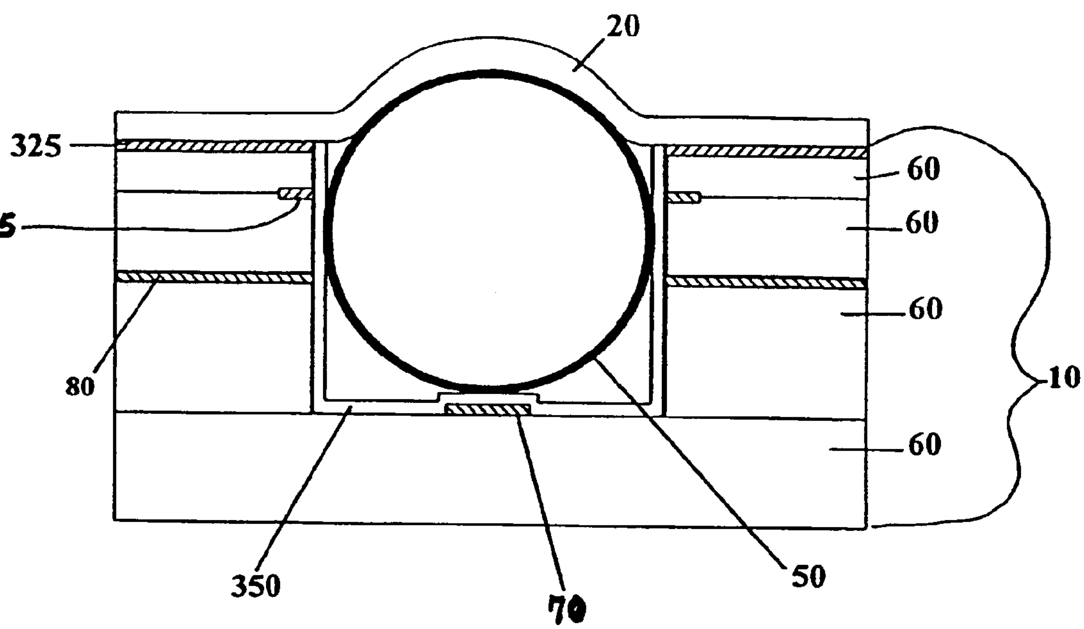


Fig. 7B

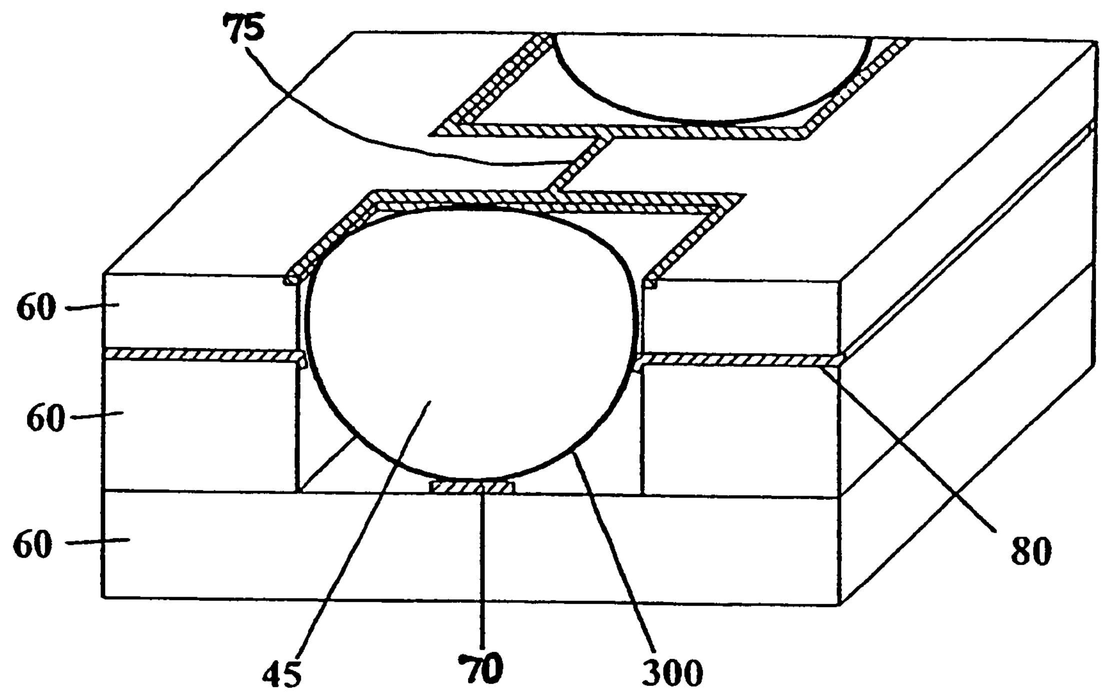


Fig. 8

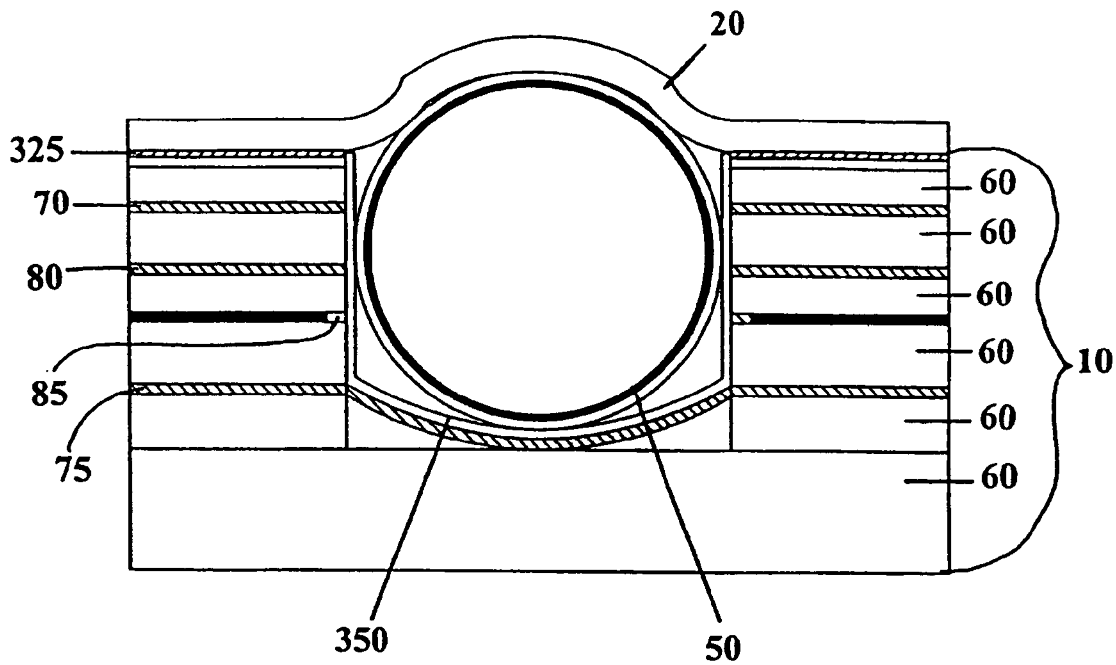


Fig. 9

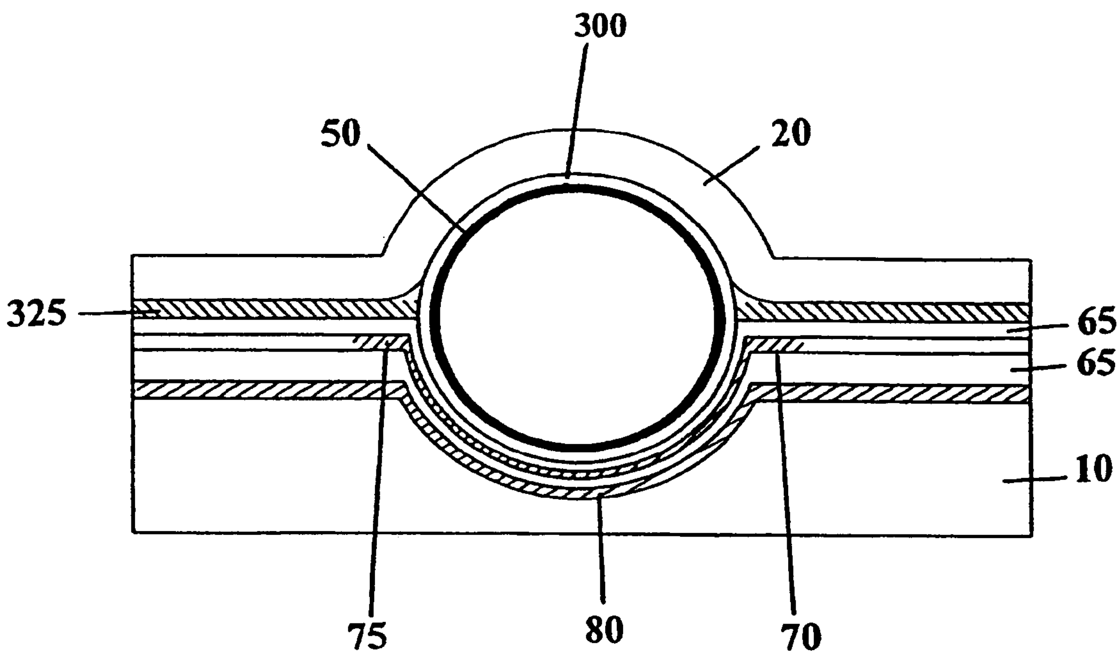


Fig. 10

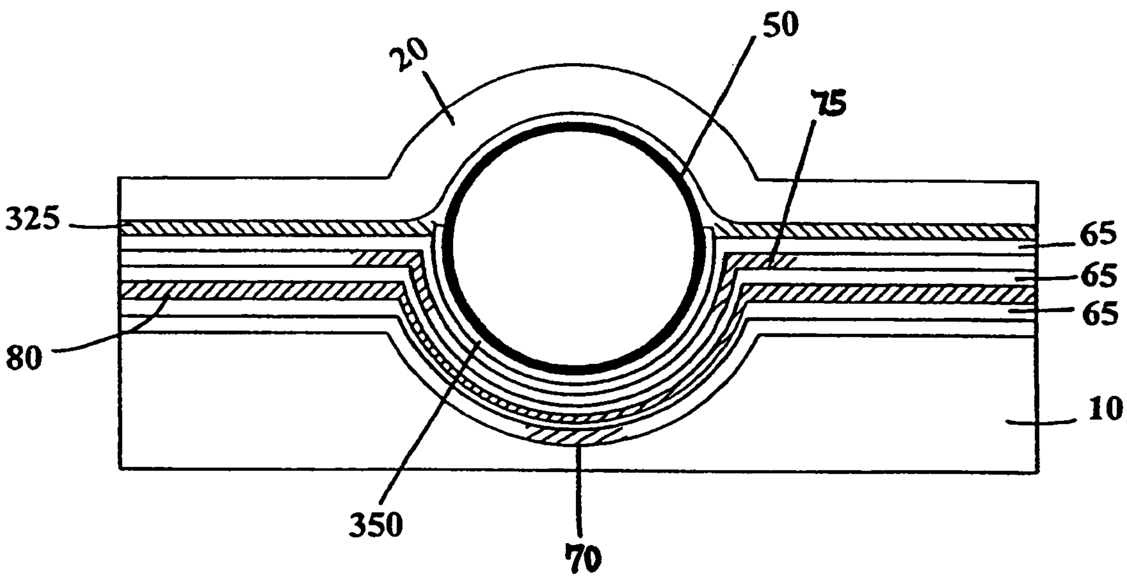


Fig. 11

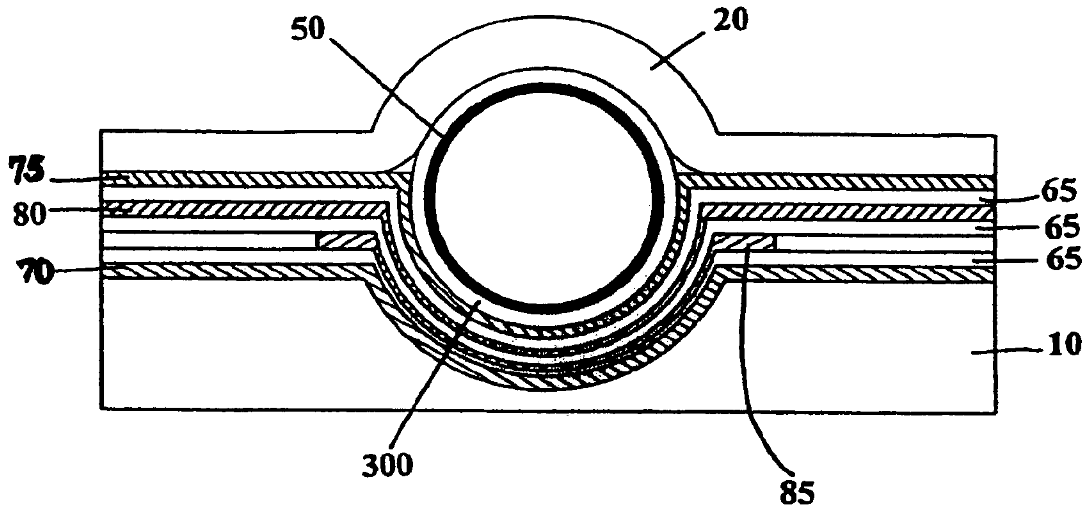


Fig. 12

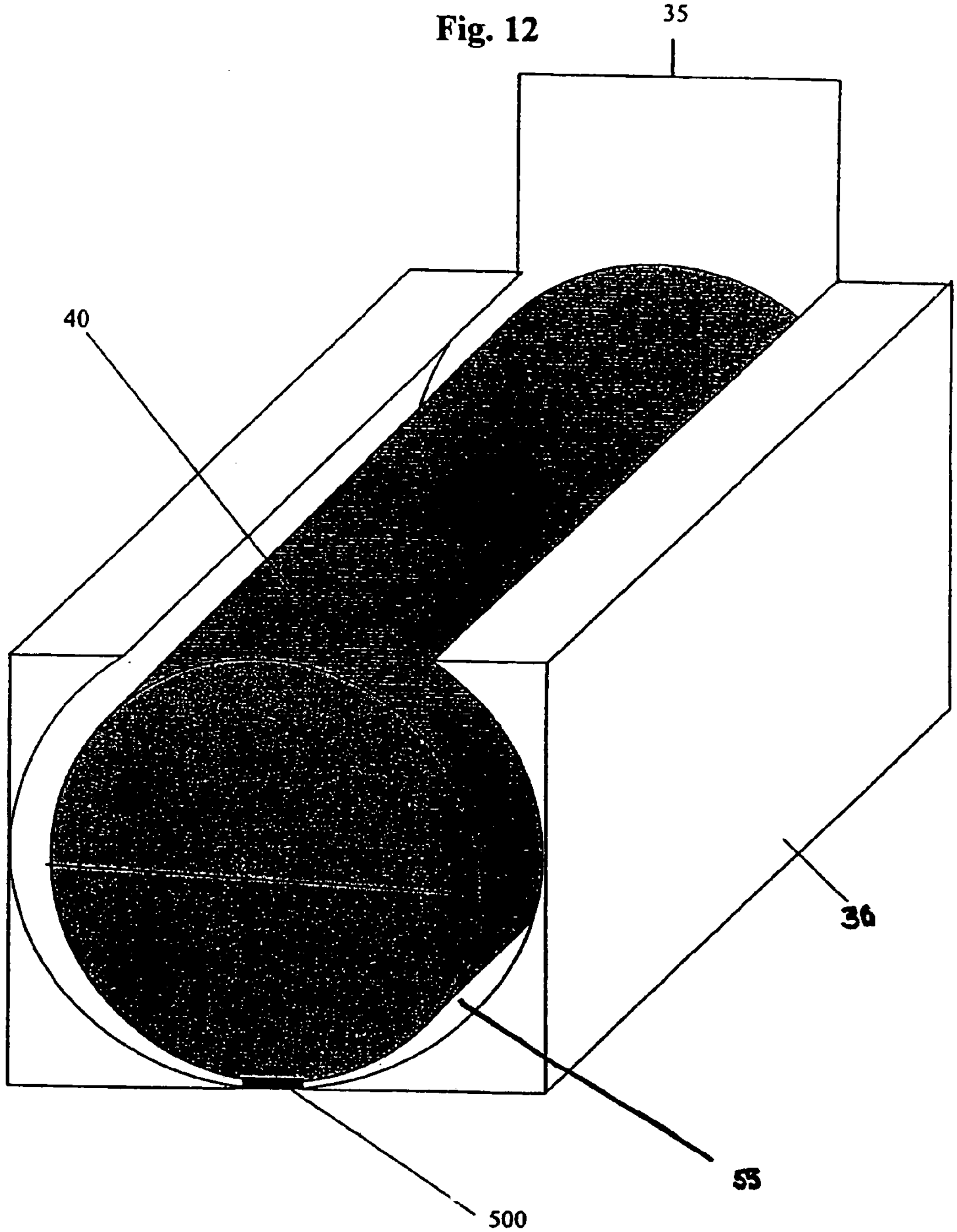


Fig. 13

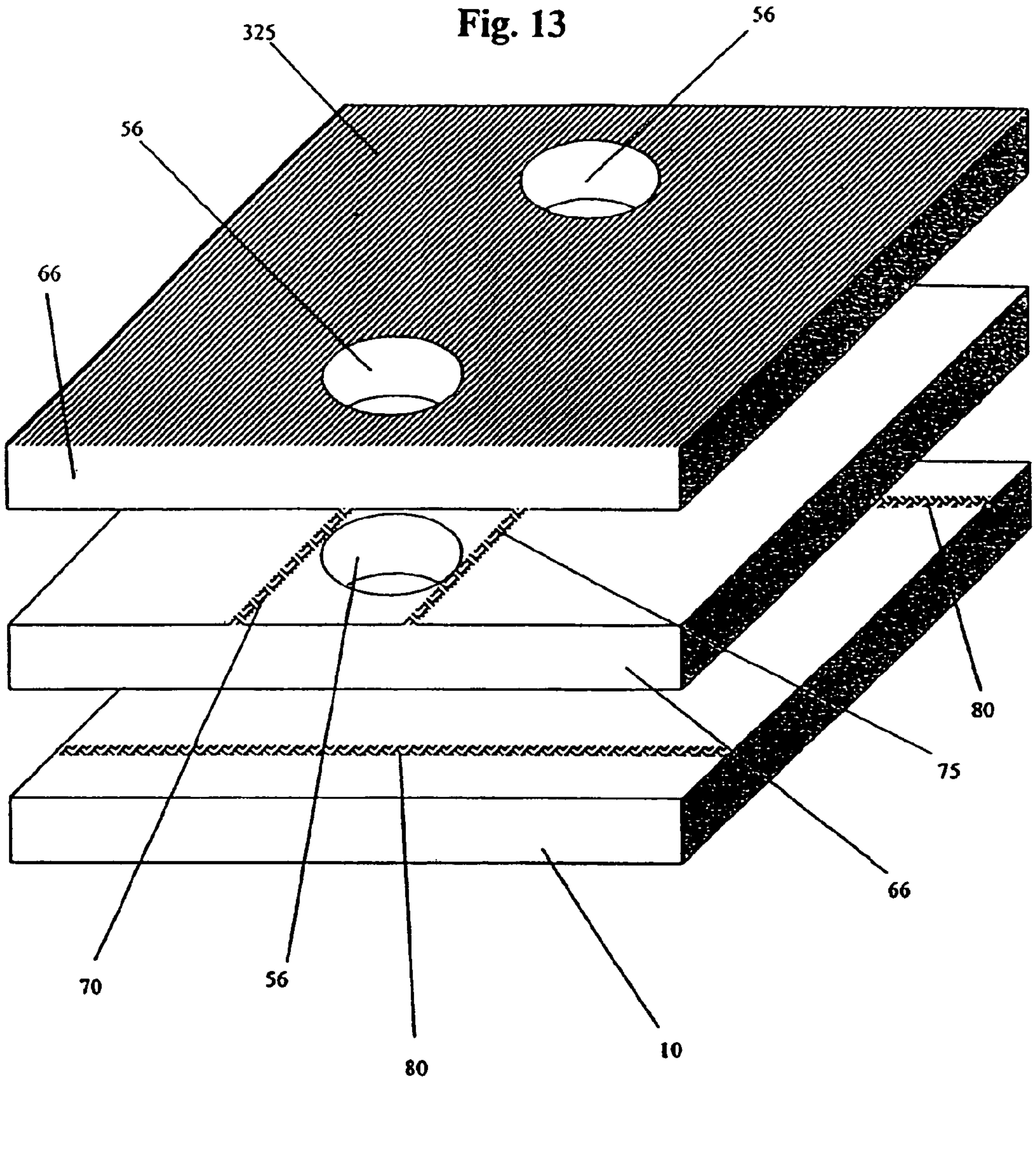


Fig. 14

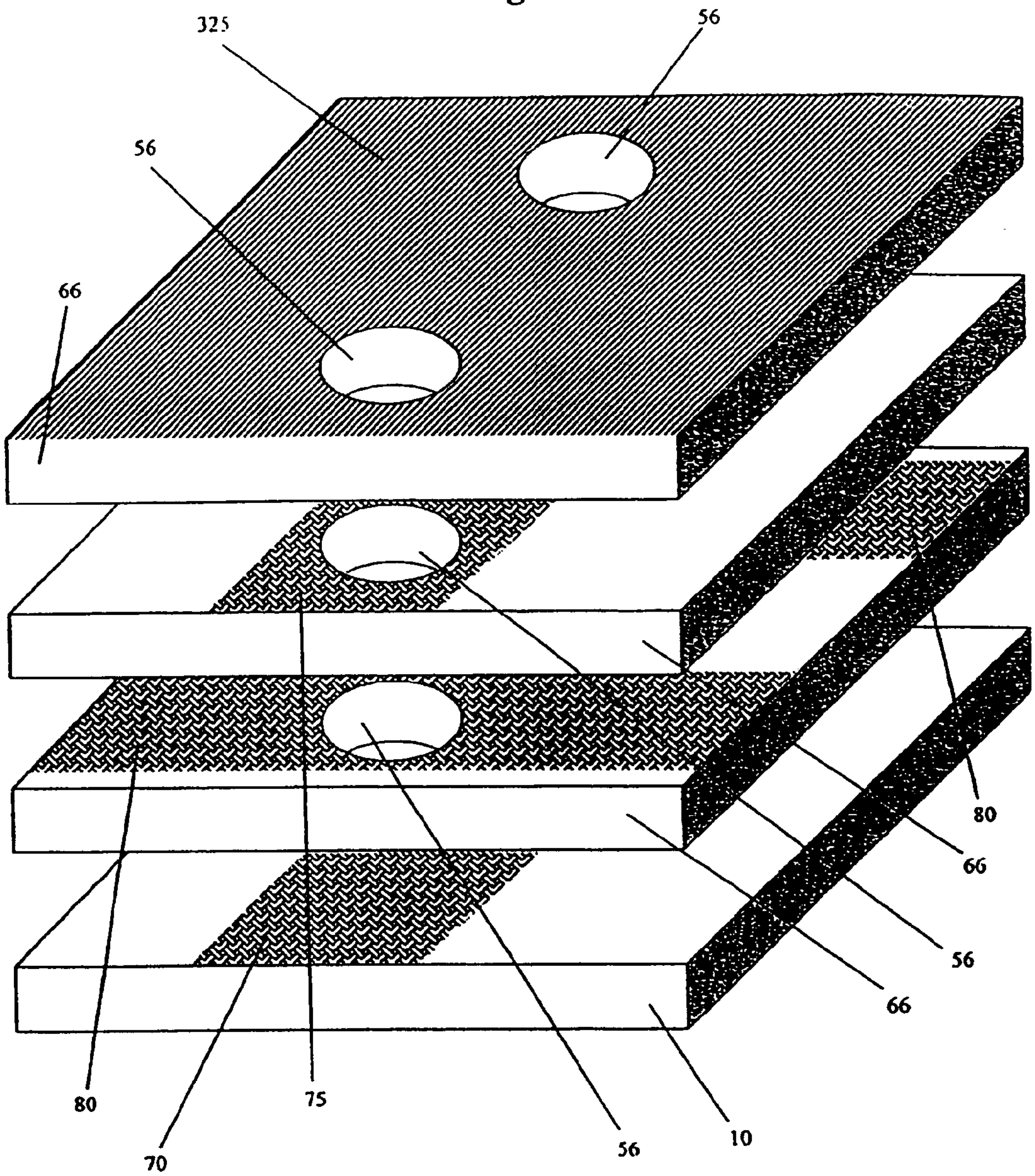
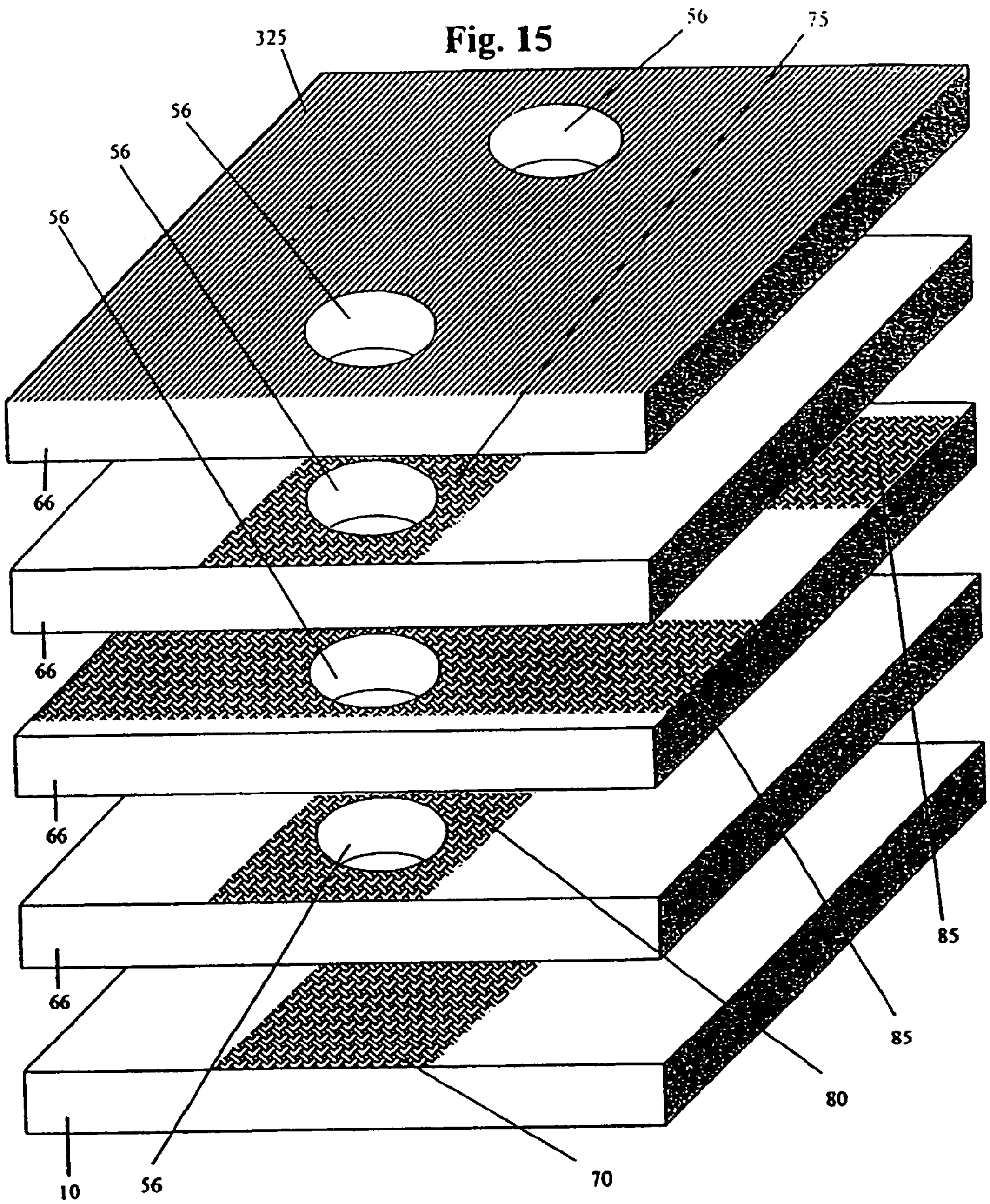


**Fig. 15**



# SOCKET FOR USE WITH A MICRO-COMPONENT IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The current application is a divisional application of U.S. patent application Ser. No. 10/643,608 filed Aug. 20, 2003 now U.S. Pat. No. 6,902,456, which is a continuation application of U.S. patent application Ser. No. 10/318,150, filed Dec. 13, 2002 now U.S. Pat. No. 6,646,388 and titled Socket for Use with a Micro-Component in a Light-Emitting Panel which is a continuation of Ser. No. 09/697,346 similarly titled U.S. Pat. No. 6,545,422 filed Oct. 27, 2000. The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a socket, for use in a light-emitting panel, in which a micro-component is at least partially disposed.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that drawn to the positive conductor and; positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.



Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors, and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or-by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are biased on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixel/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light; the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase army by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. Various embodiments of the present invention are drawn to different socket structures.

In one embodiment of the present invention a cavity is patterned on a substrate such that it is formed in the substrate. In another embodiment, a plurality of material layers form a substrate and a portion of the material layers is selectively removed to form a cavity. In another embodiment, a cavity is patterned on a substrate so that the cavity is formed in the substrate and a plurality of material layers are disposed on the substrate such that the material layers conform to the shape of the cavity. In another embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity. Other embodiments are directed to methods for forming the sockets described above.

Each socket includes at least two electrodes that are arranged so voltage applied to the two electrodes causes one or more micro-components to emit radiation. In an embodiment of the present invention, the at least two electrodes are adhered to only the first substrate, only the second substrate, or at least one electrode is adhered to the first substrate and at least one electrode is adhered to the second substrate. In another embodiment, the at least two electrodes are arranged so that the radiation emitted from the micro-component when energized is emitted throughout the field of view of the light-emitting panel such that the radiation does not cross the two electrodes. In another embodiment, at least one electrode is disposed within the material layers.

A cavity can be any shape or size. In an embodiment, the shape of the cavity is selected from a group consisting of a cube, a cone, a conical frustum, a paraboloid, spherical, cylindrical, a pyramid, a pyramidal frustum, a parallelepiped, and a prism. In another embodiment, a socket and a micro-component are described with a male-female connector type configuration. In this embodiment, the micro-component and the cavity have complimentary shapes, wherein the opening of the cavity is smaller than the diameter of the micro-component so that when the micro-component is disposed in the cavity the micro-component is held in place by the cavity.

The size and shape of the socket influences the performance and characteristics of the display and may be chosen, for example, to optimize the panel's efficiency of operation. In addition, the size and shape of the socket may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. Further, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. In an embodiment, the inside of a socket is coated with a reflective material, which provides an increase in luminosity.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two, sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a socket capable of being used in the light-emitting panel and supporting at least one micro-component.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components **40** may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel, each cylindrical-shaped structure may hold micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

A cavity **55** formed within and/or on a substrate provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. In addition, in another embodiment of the present invention as shown in FIG. **12**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is lockedlheld in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

The size and shape of the socket **30** influences the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and the electrodes disposed on or within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component that is deposited within a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

There are a variety of coatings **350** that may be at least partially added to a socket that also influence the performance and characteristics of the light-emitting panel. Types of coatings **350** include, but are not limited to, adhesives, bonding agents, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters. One skilled in the art will recognize that other coatings may also be used. The coatings **350** may be applied to the inside of the socket **30** by differential stripping, lithographic process sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used. Alternatively, or in conjunction with the variety of socket coatings **350**, a micro-component **40** may also be coated with a variety of coatings **300**. These micro-component coatings **300** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may readily hold a micro-component or plurality of micro-components in a socket or may require additional activation energy to secure the micro-components or plurality of micro-components in a socket. In an embodiment of the present invention, where the micro-component is configured to emit UV light, the inside of each of the sockets **30** is at least partially coated with phosphor in order to convert the UV light to visible light. In a color light-emitting panel, in accordance with another embodiment, red, green, and blue phosphors are used to create alternating red, green, and blue, pixels/subpixels, respectively. By combining these colors at varying intensities all colors can be formed. In another embodiment, the phosphor coating may be combined with an adhesive so that the adhesive acts as a binder for the phosphor and also binds the micro-component **40** to the socket **30** when it is cured. In addition, the socket **30** may be coated with a reflective material, including, but not limited to, optical dielectric stacks, to provide an increase in luminosity, by directing radiation traveling in the direction of the substrate in which the sockets are formed out through the field of view **400** of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **65** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **65** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the cavities **55** are patterned on the first substrate **10** so that the cavities are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the cavities **55** are formed by selectively removing a portion of the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. 6A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. 6B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. 7A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. 7B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where the cavities **55** are patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **13**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **14**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **15**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A light-emitting panel comprising:

a substrate containing a plurality of cavities arranged in a pre-determined pattern, the pre-determined pattern consists of a plurality of groups of cavities, wherein the plurality of groups of cavities are uniformly spaced, one from another, within the substrate;

at least three cavities uniformly spaced one from another forming each of the plurality of groups of cavities; and

a micro-component having ionizable gas therein within each of the at least three cavities, wherein each of the micro-components within each of the at least three cavities emits visible radiation at a different wavelength in response to an application of a voltage thereto.

**2**. The light-emitting panel of claim **1**, wherein the different wavelengths are selected from the group consisting of visible radiation in the blue, green and red spectra.

**3**. A light emitting panel comprising:

a substrate containing a plurality of cavities formed therein;

at least a first, second and third micro-component arranged within each of the plurality of cavities, wherein each of the first, second and third micro-components contains an ionizable gas, and further wherein each of the first, second, and third micro-components emits visible radiation of a different wavelength; and

at least one set of electrodes arranged within each of the plurality of cavities for selectively ionizing the gas within each of the first, second, and third microcomponents.

**4**. The light emitting panel of claim **3**, wherein the plurality of cavities are uniformly spaced apart from each other.

**5**. The light emitting panel of claim **3**, wherein the plurality of cavities are non-uniformly spaced apart from each other.

**6**. The light-emitting panel of claim **3**, wherein the different wavelengths are selected from the group consisting of visible radiation in the blue, green and red spectra.

* * * * *

US007125305B2

(12) United States Patent
Green et al.

(10) Patent No.: US 7,125,305 B2
(45) Date of Patent: *Oct. 24, 2006

(54) **LIGHT-EMITTING PANEL AND A METHOD FOR MAKING**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 418 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/614,049**

(22) Filed: **Jul. 8, 2003**

(65) **Prior Publication Data**

US 2004/0106349 A1 Jun. 3, 2004

**Related U.S. Application Data**

(63) Continuation of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**
***H01J 9/00*** (2006.01)
***H01J 9/26*** (2006.01)
***H01J 9/40*** (2006.01)

(52) **U.S. Cl.** .......................................... **445/24**; 445/25

(58) **Field of Classification Search** .................. 445/24, 445/25

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,559,190 A 1/1971 Blitzer et al. ............... 340/173
3,646,384 A 2/1972 Lay ......................... 313/109.5
3,704,052 A 11/1972 Coleman ..................... 316/17
3,704,386 A 11/1972 Cola ...................... 313/108 R
3,755,027 A 8/1973 Gilsing ........................ 156/67
3,848,248 A 11/1974 MacIntyre, Jr. ........ 340/324 M
3,969,651 A 7/1976 Greeson, Jr. .......... 315/169 TV
3,990,068 A 11/1976 Mayer et al. .......... 340/324 M
3,998,618 A 12/1976 Kreick et al. ................. 65/105
4,027,246 A 5/1977 Caccoma et al. ........ 235/151.1
4,035,690 A 7/1977 Roeber ................. 315/169 TV
4,303,433 A 12/1981 Torobin ...................... 65/21.4
4,379,301 A 4/1983 Fischbeck ................... 346/1.1
4,386,358 A 5/1983 Fischbeck ................... 346/1.1
4,393,326 A 7/1983 Kamegaya et al. ......... 313/582
4,429,303 A 1/1984 Aboelfotoh ................. 340/701

(Continued)

FOREIGN PATENT DOCUMENTS

JP 4-287397 10/1992

(Continued)

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42805, dated Dec. 21, 2004 (mailing date).

(Continued)

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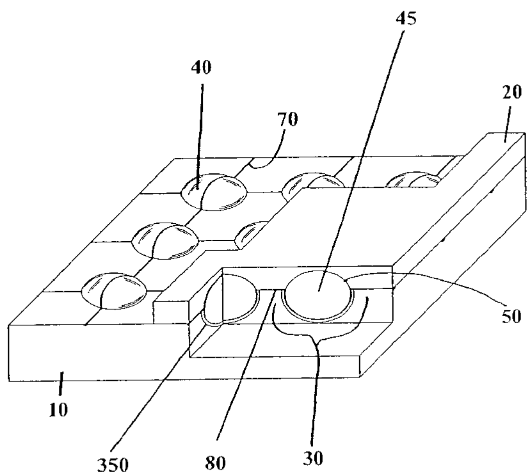
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous inline process.

**14 Claims, 22 Drawing Sheets**



U.S. PATENT DOCUMENTS

4,534,743 A 8/1985 D'Onofrio et al. ........... 445/24
4,554,537 A 11/1985 Dick .......................... 340/775
4,563,617 A 1/1986 Davidson .................... 315/312
4,591,847 A 5/1986 Criscimagna et al. ....... 340/776
4,654,561 A 3/1987 Shelton ................ 315/111.71
4,658,269 A 4/1987 Rezanka ...................... 346/75
4,697,123 A 9/1987 Shinoda et al. .......... 315/169.4
4,728,864 A 3/1988 Dick ...................... 315/169.3
4,833,463 A 5/1989 Dick et al. .................. 340/775
4,843,281 A 6/1989 Mendelsohn ................ 313/587
4,887,003 A 12/1989 Parker ........................ 313/634
4,912,364 A 3/1990 Holló et al. ................ 313/623
5,019,807 A 5/1991 Stapleton et al. ........... 340/718
5,030,888 A 7/1991 Salavin et al. ........... 315/169.4
5,062,916 A 11/1991 Aufderheide et al. ....... 156/269
5,068,916 A 11/1991 Harrison et al. .............. 455/39
5,075,597 A 12/1991 Deschamps et al. ..... 315/169.4
5,126,632 A 6/1992 Parker ........................ 313/634
5,150,007 A 9/1992 Andreadakis ............... 313/586
5,315,129 A 5/1994 Forrest et al. ................ 257/21
5,396,149 A 3/1995 Kwon ........................ 313/486
5,500,287 A 3/1996 Henderson .................. 428/403
5,501,871 A 3/1996 Henderson .................. 427/160
5,510,678 A 4/1996 Sakai et al. ................... 315/58
5,514,934 A 5/1996 Matsumoto et al. ........ 313/607
5,674,351 A 10/1997 Lovoi ..................... 156/629.1
5,675,212 A 10/1997 Schmid et al. .............. 313/422
5,686,790 A 11/1997 Curtin et al. ............... 313/493
5,703,436 A 12/1997 Forrest et al. .............. 313/506
5,707,745 A 1/1998 Forrest et al. .............. 428/432
5,721,160 A 2/1998 Forrest et al. ................ 438/28
5,725,787 A 3/1998 Curtin et al. ................. 216/25
5,746,635 A 5/1998 Spindt et al. ................. 445/24
5,747,931 A 5/1998 Riddle et al. ............... 313/581
5,755,944 A 5/1998 Haven et al. ............... 204/486
5,757,026 A 5/1998 Forrest et al. ................ 257/40
5,757,131 A 5/1998 Tsuchiya .................... 375/582
5,757,139 A 5/1998 Forrest et al. ........... 315/169.3
5,777,782 A 7/1998 Sheridon .................... 359/296
5,788,814 A 8/1998 Sun et al. ............... 204/297 R
5,793,158 A 8/1998 Wedding, Sr. .............. 313/493
5,798,604 A 8/1998 Duboc, Jr. et al. .......... 313/495
5,808,403 A 9/1998 Clerc ........................ 313/336
5,811,833 A 9/1998 Thompson ................... 257/40
5,815,306 A 9/1998 Sheridon et al. ............ 359/296
5,825,451 A 10/1998 Ma et al. .................... 349/187
5,837,221 A 11/1998 Bernstein et al. .......... 424/9.52
5,844,363 A 12/1998 Gu et al. .................... 313/506
5,853,446 A 12/1998 Carre et al. .................. 65/17.3
5,862,054 A 1/1999 Li ......................... 364/468.28
5,865,657 A 2/1999 Haven et al. ................. 445/24
5,897,414 A 4/1999 Bergeron et al. ............. 445/3
5,898,266 A 4/1999 Spindt et al. ............... 313/495
5,913,704 A 6/1999 Spindt et al. ................. 445/24
5,914,150 A 6/1999 Porter et al. .................. 427/77
5,917,646 A 6/1999 Sheridon .................... 359/296
5,920,080 A 7/1999 Jones .......................... 257/40
5,939,826 A 8/1999 Ohsawa et al. ............. 313/582
5,945,174 A 8/1999 Shaw et al. ................. 427/509
5,953,587 A 9/1999 Forrest et al. ................ 438/99
5,964,630 A 10/1999 Slusarczuk et al. ........... 445/25
5,965,109 A 10/1999 Lohrmann ................. 424/9.52
5,967,871 A 10/1999 Kaake et al. ................. 445/24
5,969,472 A 10/1999 Kisner ........................ 313/484
5,975,683 A 11/1999 Smith et al. .................. 347/55
5,984,747 A 11/1999 Bhagavatula et al. ......... 445/24
5,985,460 A 11/1999 Wang et al. ................ 428/426
5,986,409 A 11/1999 Farnworth et al. ....... 315/169.4
5,990,614 A 11/1999 Spindt ........................ 313/495
5,990,620 A 11/1999 Lepselter .................... 313/585
6,002,198 A 12/1999 Spindt et al. ............... 313/292
6,013,538 A 1/2000 Burrows et al. .............. 438/22
6,017,584 A 1/2000 Albert et al. ............ 427/213.3
6,019,657 A 2/2000 Chakvorty et al. ........... 445/24
6,022,652 A 2/2000 Haven et al. ................. 430/26
6,023,259 A 2/2000 Howard et al. ............... 345/76
6,025,097 A 2/2000 Drumm ......................... 430/7
6,030,269 A 2/2000 Drumm ........................ 445/52
6,030,715 A 2/2000 Thompson et al. ......... 428/690
6,033,547 A 3/2000 Trau et al. .................. 204/622
6,037,710 A 3/2000 Poole et al. ................ 313/422
6,037,918 A 3/2000 Hansen et al. ................ 345/74
6,038,002 A 3/2000 Song ........................... 349/43
6,039,619 A 3/2000 Kang et al. ................... 445/24
6,045,930 A 4/2000 Thompson et al. ......... 428/690
6,046,543 A 4/2000 Bulovic et al. ............. 313/504
6,048,469 A 4/2000 Xiang et al. .......... 252/301.6 R
6,048,630 A 4/2000 Burrows et al. ............ 428/690
6,049,366 A 4/2000 Hakemi et al. ............... 349/86
6,069,443 A 5/2000 Jones et al. ................. 313/504
6,072,276 A 6/2000 Okajima ..................... 313/581
6,079,814 A 6/2000 Lean et al. ................... 347/55
6,080,606 A 6/2000 Gleskova et al. ........... 438/151
6,087,196 A 7/2000 Sturm et al. .................. 438/29
6,091,195 A 7/2000 Forrest et al. .............. 313/504
6,091,380 A 7/2000 Hashimoto et al. ........... 345/60
6,091,874 A 7/2000 Higashi et al. ............. 385/130
6,097,147 A 8/2000 Baldo et al. ................ 313/506
6,130,655 A 10/2000 Lammers ..................... 345/72
6,137,553 A 10/2000 Izumi et al. .................. 349/49
6,201,518 B1 3/2001 Kane et al. ................... 345/60
6,255,777 B1 7/2001 Kim et al. .................. 313/582
6,262,706 B1 7/2001 Albert et al. ............... 345/107
6,265,826 B1 7/2001 Miyazaki .................... 313/586
6,281,863 B1 8/2001 Sasaki et al. ................ 345/60
6,285,129 B1 9/2001 Park et al. .................. 313/586
6,285,434 B1 9/2001 Ma et al. .................... 349/189
6,288,488 B1 9/2001 Amemiya ................... 313/582
6,288,693 B1 9/2001 Song et al. ................... 345/68
6,291,925 B1 9/2001 Jacobson .................... 310/319
6,292,159 B1 9/2001 Someya et al. ............... 345/60
6,292,160 B1 9/2001 Mikoshiba et al. ........... 345/60
6,295,040 B1 9/2001 Nhan et al. ................... 345/60
6,296,539 B1 10/2001 Awaji et al. .................. 445/24
6,297,590 B1 10/2001 Nanto et al. ................ 313/586
6,300,152 B1 10/2001 Kim ............................ 438/30
6,300,932 B1 10/2001 Albert ........................ 345/107
6,304,031 B1 10/2001 Wani et al. ................. 313/582
6,304,032 B1 10/2001 Asano ........................ 313/582
6,304,238 B1 10/2001 Tsuchida ..................... 345/87
6,307,319 B1 10/2001 Lee ............................ 313/590
6,312,304 B1 11/2001 Duthaler et al. .............. 445/24
6,312,971 B1 11/2001 Amundson et al. ........... 438/99
6,319,325 B1 11/2001 Hiratsuka et al. ........... 118/718
6,322,010 B1 11/2001 Sasaki et al. ............... 239/568
6,545,422 B1 4/2003 George et al. ........... 315/169.3
6,570,335 B1 5/2003 George et al. ........... 315/169.3
6,612,889 B1 9/2003 Green et al. .................. 445/24
2001/0008825 A1 7/2001 Toyoda et al. ................ 445/24
2001/0033256 A1 10/2001 Moore ......................... 345/60
2001/0053570 A1 12/2001 Kido .......................... 438/149
2002/0008470 A1 1/2002 Uegaki et al. .............. 313/567
2002/0009536 A1 1/2002 Iguchi et al. ................. 427/10
2002/0016075 A1 2/2002 Peng et al. ................. 438/700
2002/0017864 A1 2/2002 Watanabe et al. ........... 313/586
2002/0022565 A1 2/2002 Sreeram et al. ............... 501/16
2002/0024295 A1 2/2002 Miyashita et al. .......... 313/495
2003/0094891 A1 5/2003 Green et al. ................ 313/495
2003/0164684 A1 9/2003 Green et al. ................ 313/582

FOREIGN PATENT DOCUMENTS

JP 10-3869 1/1998

WO WO 00/36465 6/2000

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US03/22868, dated Sep. 27, 2004 (mailing date).
International Search Report for Application No. PCT/US03/22868, dated Jun. 1, 2004 (mailing date).
Written Opinion for Application No. PCT/US01/42805, dated Apr. 2, 2004 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).
International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).
Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
Preliminary Examination Report for U.S. Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.
Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.
Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
Sheats, James, "Introduction to Organic Light-Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.thm.
Sauvante, Michael, "Roll-to-Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www-star.stanford.edu/~vlf/plasma_display/index.htm.
"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.
"Runco Plasma Wall PL-42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.
"Runco Plasma Wall Pl-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.
"Runco Plasma Wall™ PL-61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.
"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.
"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.
"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.
"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.
"LG PDP Now Available at World Renowned Harrods Department Store" [onlne], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.
"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.
"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.
"LG Electronics Becomes First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.
"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.
Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21-25, 2001.
Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar. 2001, pp. 17-17-24.
Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.
"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.
Alien Technology Corporation's Technology Overview, Copyright © 2000, Alien Technology™, http://www.alientechnology.com/d/technology/overview.html.
Anonymous, "Alien Technology Corporation White Paper—Fluidic Self Assembly," Alien Technology Corp., Oct. 1999, pp. 1-7.
Kurihara, M., Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372-1378.
Rauf, S., Kushner, M. J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10-11.
Shin, Y. K., Lee, J. K., Shon, C. H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 14-15.
"Transparent Conductive Coatings," Copyright 1998, 4 pp.
Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides" *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep. 1997, pp. 1241.
Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.
"Flat Panel Displays in Perspective," 44 pp., Sep. 1995.

Fig. 1

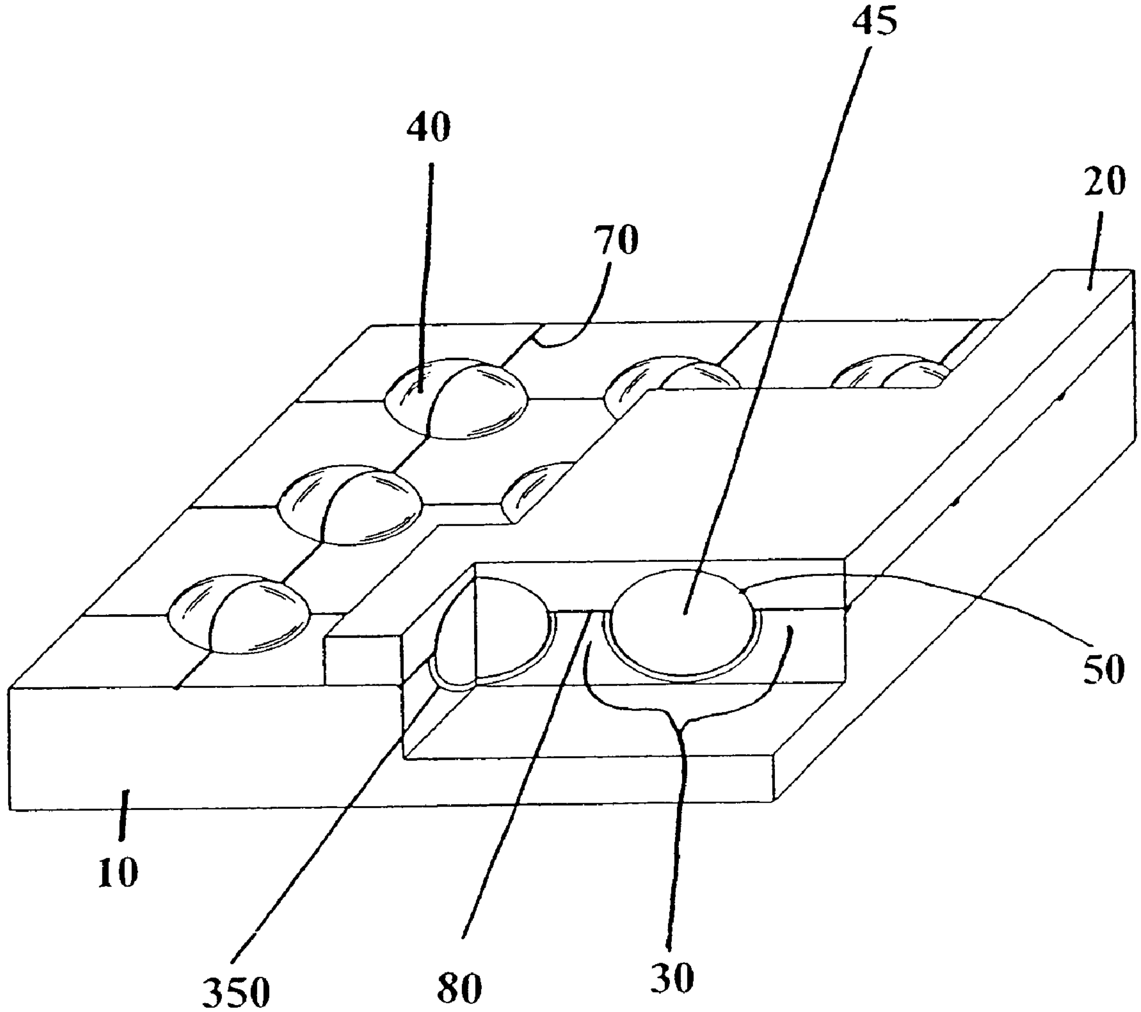
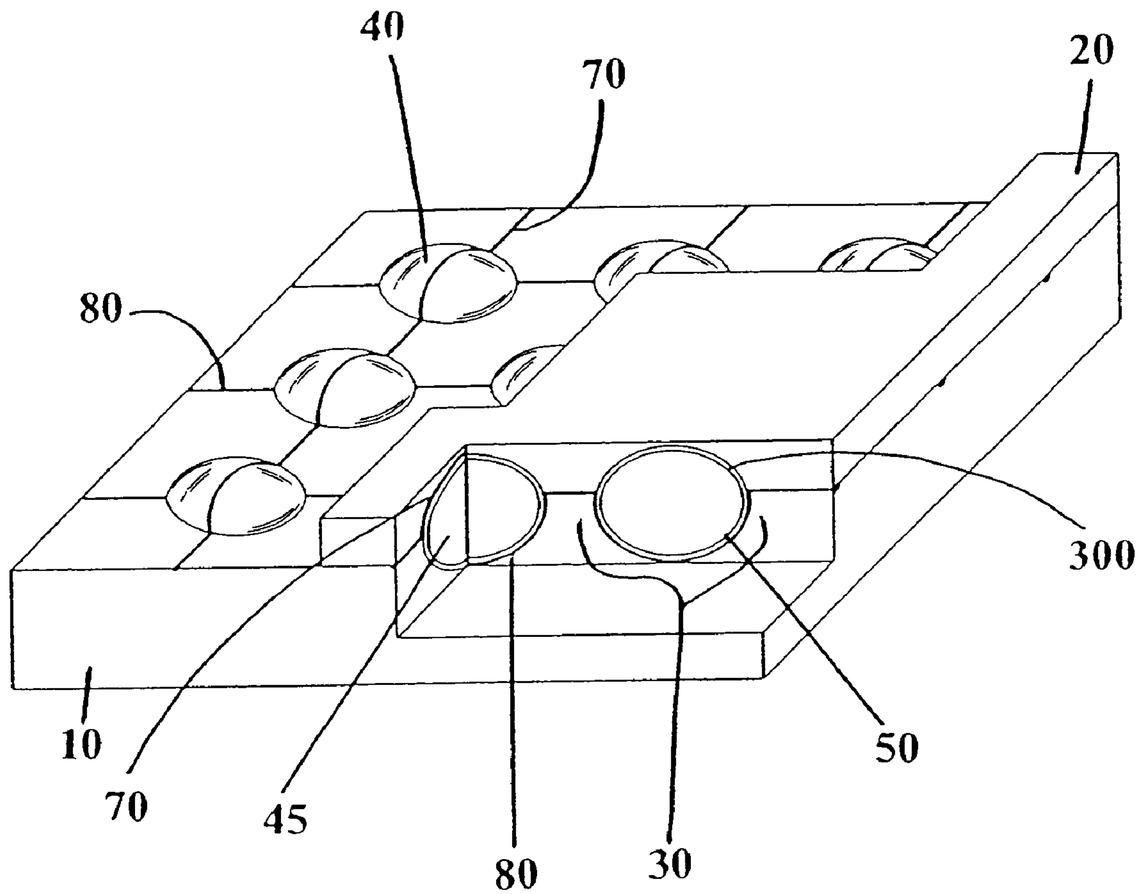


Fig. 2



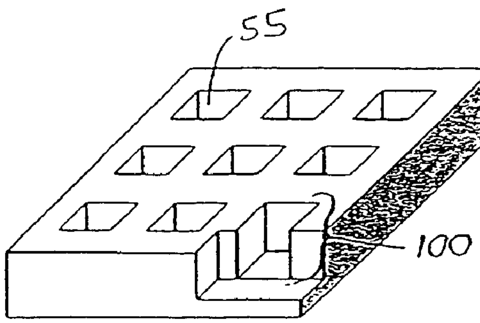



Fig. 3A

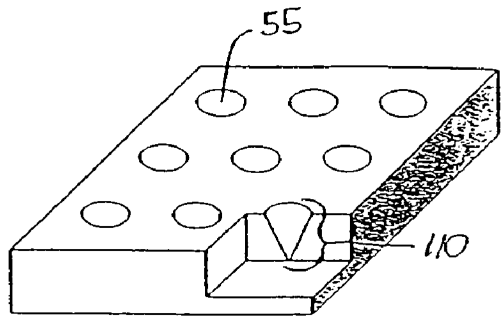



Fig. 3B

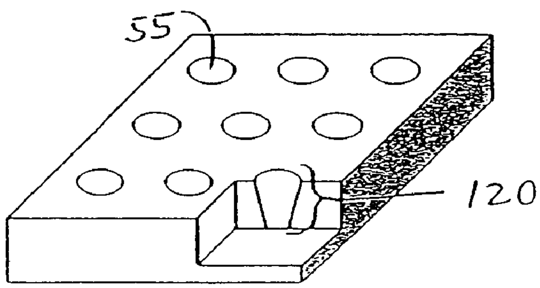



Fig. 3C

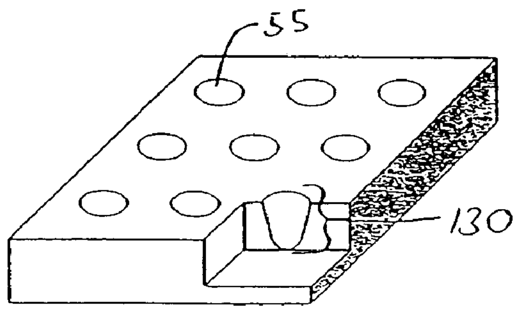



Fig 3D

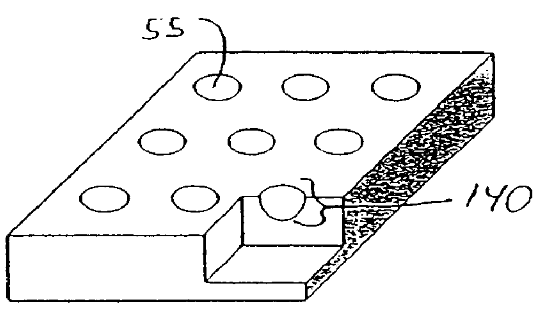



Fig 3E

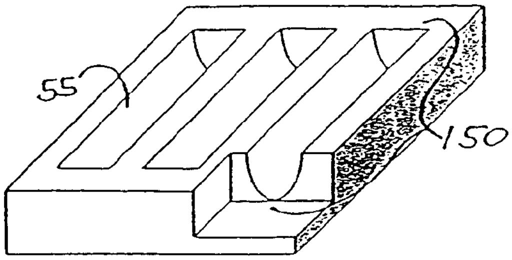



Fig. 3F

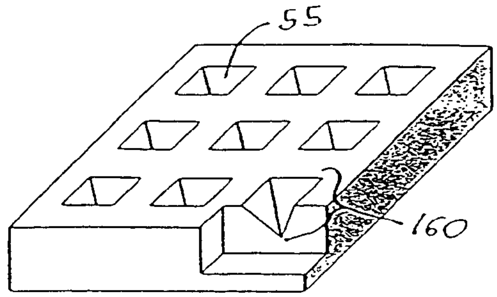



Fig. 3G

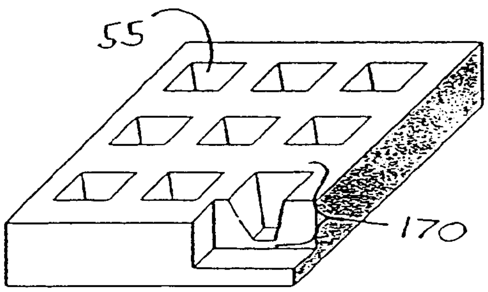



Fig. 3H

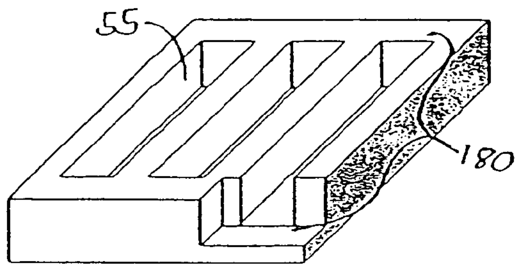



Fig. 3I

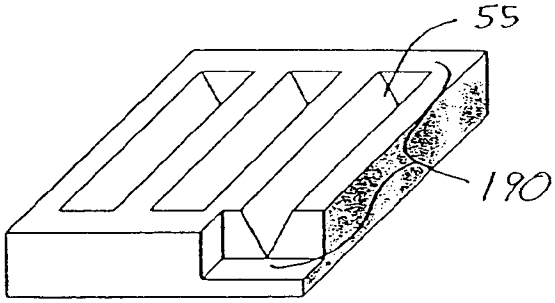



Fig. 3J

Fig. 4

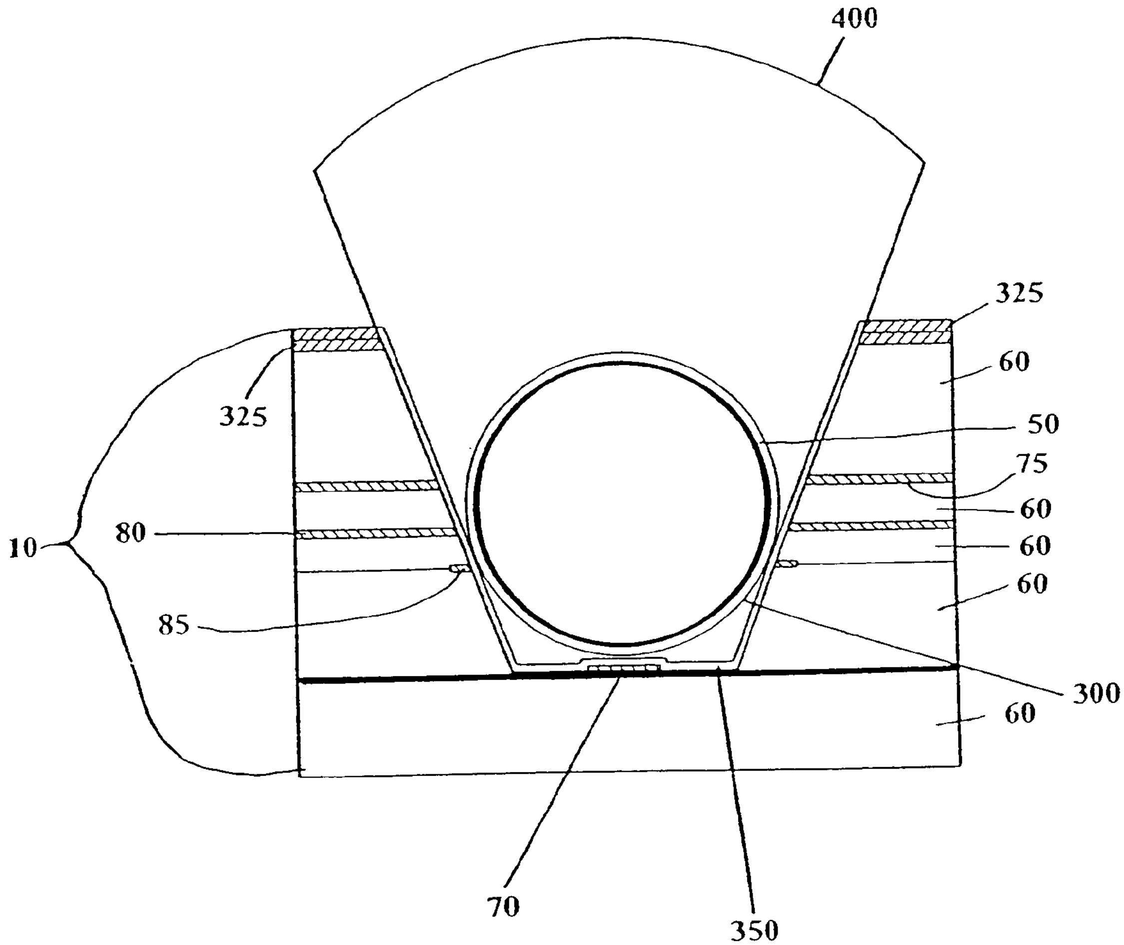
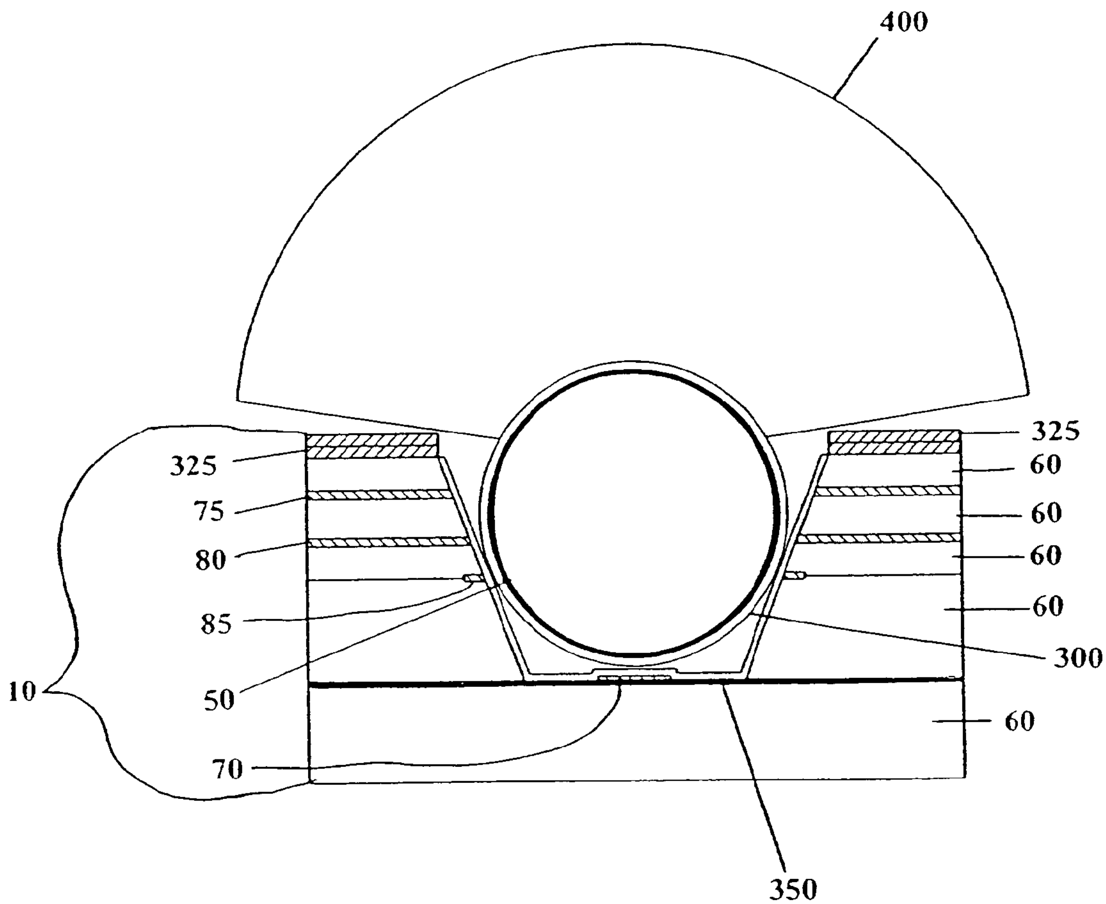


Fig. 5



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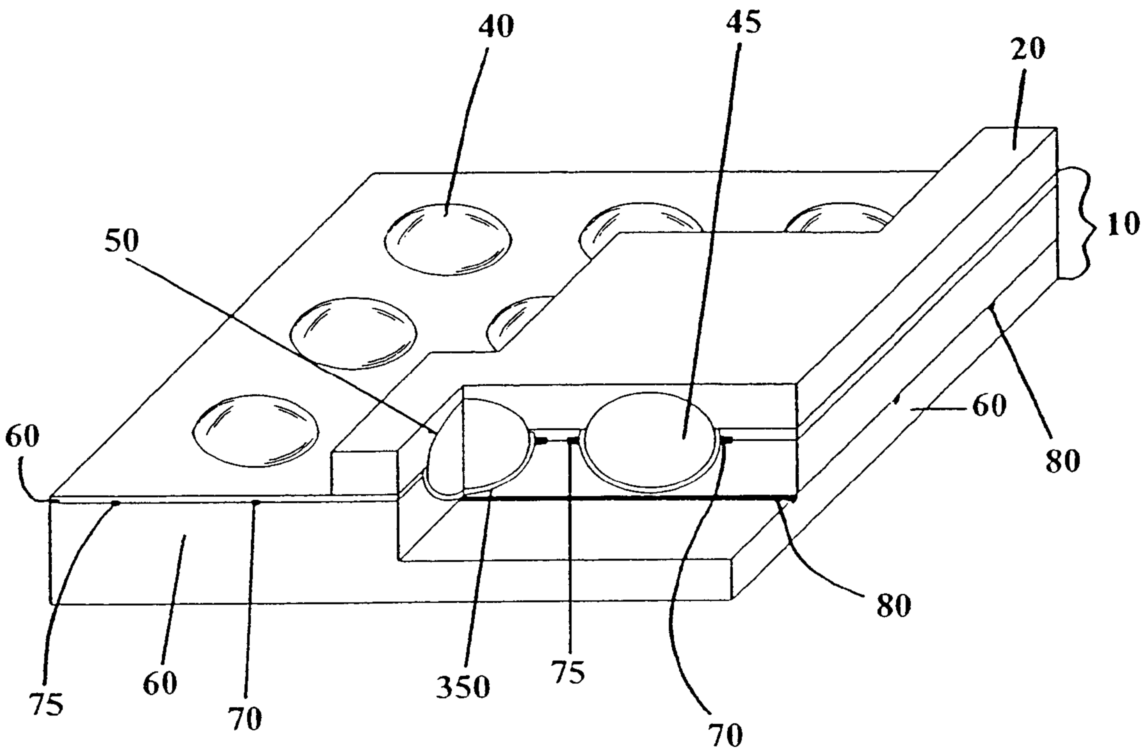

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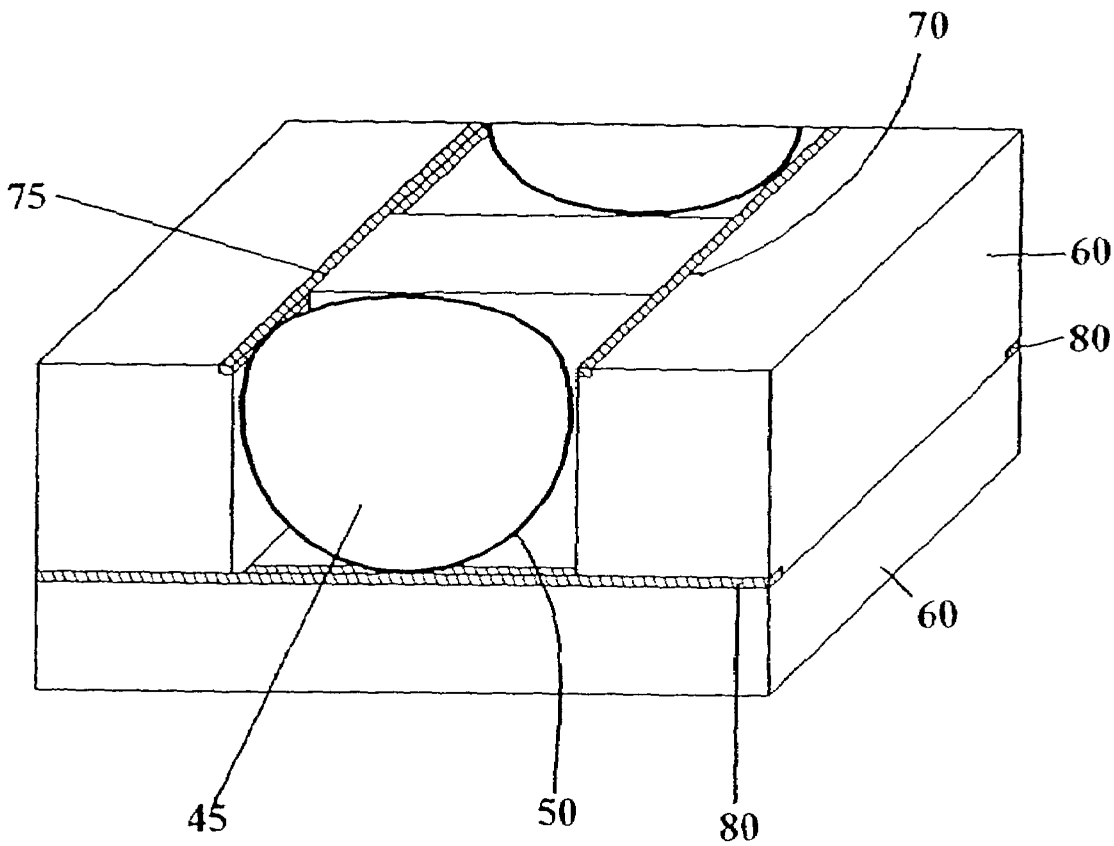

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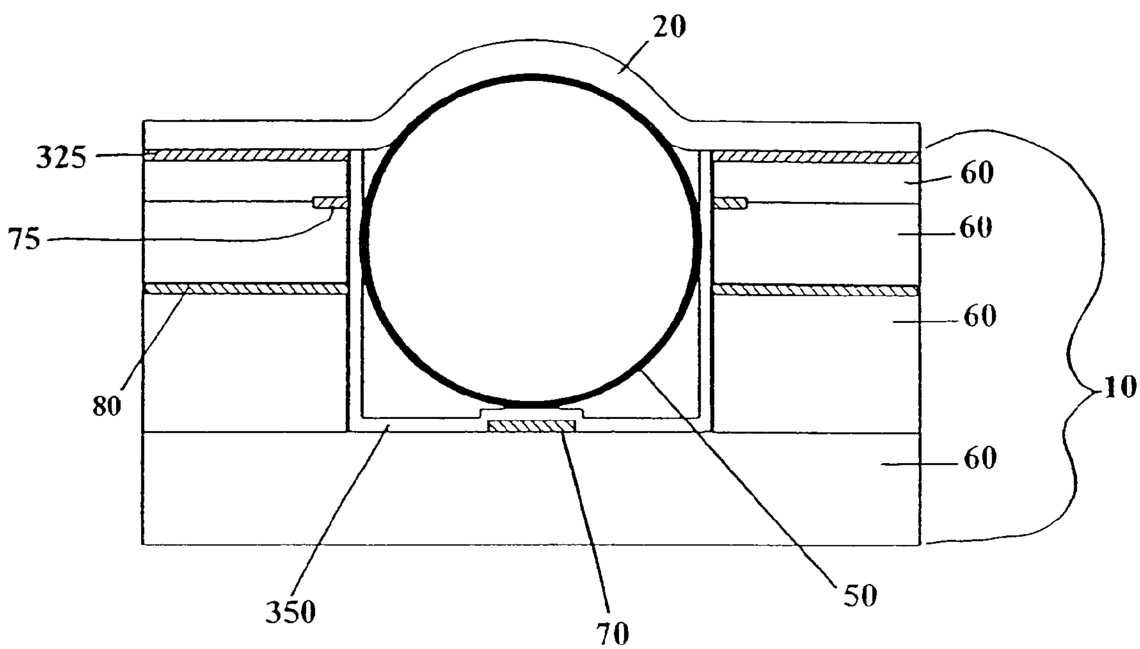
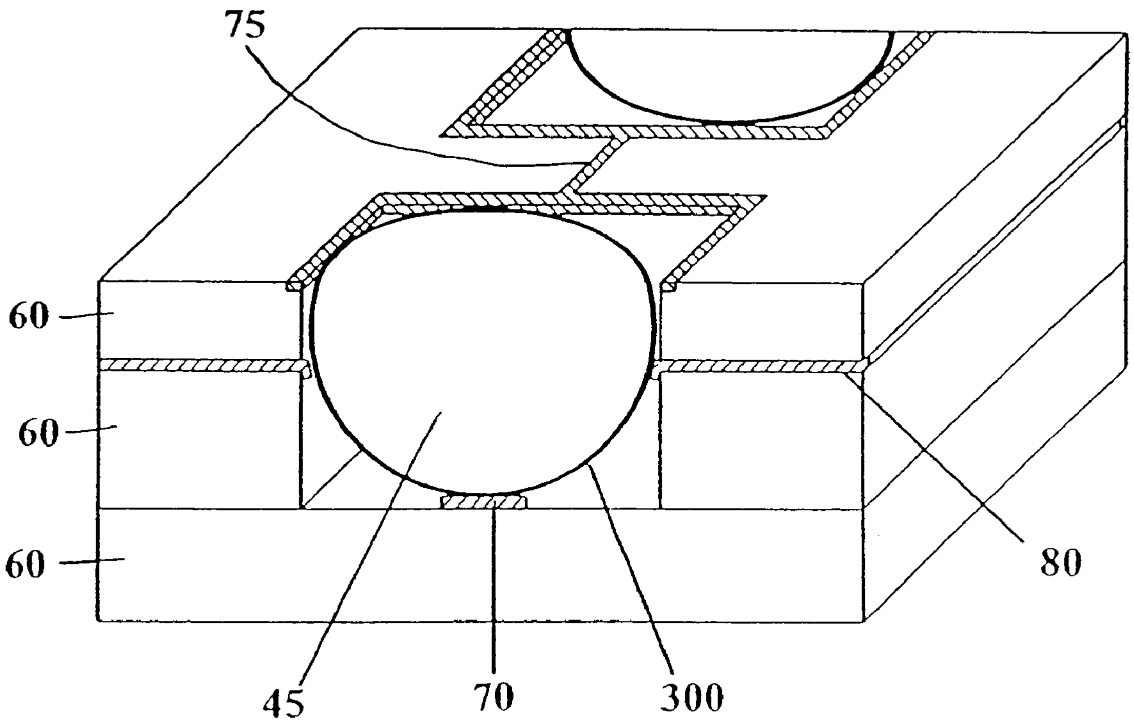


Fig. 7B



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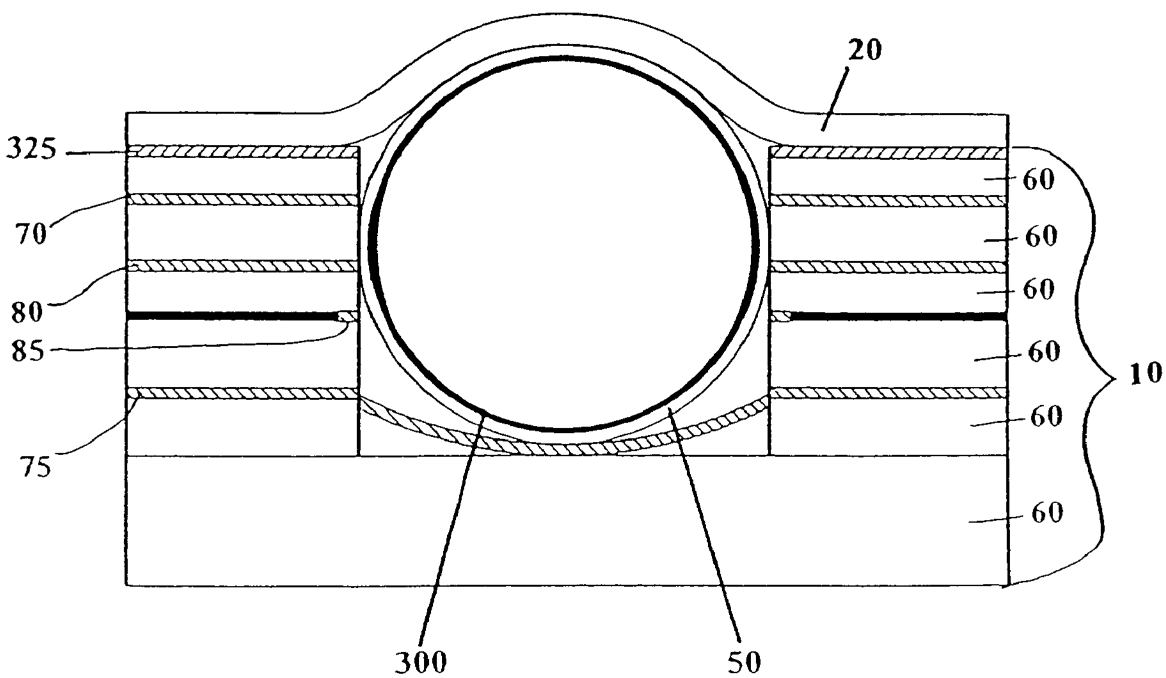


Fig. 9

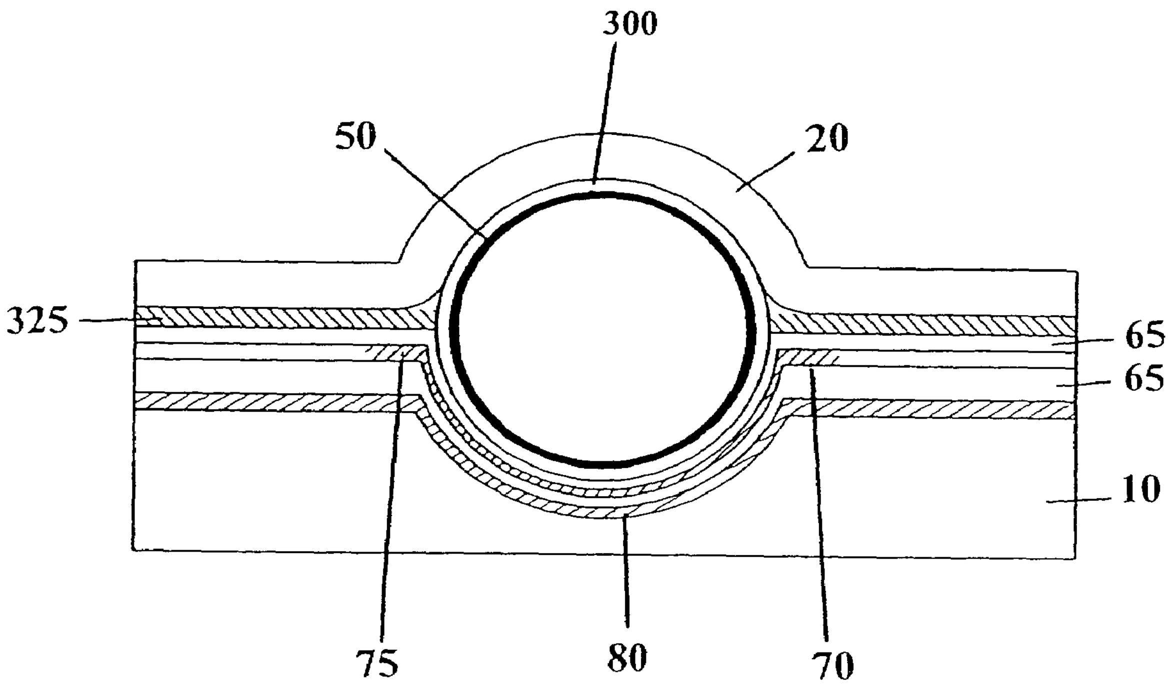


Fig. 10

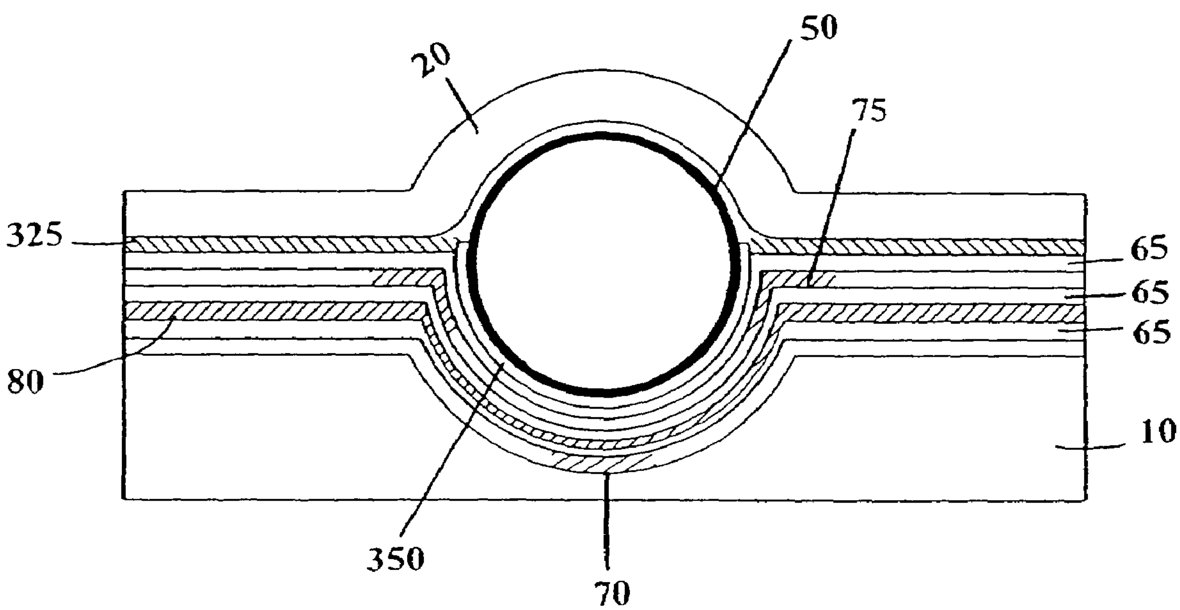
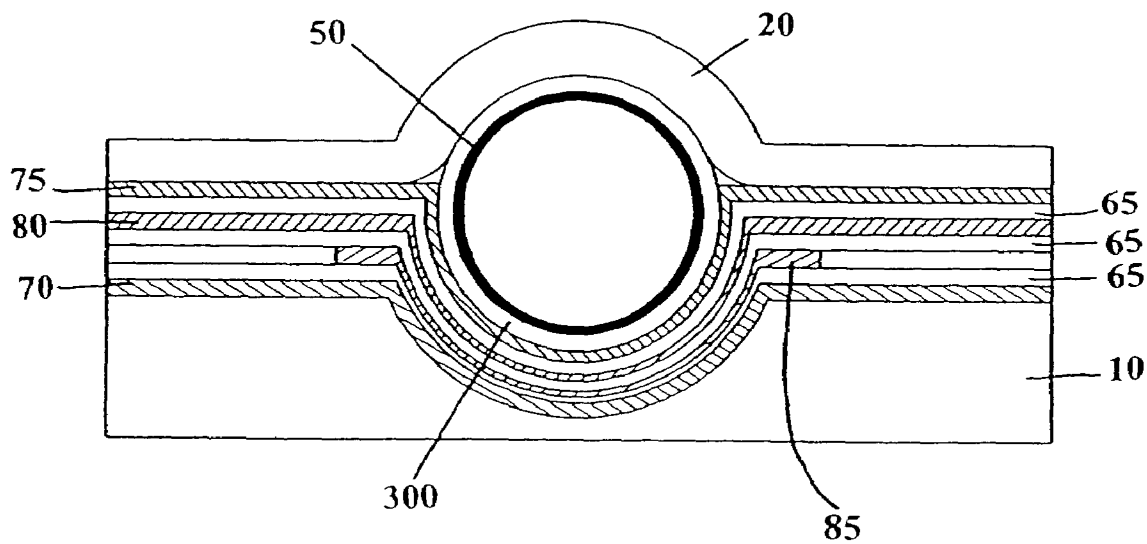
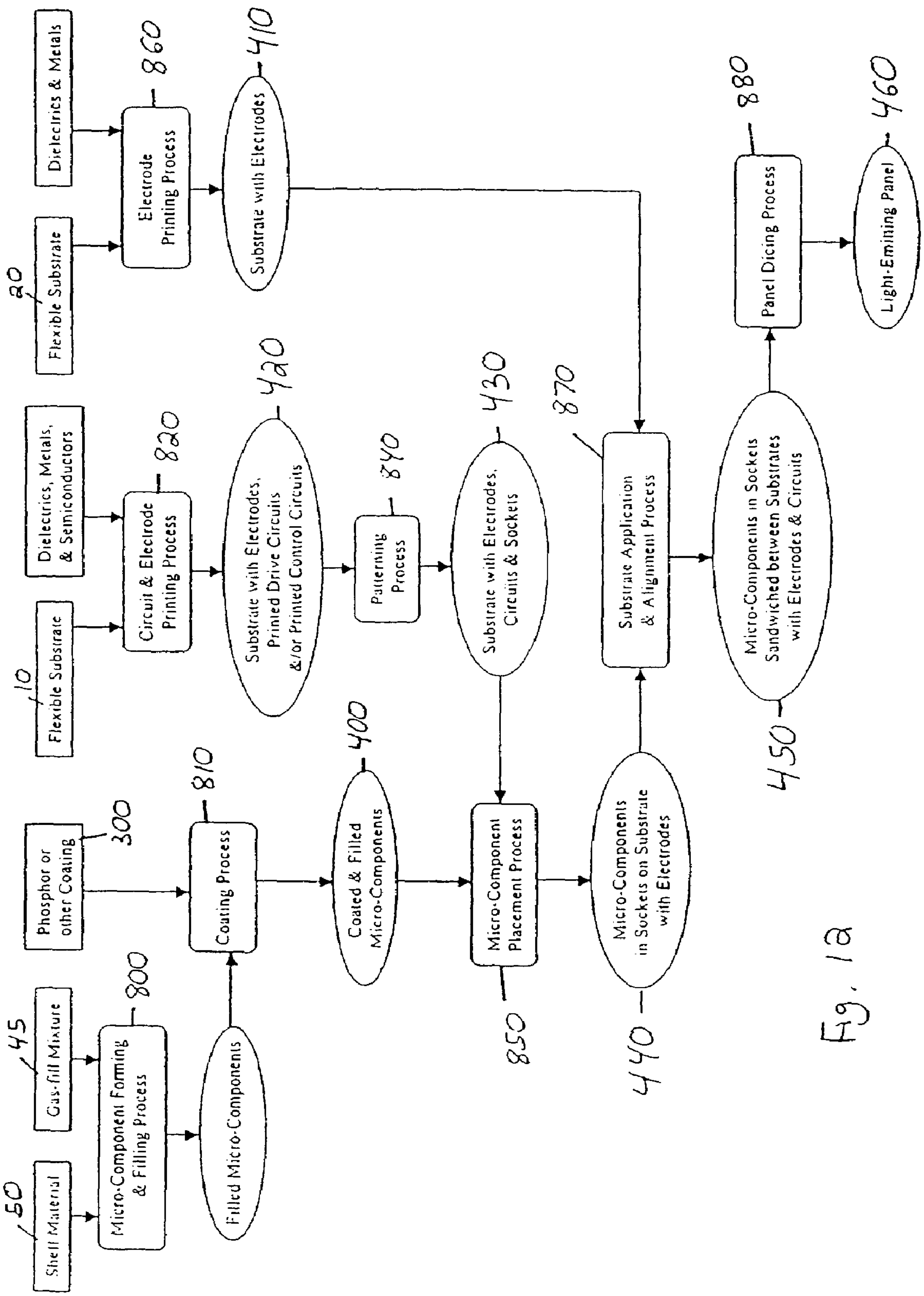


Fig. 11

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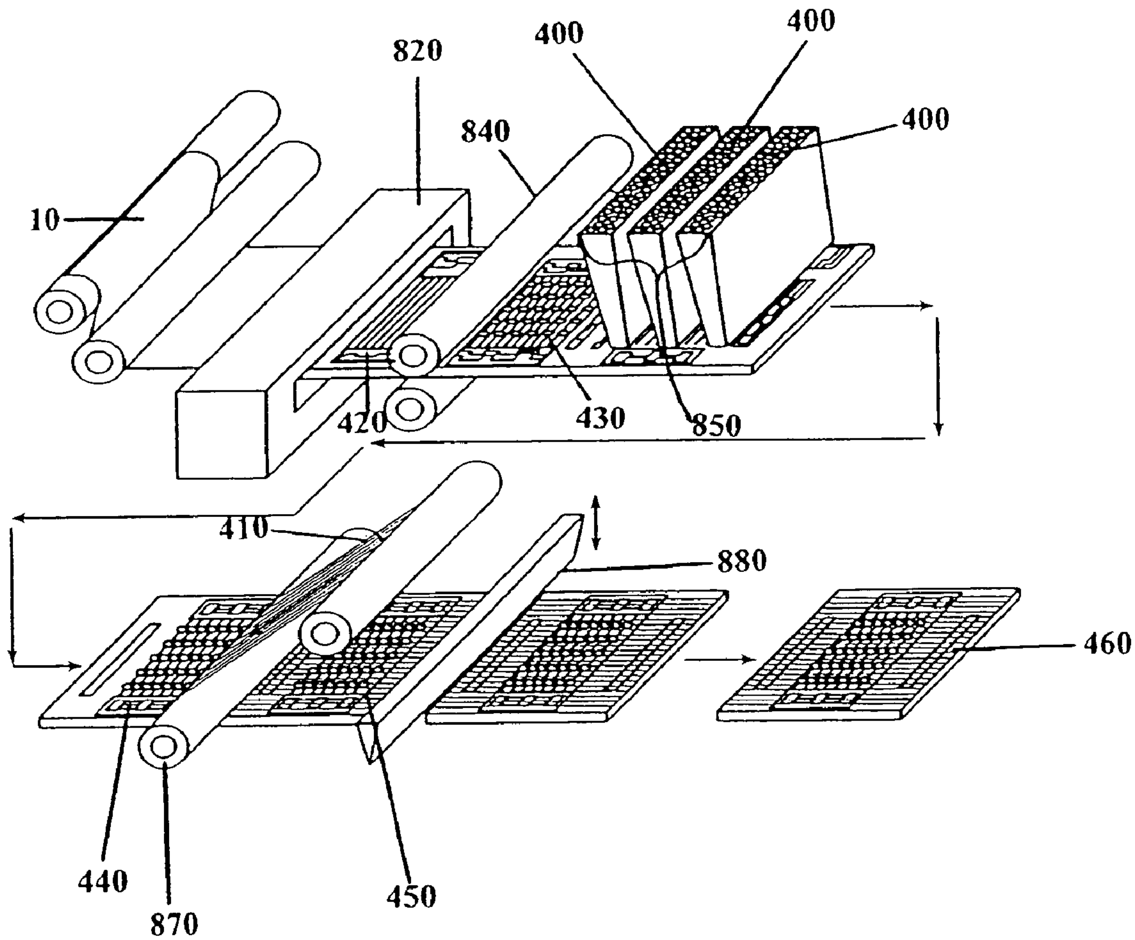
50
Gas-fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits &/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched between Substrates with Electrodes & Circuits
450
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Panel Dicing Process
880
Light-Emitting Panel
460

Fig. 12

Fig. 13



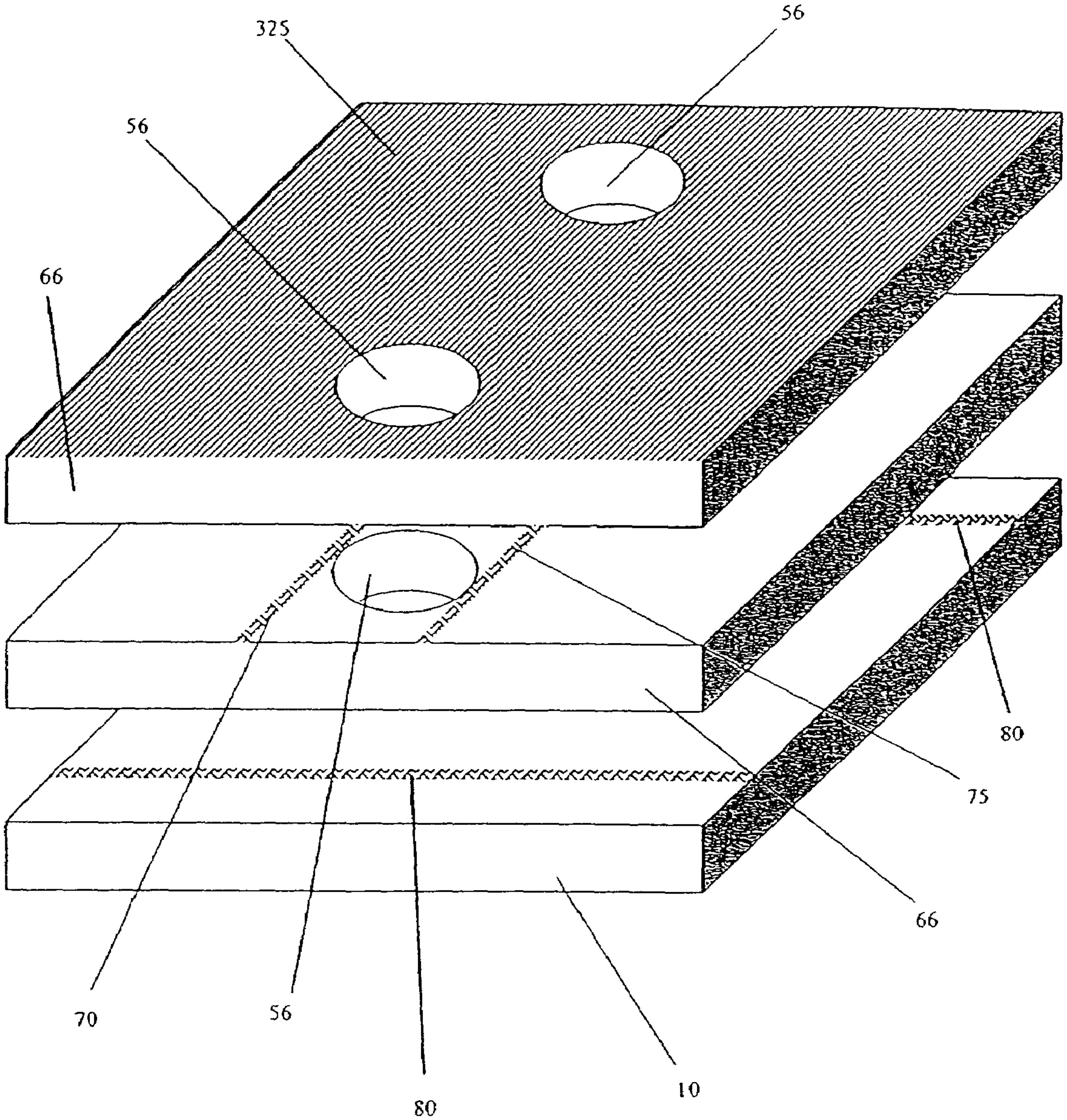
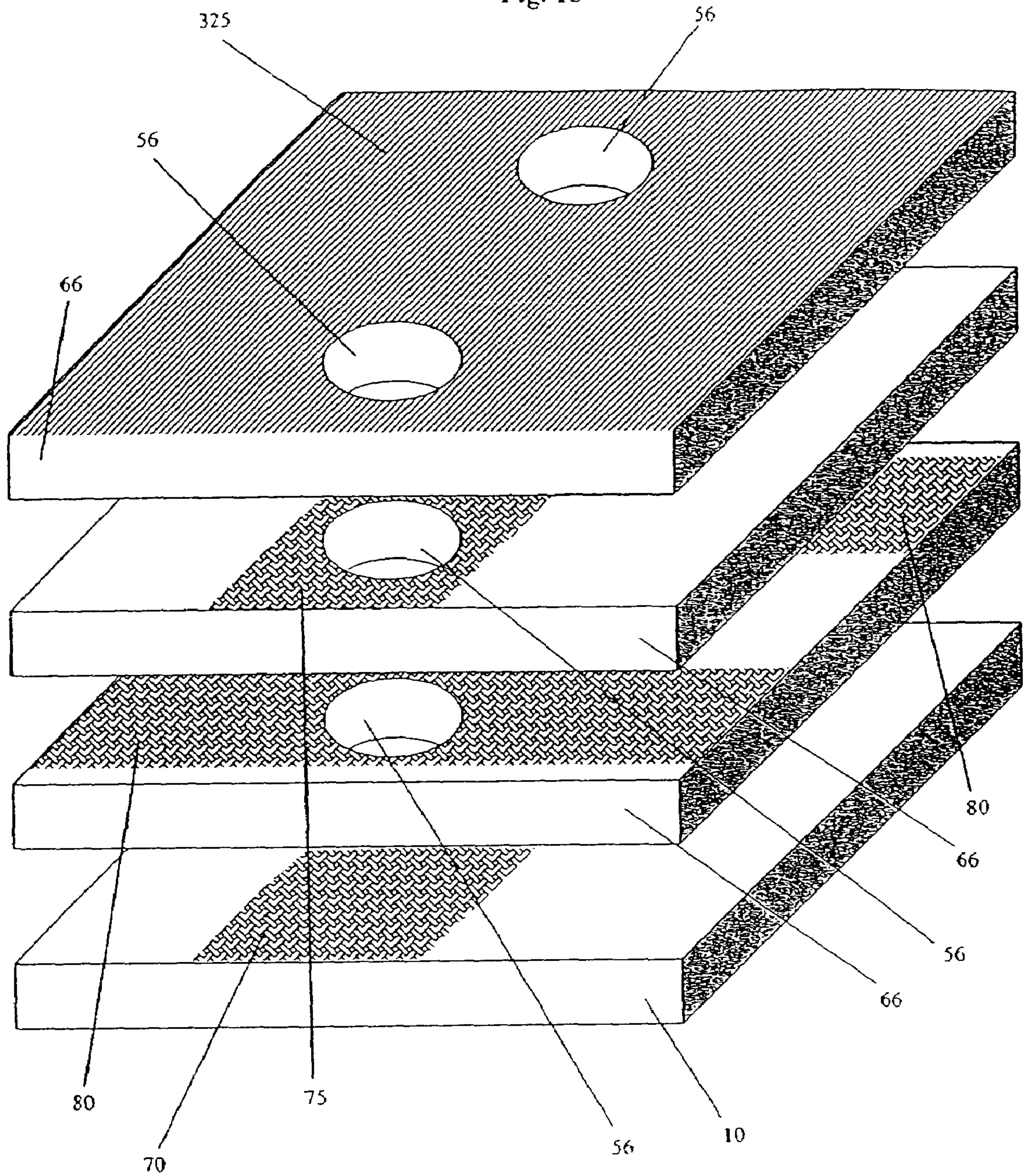



Fig. 14

Fig. 15



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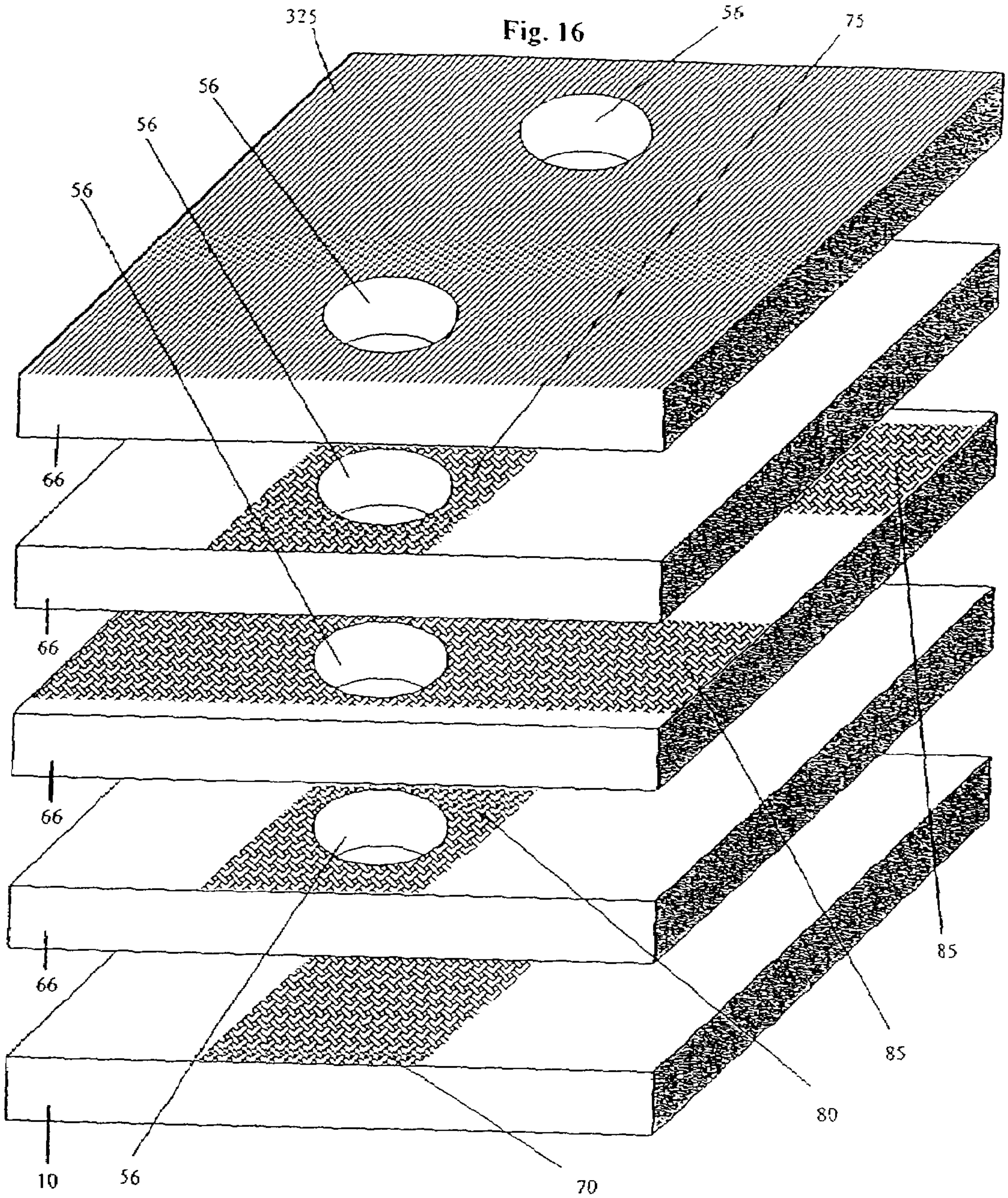


Fig. 17

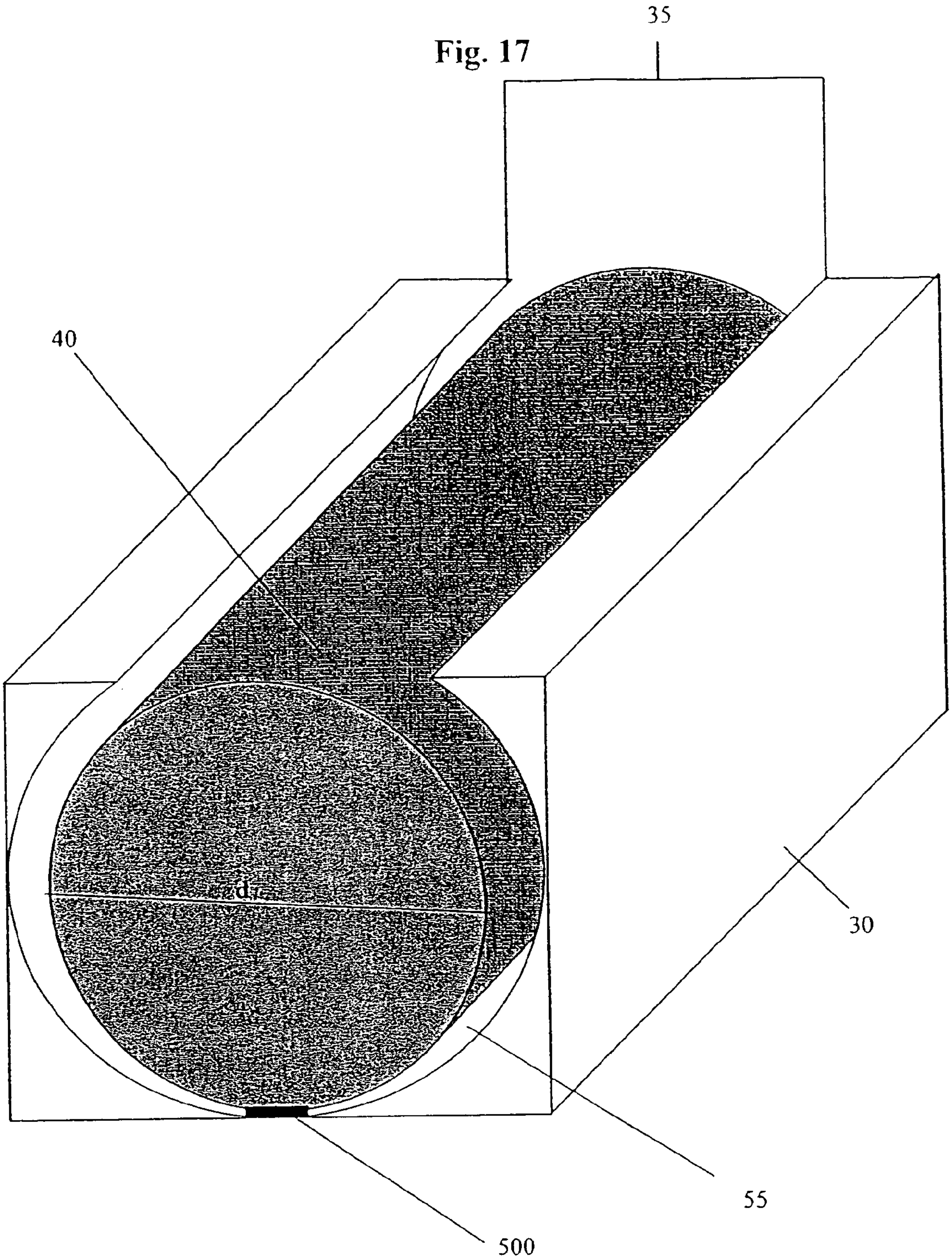


Fig. 18

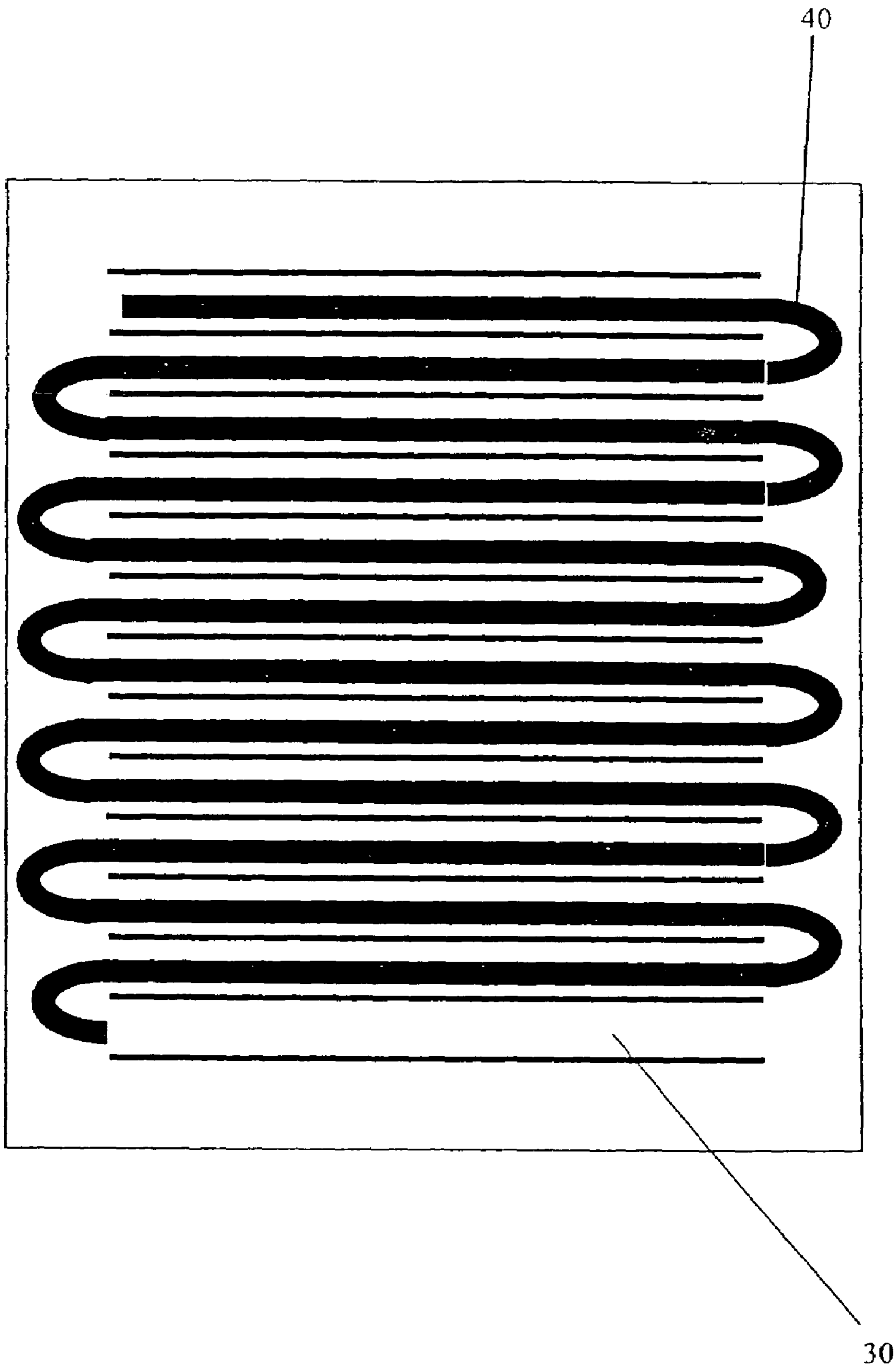
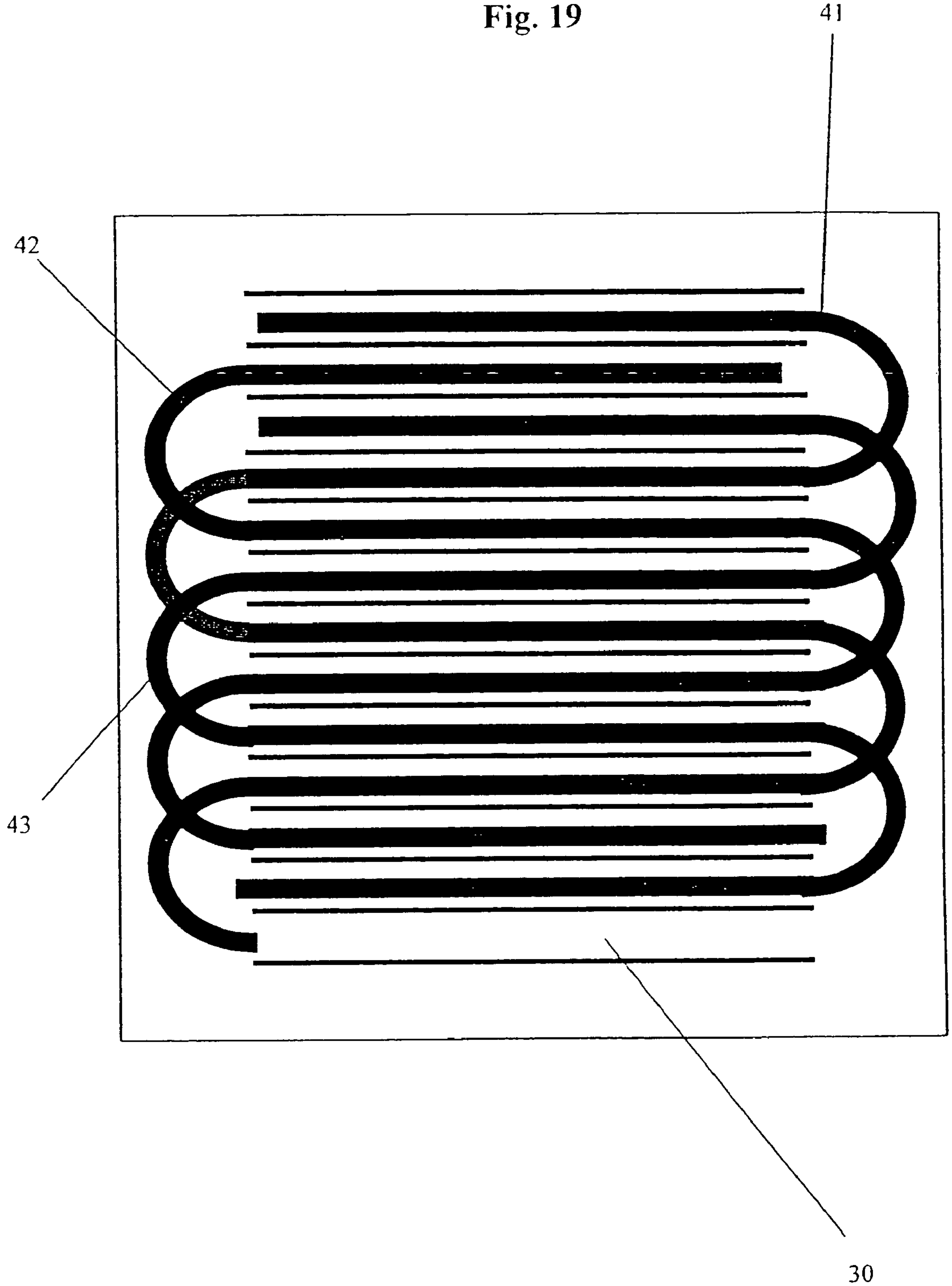


Fig. 19



# LIGHT-EMITTING PANEL AND A METHOD FOR MAKING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 09/697,344, now U.S. Pat. No. 6,612,889 entitled, "A Light-Emitting Panel and a Method for Making," filed Oct. 27, 2000. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000; and U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use in a Light-Emitting Panel filed Oct. 27, 2000.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.



Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is

particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In another embodiment of the present invention, at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, at least two electrodes are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In yet another embodiment, disposed in, or proximate to, each socket is at least one enhancement material.

Another preferred embodiment of the present invention is drawn to a web fabrication method for manufacturing light-emitting panels. In an embodiment, the web fabrication process includes providing a first substrate, disposing a plurality of micro-components on the first substrate, disposing a second substrate on the first substrate so the at the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrates to form individual light-emitting panels. In another embodiment, the web fabrication method includes the following process steps: a micro-component forming process; a micro-component coating process; a circuit and electrode printing process; a patterning process; a micro-component placement process; an electrode printing process; a second substrate application and alignment process; and a panel dicing process.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A**–**3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in

FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the fist substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17** and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A web fabrication process for manufacturing a plurality of light-emitting panels, the process comprising:

providing a first substrate;

disposing a plurality of micro-components on the first substrate, each micro-component emitting light when exposed to a triggering voltage;

disposing a second substrate on the first substrate such that the plurality of micro-components are disposed between the first substrate and the second substrate; and

dicing the first and second substrates to form the plurality of light-emitting panels.

**2**. The process of claim **1**, wherein providing the first substrate comprises pulling a web of the first substrate off of a roll.

**3**. The process of claim **1**, wherein further comprising forming a plurality of sockets in the first substrate.

**4**. The process of claim **1**, further comprising forming a plurality of sockets in the first substrate and wherein disposing the plurality of micro-components comprises disposing each micro-component at least partially within each socket.

**5**. The process of claim **4**, wherein providing the first substrate comprises forming the first substrate with a plurality of material layers and forming the plurality of sockets comprises selectively removing portions of the material layers to form a plurality of cavities.

**6**. The process of claim **4**, wherein forming the plurality of sockets comprises patterning the first substrate with a plurality of cavities.

**7**. The process of claim **6**, further comprising disposing a material layer on the first substrate so that the material layer conforms to a shape of each socket and disposing at least one electrode between the first substrate and the material layer.

**8**. The process of claim **6**, further comprising disposing a plurality of material layers on the first substrate so that the plurality of material layers conform to a shape of each socket and disposing at least one electrode within the plurality of material layers.

**9**. The process of claim **4**, wherein providing the first substrate comprises forming the first substrate by disposing a plurality of material layers and forming the plurality of sockets comprises selectively removing portions of the material layers to form a plurality of cavities.

**10**. The process of claim **9**, further comprising disposing an electrode on at least one of the first substrate and the second substrate.

**11**. The process of claim **10**, wherein the electrode is disposed between two material layers of the plurality of material layers.

**12**. The process of claim **1**, further comprising providing control electronics for the light-emitting panels.

**13**. The process of claim **1**, wherein providing the first substrate, disposing the plurality of micro-components, disposing the second substrate, and dicing the first and second substrates is performed as a continuous high-speed inline process.

**14**. The process of claim **1**, wherein providing the second substrate comprises pulling a web of the second substrate off of a roll.

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US007137857B2

# (12) United States Patent
George et al.

(10) Patent No.: **US 7,137,857 B2**

(45) Date of Patent: ***Nov. 21, 2006**

(54) **METHOD FOR MANUFACTURING A LIGHT-EMITTING PANEL**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **10/417,256**

(22) Filed: **Apr. 17, 2003**

(65) **Prior Publication Data**

US 2004/0004445 A1 Jan. 8, 2004

**Related U.S. Application Data**

(63) Continuation of application No. 09/697,345, filed on Oct. 27, 2000, now Pat. No. 6,570,335.

(51) **Int. Cl.**
***H01J 9/00*** (2006.01)

(52) **U.S. Cl.** .......................................... **445/24**; 445/62

(58) **Field of Classification Search** ............. 315/169.3, 315/169.4; 313/484–486, 501, 506, 581–582, 313/306–307; 445/24, 62
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 A | | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | | 2/1972 | Lay | 313/109.5 |
| 3,704,052 A | | 11/1972 | Coleman | 316/17 |
| 3,755,027 A | | 8/1973 | Gilsing | 156/67 |
| 3,789,471 A | * | 2/1974 | Spindt et al. | 445/52 |
| 3,848,248 A | | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 A | | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 A | | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 A | | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 A | | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 A | | 7/1977 | Roeber | 315/169 TV |
| 4,143,297 A | * | 3/1979 | Fischer | 313/502 |
| 4,233,623 A | * | 11/1980 | Pavliscak | 348/797 |
| 4,303,433 A | | 12/1981 | Torobin | 65/21.4 |
| 4,320,418 A | * | 3/1982 | Pavliscak | 348/797 |
| 4,379,301 A | | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 A | | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 A | | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 A | | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 A | | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 A | | 11/1985 | Dick | 340/775 |

(Continued)

FOREIGN PATENT DOCUMENTS

JP 4-287397 10/1992

(Continued)

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).

(Continued)

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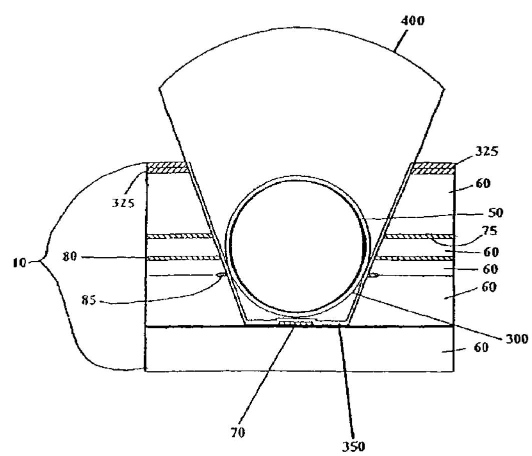
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two subtrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of energizing a micro-component is also disclosed.

**10 Claims, 18 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | 3/1990 | Hollo et al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Salavin et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 2001/0008825 | A1 | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| JP | 10-3869 | 1/1998 |
| WO | WO 00/36465 | 6/2000 |

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
Jacobson, et al., "The Last Book" [online] *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.
Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.
Franjione, et al., "The Art and Science of Microencapsulation" [online], *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
Sheats, James, "Introduction to Organic Light-Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.
Sauvante, Michael, "Roll-to-Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.
Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http:/www-star.stanford.edu/~vlf/plasma_display/index.htm.
Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21-25, 2001.
Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," *Journal of Microelectromechanical Systems*, vol. 10, No. 1, Mar. 2001, pp. 17-24.
"Runco Plasma Wall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.
"Runco Plasma Wall PL-42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.
"Runco Plasma Wall Pl-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.
"Runco Plasma Wall™ PL-61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.
"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.
"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.
"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.
"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.
"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read/asp?nSeqno21.
"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.
"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001[retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay,com/eng/news/e_read.asp?nSeqNo=16&type=&word=.
"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.
"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.
Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.
"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.
Alien Technology Corporation's Technology Overview; Copyright © 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.
Anonymous, "Alien Technology Corporation White Paper—Fluidic Self Assembly", Alien Technology Corp., Oct. 1999, pp. 1-7.
Kurihara, M. Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372-1378.
Raulf, S., Kushner, M.J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10-11.
Shin, Y.K., Lee, J.K., Shon, C.H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 14-15.
"Transparent Conductive Coatings," Copyright 1998, 4 pp.
Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep. 1997, pp. 1241-.
Stearns, Thomas H., "Flexible Printed Circuity," 6 pp., 1996.
"Flat Panel Displays in Perspective," 44 pp., Sep. 1995.
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

* cited by examiner

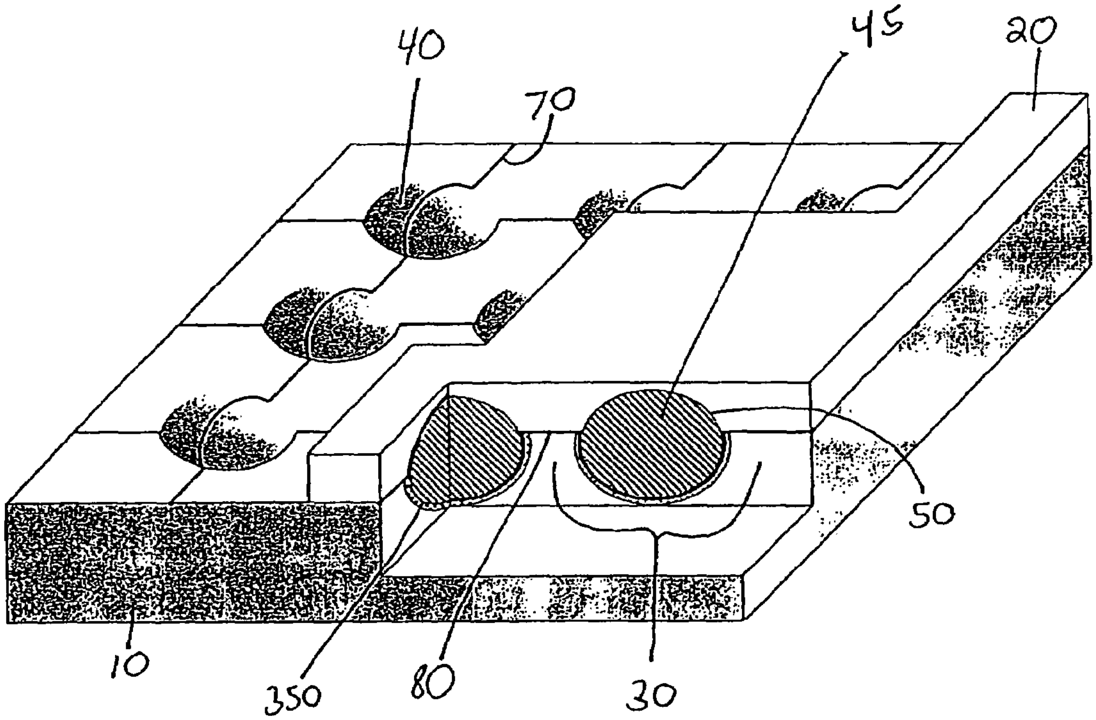



Fig. 1

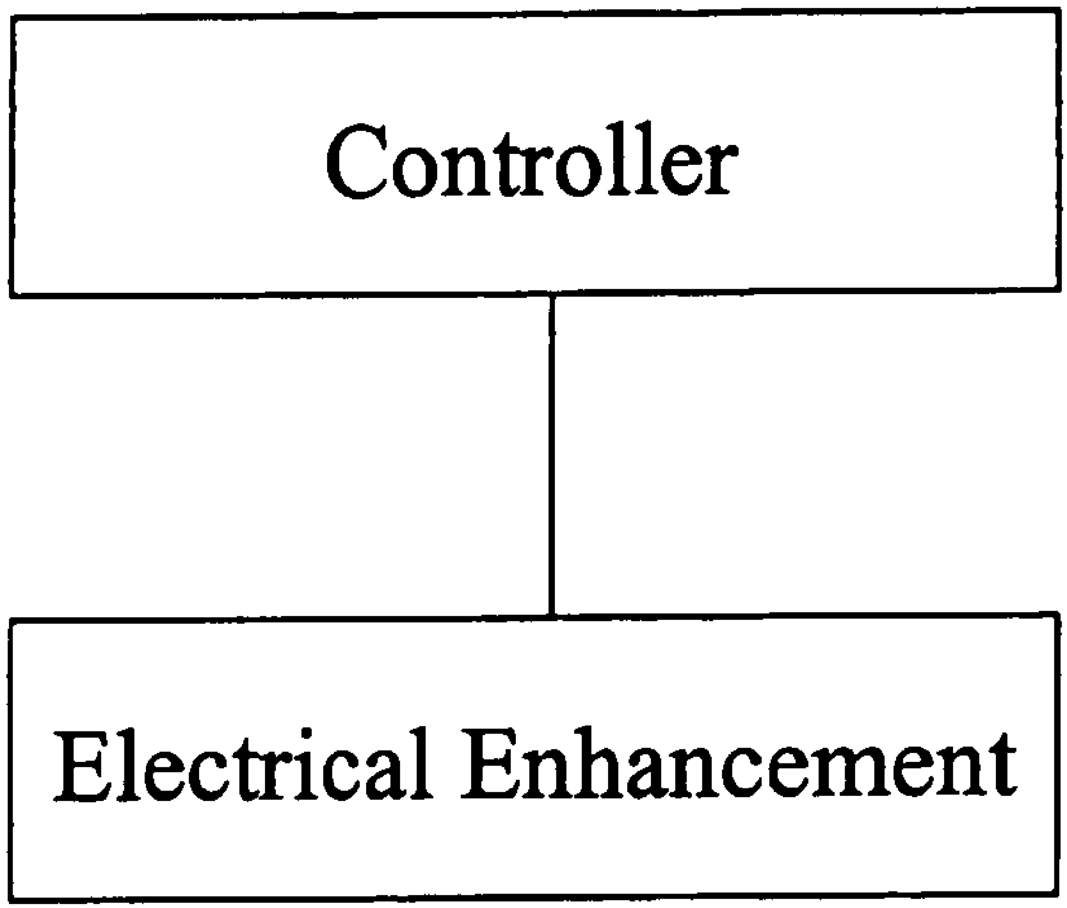



FIG. 1A

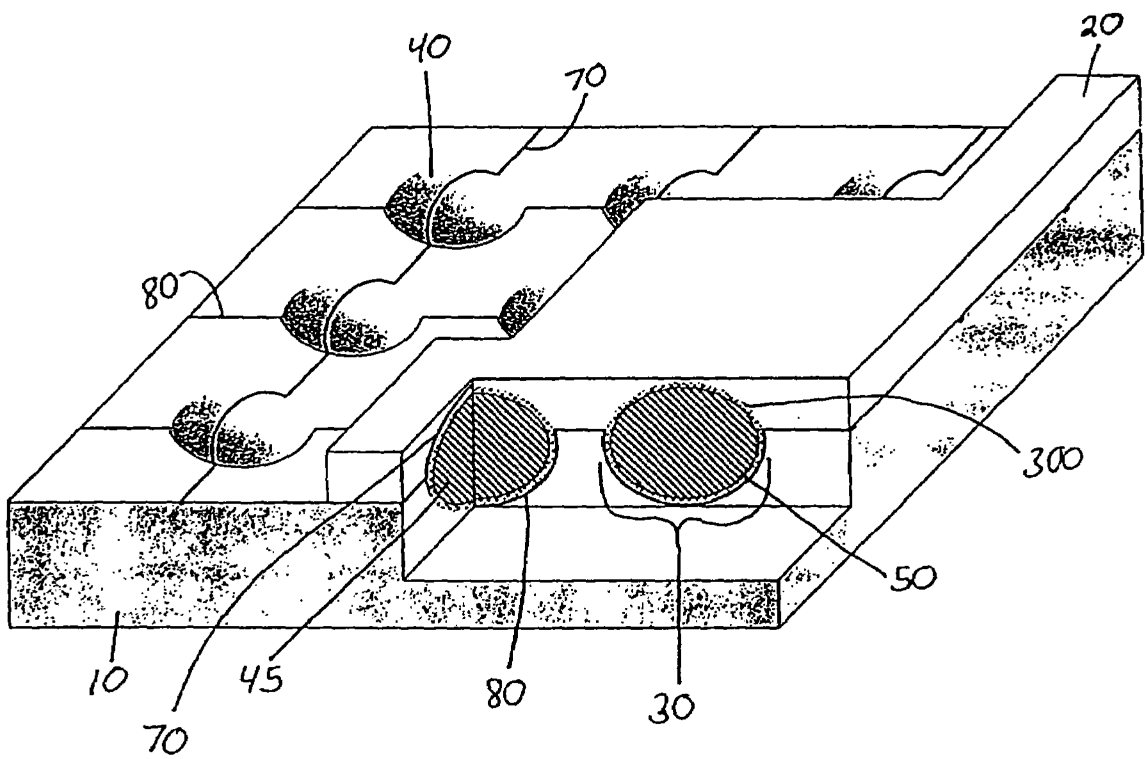



Fig. 2

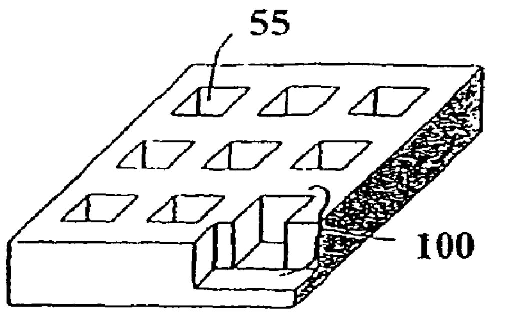



Fig. 3A

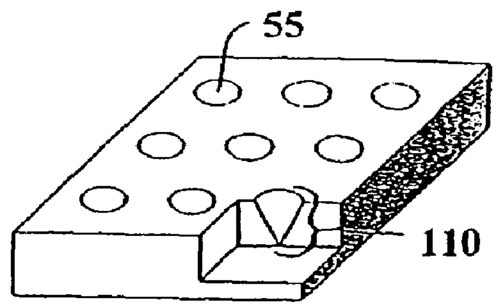



Fig. 3B

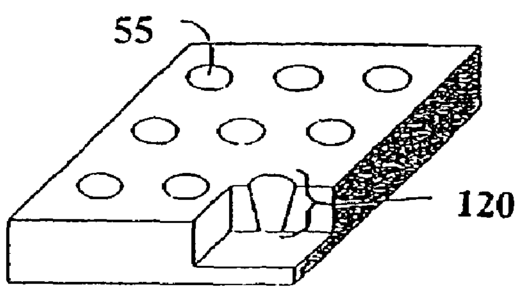



Fig. 3C

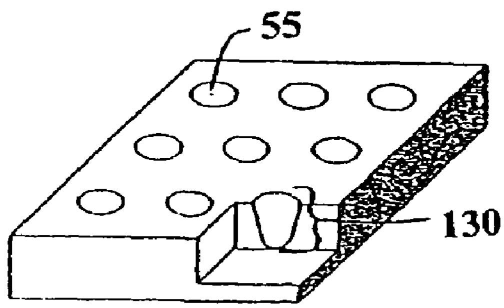



Fig. 3D

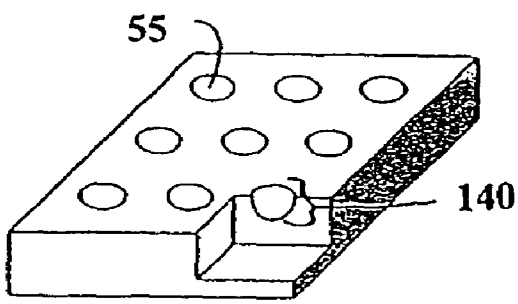



Fig. 3E

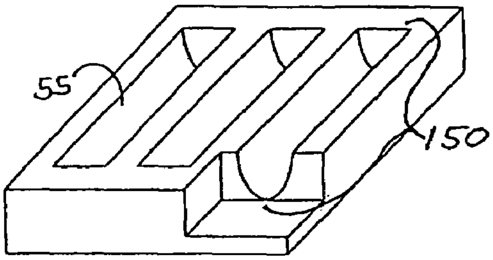



Fig. 3F

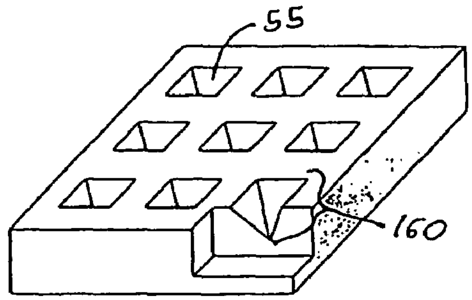



Fig. 3G

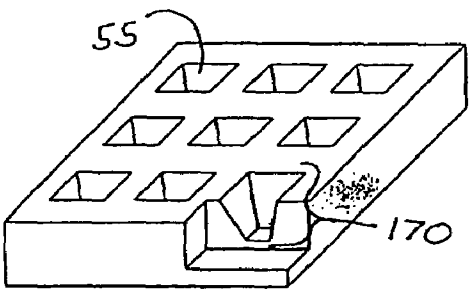



Fig. 3H

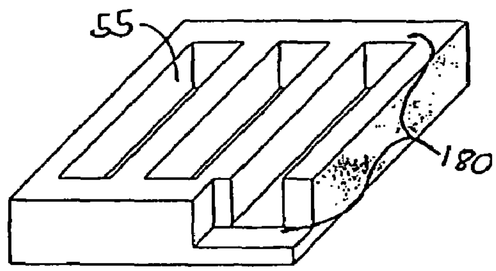



Fig. 3I

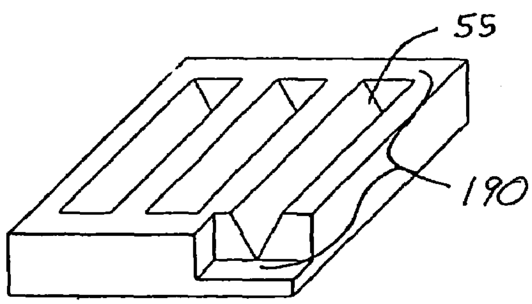
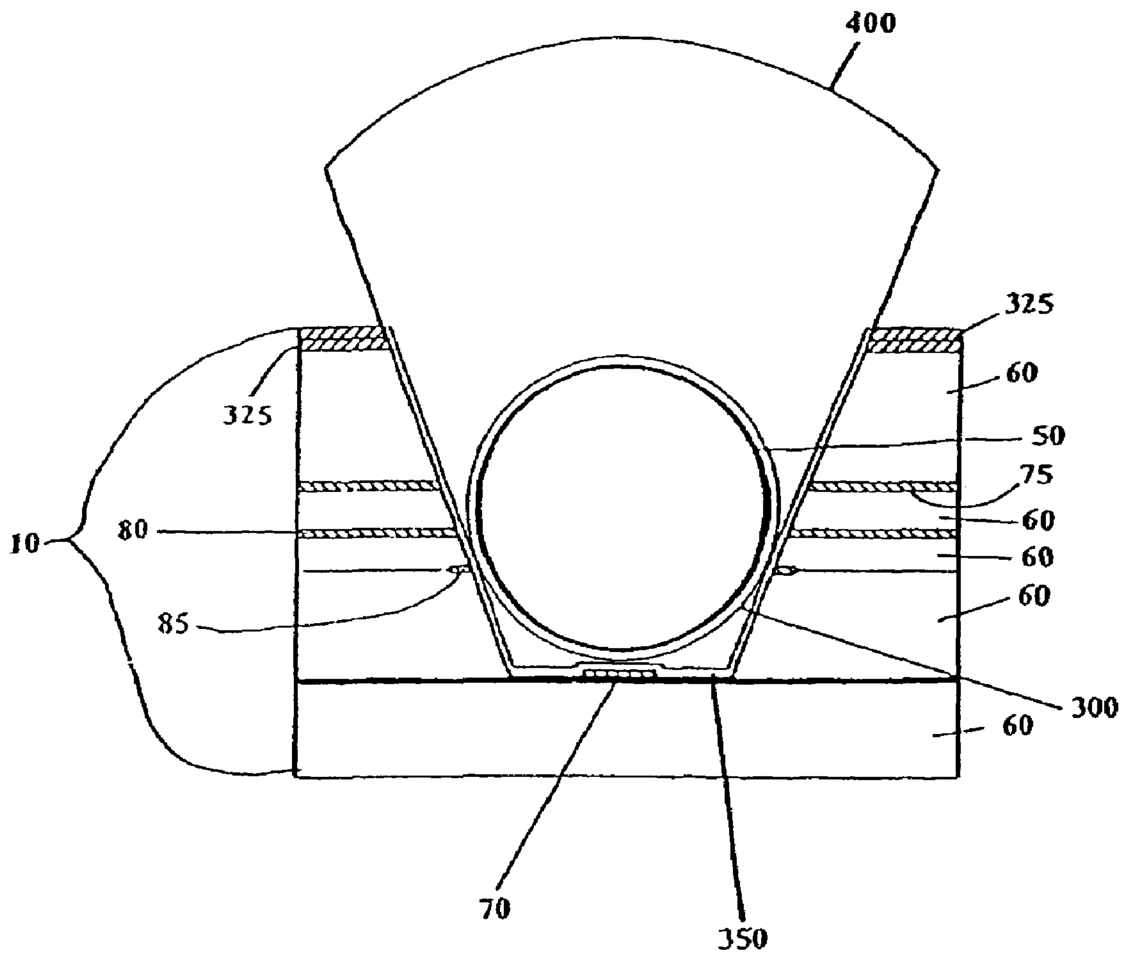



Fig. 3J

Fig. 4



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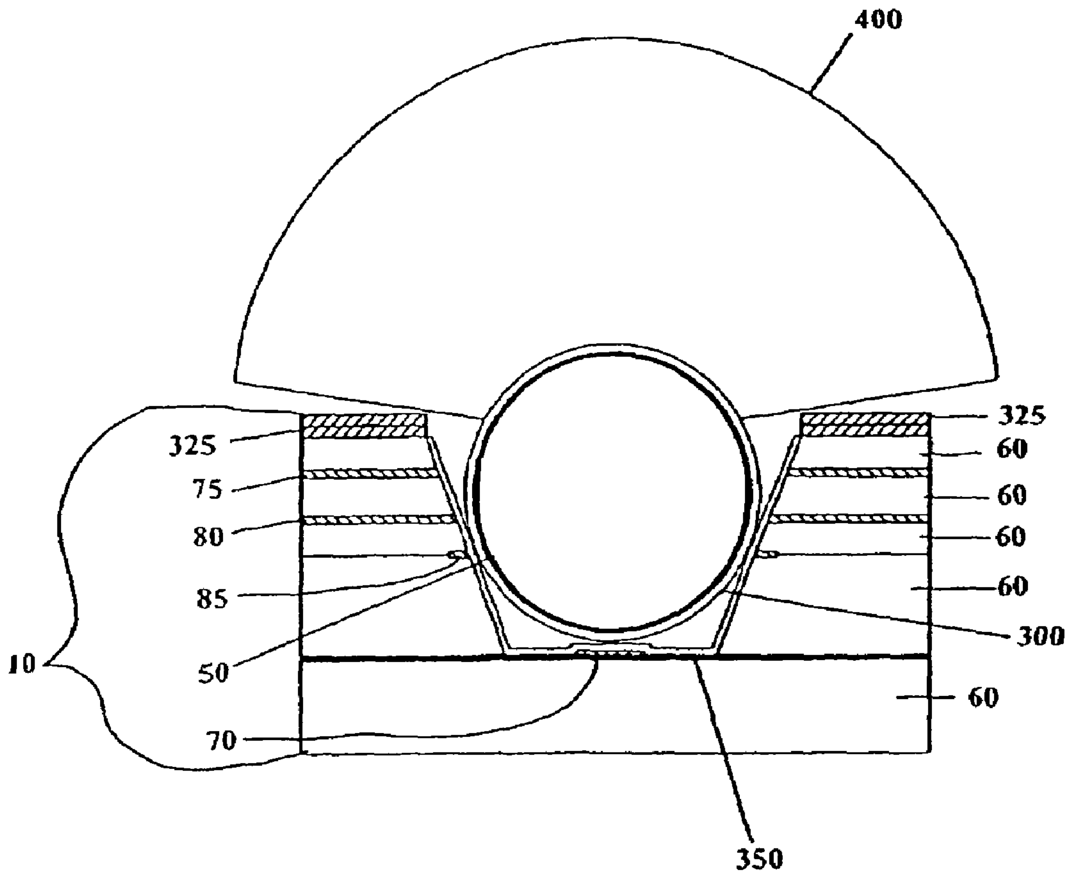


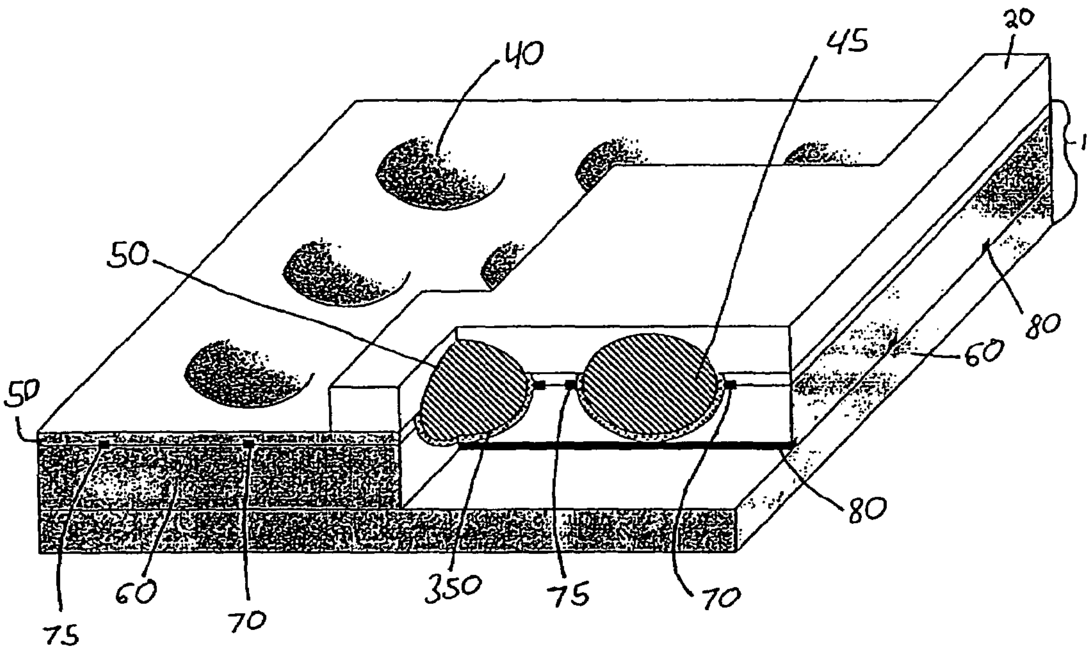



Fig. 6A

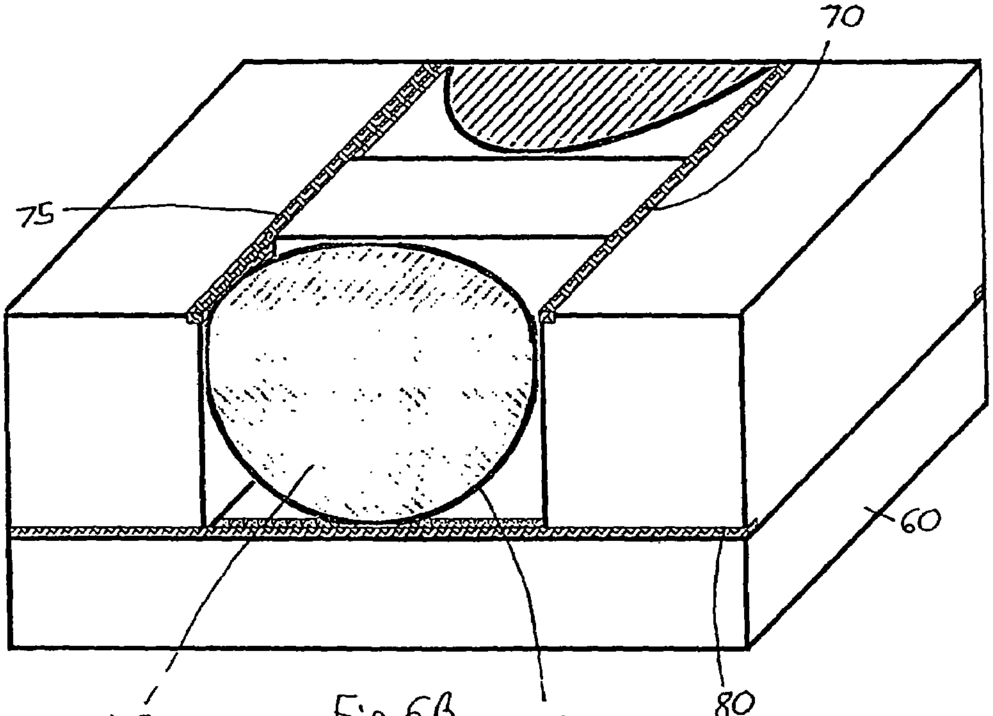



Fig 6B

Fig. 7A

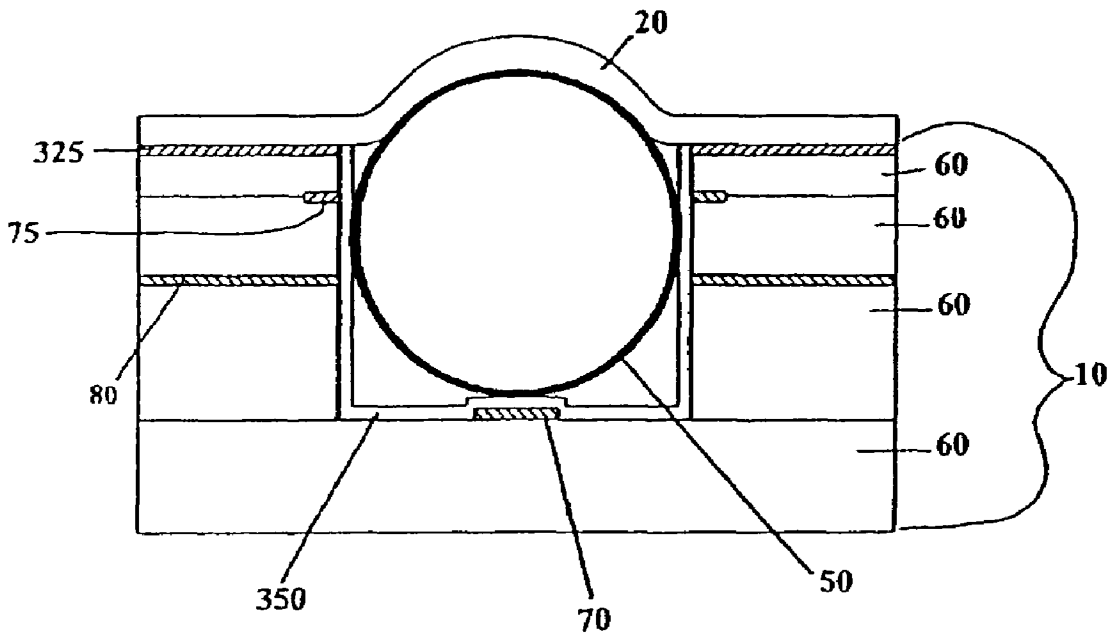
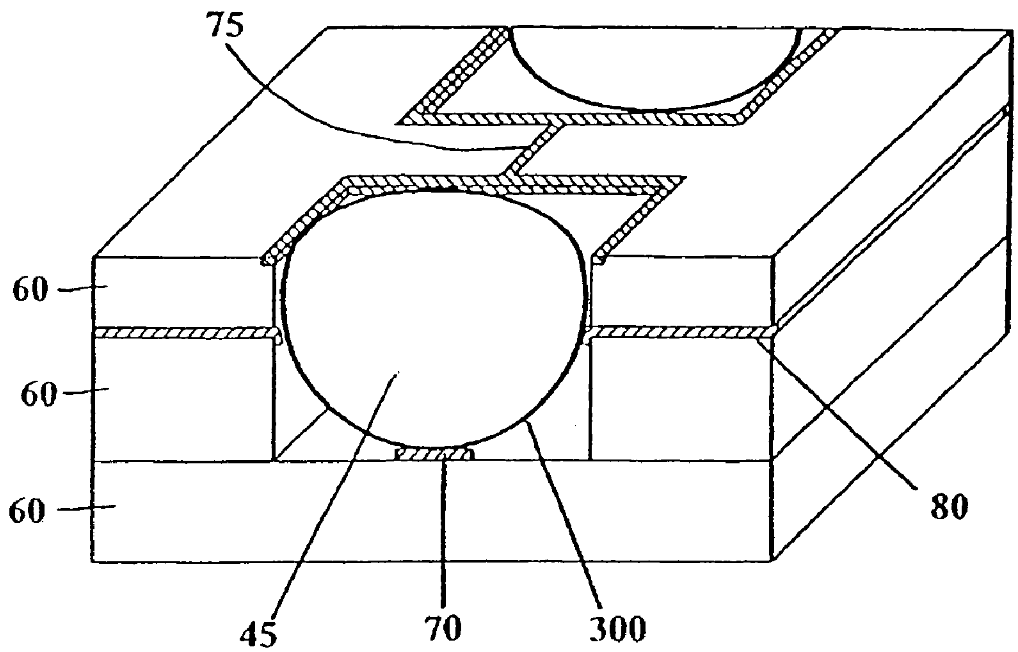


Fig. 7B



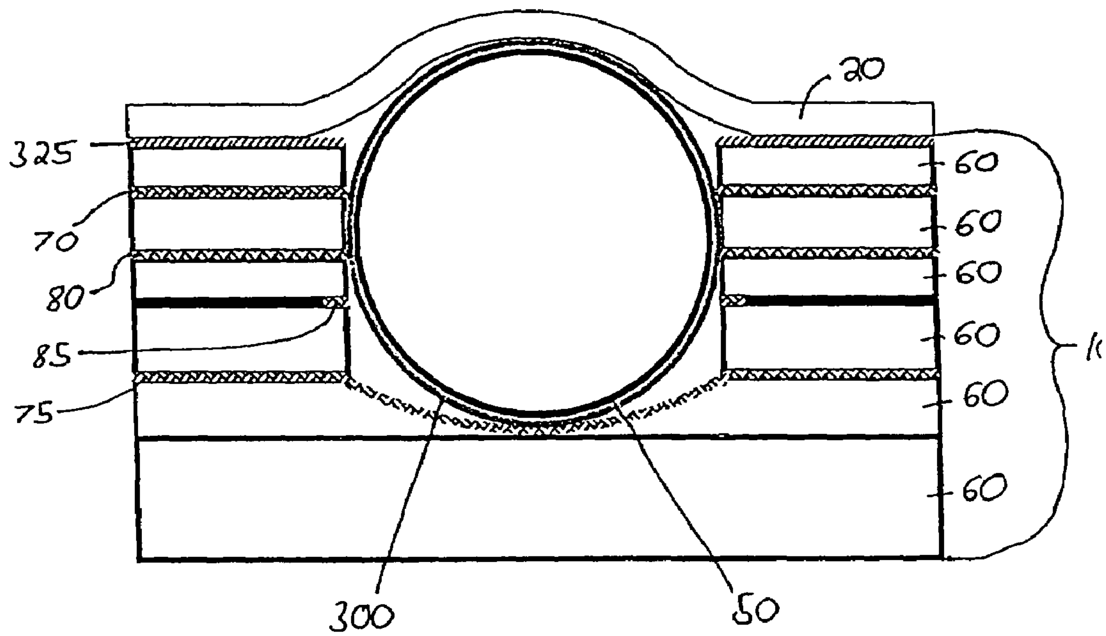



Fig. 8

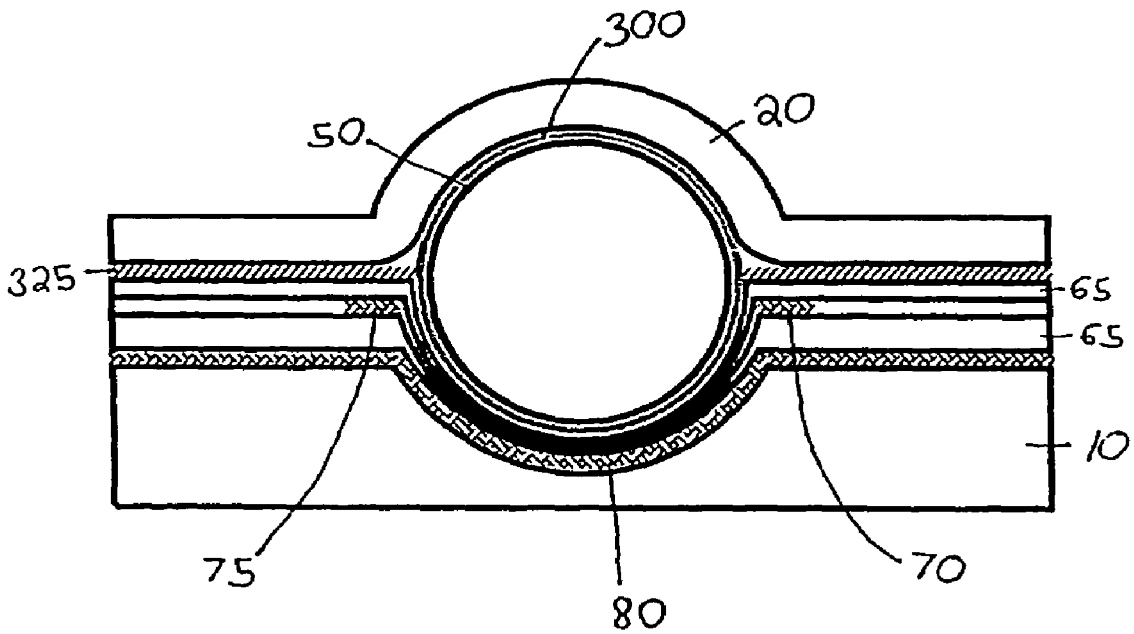



Fig. 9

Fig. 10

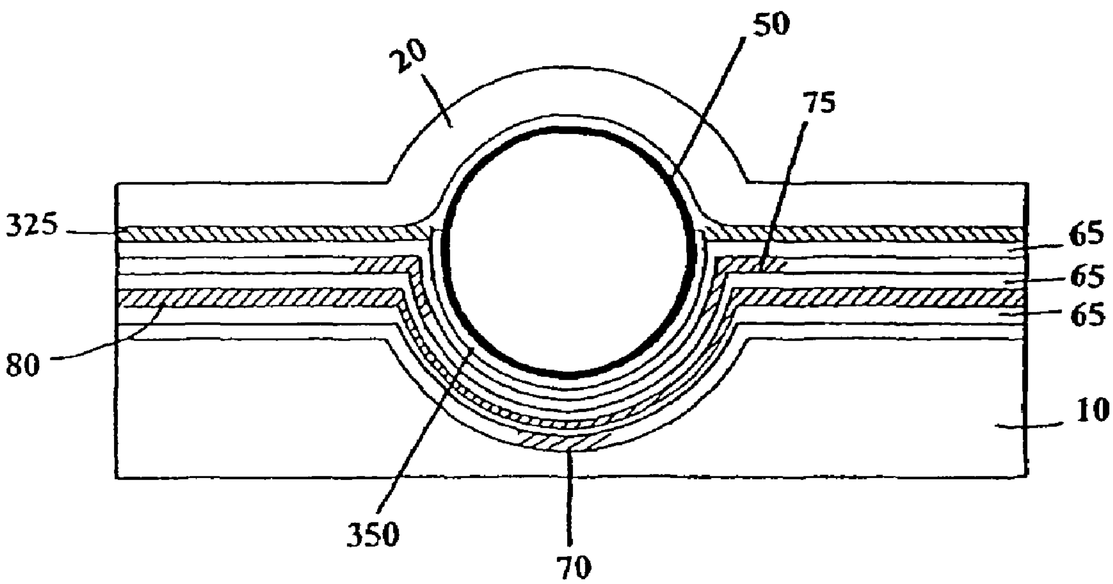
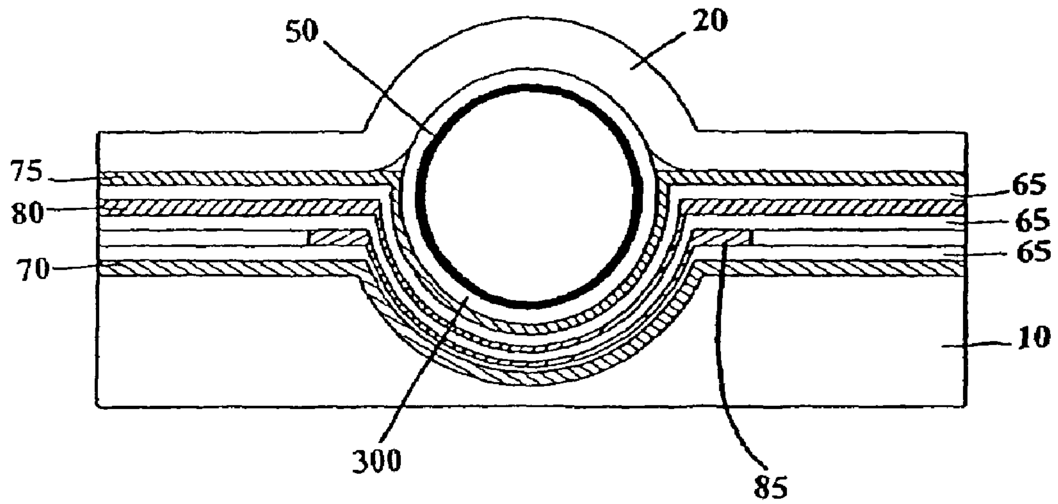


Fig. 11



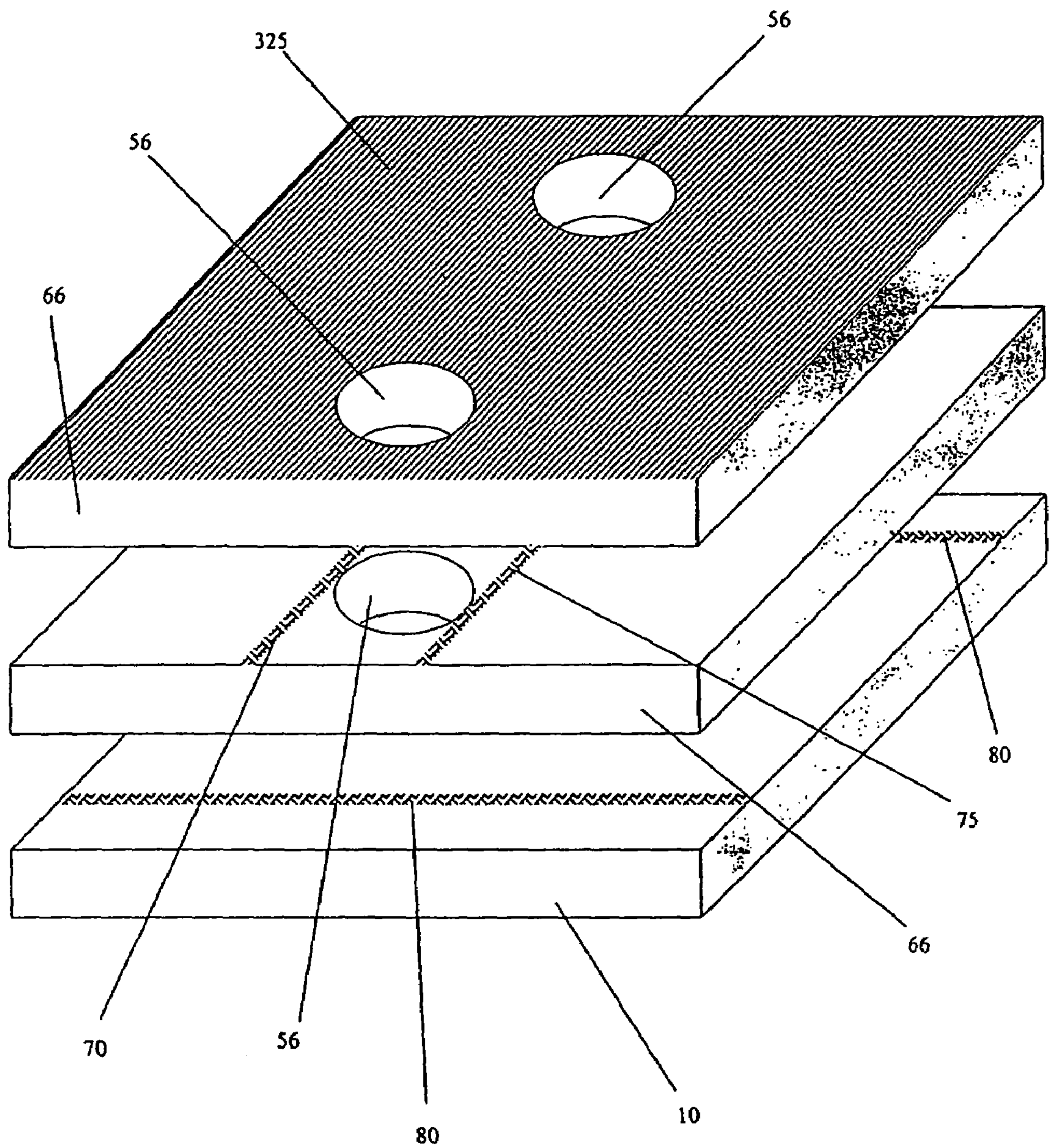



Fig. 12

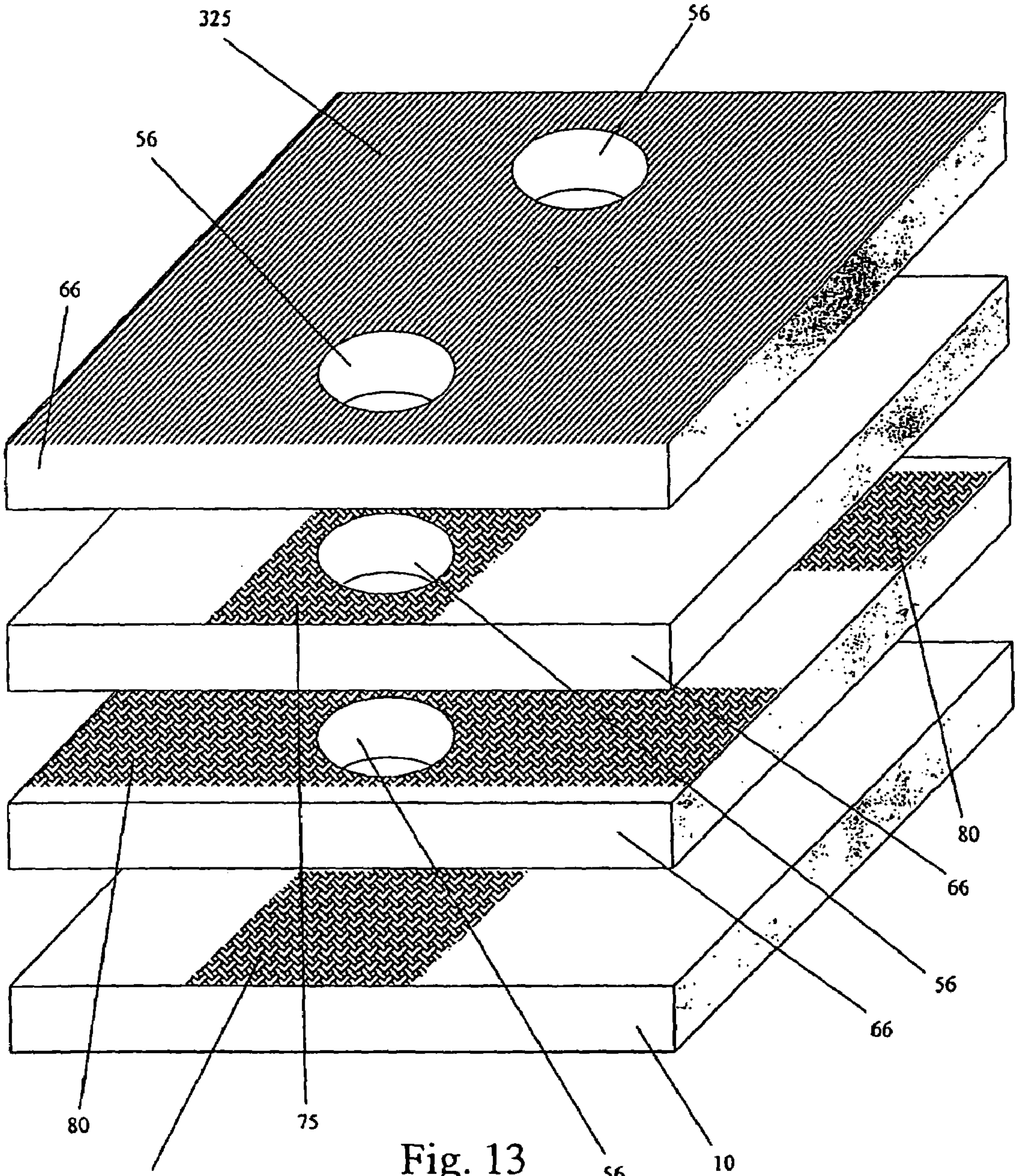



Fig. 13

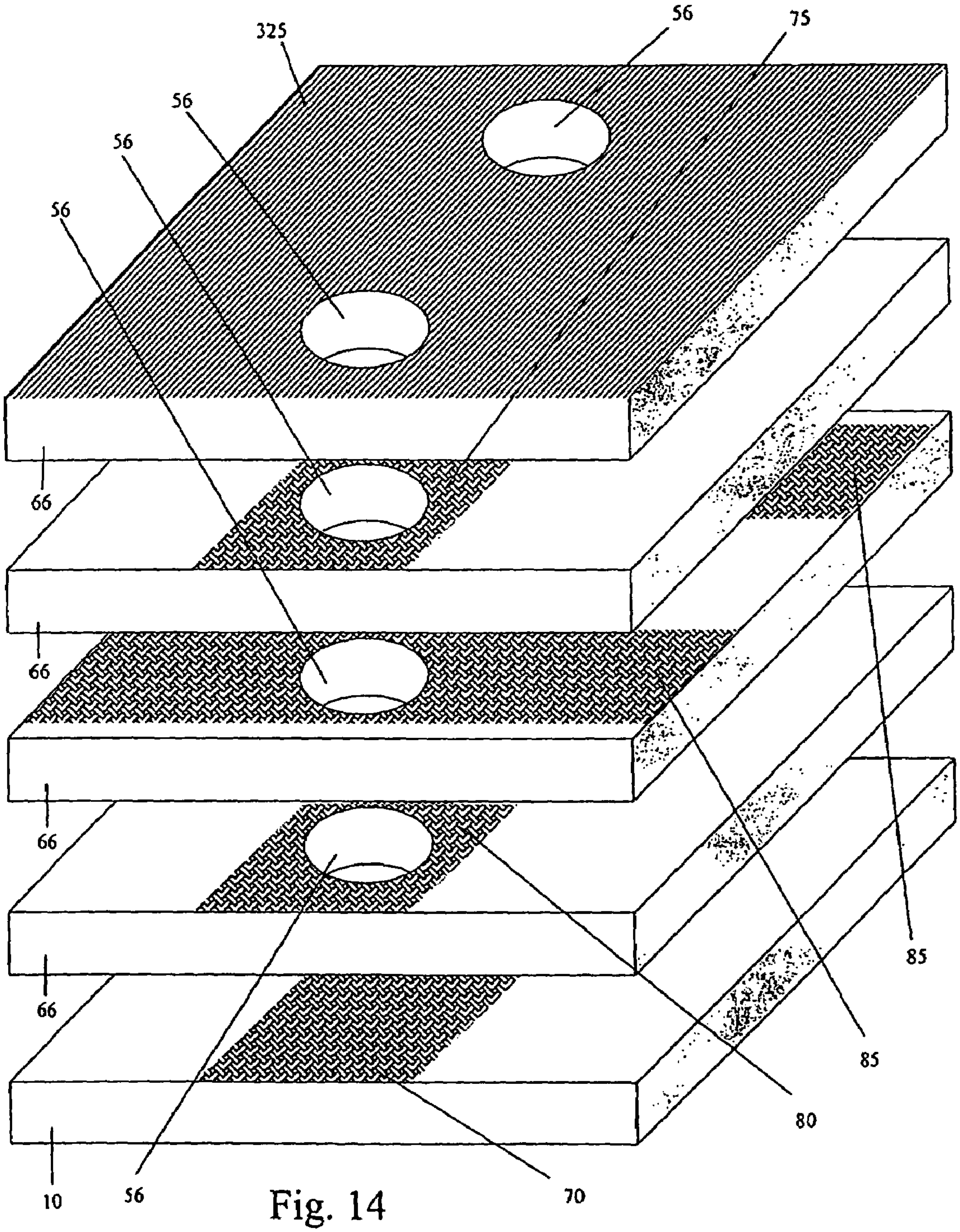



Fig. 14

# METHOD FOR MANUFACTURING A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

The current application is a continuation application of U.S. application Ser. No. 09/697,345, filed Oct. 27, 2000 and titled A Method and System for Energizing a Micro-Component in a Light-Emitting Panel, now U.S. Pat. No. 6,570, 335. The following applications filed on the same date as the present application are herein incorporated by reference: U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use with a Micro-Component in a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,545,422; U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,762,566; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000, now U.S. Pat. No. 6,620,012; and U.S. patent application Ser. No. 09/697,344 entitled A Light-Emitting Panel and a Method of Making filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to a light-emitting panel and methods of fabricating the same. The present invention further relates to a method and system for energizing micro-components in a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In an embodiment of the present invention, the plurality of sockets include a cavity that is patterned in the first substrate and at least two electrodes adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, the plurality of sockets include a cavity that is patterned in the first substrate and at least two electrodes that are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In another embodiment, a first substrate comprises a plurality of material layers and a socket is formed by selectively removing a portion of the plurality of material layers to form a cavity and disposing at least one electrode on or within the material layers.

In another embodiment, a socket includes a cavity patterned in a first substrate, a plurality of material layers disposed on the first substrate so that the plurality of material layers conform to the shape of the socket and at least one electrode disposed within the material layers.

In another embodiment, a plurality of material layers, each including an aperture, are disposed on a substrate. In this embodiment, the material layers are disposed so that the apertures are aligned, thereby forming a cavity.

Other embodiments are directed to methods for energizing a micro-component in a light-emitting display using the socket configurations described above with voltage provided to at least two electrodes causing at least one micro-component at least partially disposed in the cavity of a socket to emit radiation.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings, wherein:

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **1**A depicts a controller connected to an electrical enhancement according to an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.



FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **13** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be disposed on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3A–3J**, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket.

In an embodiment for a light-emitting panel, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a light-emitting panel, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either on or within the material layers, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a light-emitting panel, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, antiglare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasmaforming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. The electrodes may be disposed in the light-emitting panel using any technique known to one skilled in the art including, but not limited to, any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** each include a cavity patterned in the first substrate **10**, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In an embodiment for a method of energizing a micro-component, the electrodes may be disposed either before the cavity is formed or after the cavity is formed. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration and the address function will be performed between at least one of the sustain electrodes and the address electrode. It is believed that energizing a micro-component with this arrangement of electrodes will produce increased luminosity. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing function from the sustain electrodes. It is believed that this arrangement will provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. It is also believed that by separating the sustain and address electrodes so different voltage sources may be used to provide the address and sustain functions, a lower or different type of voltage source may be used to provide the address or sustain functions.

In an embodiment where a cavity **55** is patterned in the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In an embodiment for a method of energizing a micro-component, electrodes formed on the first substrate may be disposed either before the cavity was patterned or after the cavity was patterned. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration and the address function will be performed between at least one of the sustain electrodes and the address electrode. It is believed that energizing a micro-component with this arrangement of electrodes will produce increased luminosity. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing function from the sustain electrodes. It is believed that this arrangement will provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. It is also believed that by separating the sustain and address electrodes so different voltage sources may be used to provide the address and sustain functions a lower or different type of voltage source may be used to provide the address or sustain functions.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **12**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **13**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. In this mid-plane configuration, the sustain function will be performed by the two sustain electrodes much like in the co-planar configuration and the address function will be performed between at least one of the sustain electrodes and the address electrode. It is believed that energizing a micro-component with this arrangement of electrodes will produce increased luminosity. As seen in FIG. **14**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode. This configuration completely separates the addressing function from the sustain electrodes. It is believed that this arrangement will provide a simpler and cheaper means of addressing, sustain and erasing, because complicated switching means will not be required since different voltage sources may be used for the sustain and address electrodes. It is also believed that by separating the sustain and address electrodes so different voltage sources may be used to provide the address and sustain functions a lower or different type of voltage source may be used to provide the address or sustain functions.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A method for manufacturing a light-emitting panel, comprising:

providing a substrate;

forming a plurality of sockets within the substrate;

placing a micro-component within each of the sockets, each micro-component emitting radiation where a trigger voltage is applied across the micro-component;

forming two electrodes for each of the micro-components; and

disposing an electrical enhancement on the substrate, the electrical enhancement for altering an electrical characteristic of the micro-components.

**2**. The method of claim **1**, wherein disposing the electrical enhancement comprises providing the electrical enhancement for lowering an address voltage necessary to ionize a plasma-forming gas within the micro-components.

**3**. The method of claim **1**, wherein disposing the electrical enhancement comprises providing the electrical enhancement for lowering a sustain voltage necessary to sustain an ionization charge in the micro-components.

**4**. The method of claim **1**, wherein disposing the electrical enhancement comprises providing the electrical enhancement for increasing a luminosity transport efficiency of the micro-components.

**5**. The method of claim **1**, wherein disposing the electrical enhancement comprises providing the electrical enhancement for increasing a radiation transport efficiency of the micro-components.

**6**. The method of claim **1**, wherein disposing the electrical enhancement comprises providing the electrical enhancement for augmenting an energizing frequency of the micro-components.

**7**. The method of claim **1**, wherein disposing the electrical enhancement comprises providing the electrical enhancement for altering power requirements necessary to energize the micro-components.

**8**. The method of claim **1**, further comprising individually controlling the electrical enhancement for each of the micro-components.

**9**. The method of claim **8**, wherein individually controlling comprises controlling a luminosity of each of the micro-components.

**10**. The method of claim **8**, wherein individually controlling comprises controlling a frequency at which the micro-components emit radiation.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 7,137,857 B2
APPLICATION NO. : 10/417256
DATED : November 21, 2006
INVENTOR(S) : Edward Victor George et al.



It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE CLAIMS -

In Column 14, line 4, please change “each micro-component emitting radiation where a trig-” to -- each micro-component emitting radiation when a trig- --

IN THE DRAWINGS:

Please replace Fig. 6A with the following figure (some of the reference numbers were cut off when figure was included in the issued patent):

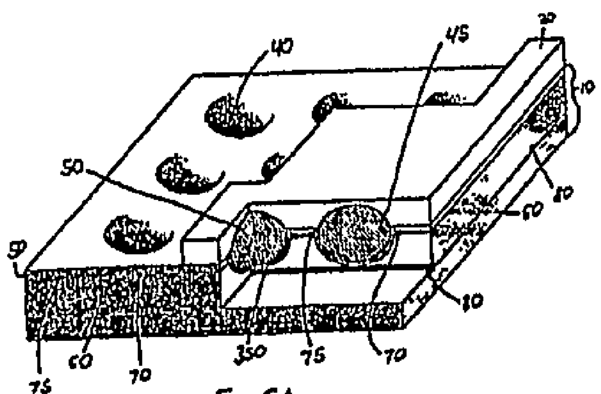



Fig. 6A

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 7,137,857 B2 Page 2 of 2
APPLICATION NO. : 10/417256
DATED : November 21, 2006
INVENTOR(S) : Edward Victor George et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

IN THE DRAWINGS:

Please replace Fig. 6B and Fig. 8 with the following figures (some of the reference numbers were cut off when figure was included in the issued patent):

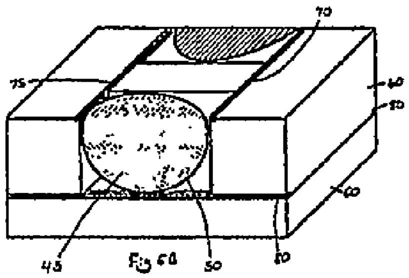



Fig 6B

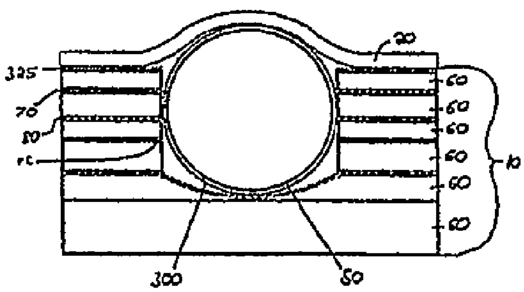



Fig. 8

Signed and Sealed this

Third Day of July, 2007

Jon W. Dudas

JON W. DUDAS

*Director of the United States Patent and Trademark Office*

US007236151B2

(12) **United States Patent**
**Doane et al.**

(10) **Patent No.: US 7,236,151 B2**
(45) **Date of Patent: Jun. 26, 2007**

(54) **LIQUID CRYSTAL DISPLAY**

(75) Inventors: **J. William Doane**, Kent, OH (US); **Asad A. Khan**, Kent, OH (US); **Irina Shiyanovskaya**, Stow, OH (US); **Albert Green**, Springfield, VA (US)

(73) Assignee: **Kent Displays Incorporated**, Kent, OH (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/006,100**

(22) Filed: **Dec. 7, 2004**

(65) **Prior Publication Data**

US 2005/0162606 A1 Jul. 28, 2005

**Related U.S. Application Data**

(60) Provisional application No. 60/565,586, filed on Apr. 27, 2004, provisional application No. 60/539,873, filed on Jan. 28, 2004.

(51) **Int. Cl.**
***G09G 3/36*** (2006.01)

(52) **U.S. Cl.** ........................................ **345/87**; 345/107

(58) **Field of Classification Search** .......... 345/87–100, 345/105, 107, 204; 349/113, 114, 115, 125, 349/127, 132, 137, 147; 348/790, 791, 792, 348/793, 794

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| 3,600,060 | A | 8/1971 | Churchill |
| 3,680,950 | A | 8/1972 | Haas et al. |
| 4,362,903 | A | 12/1982 | Eichelberger et al. |
| 4,510,188 | A | 4/1985 | Ruggeri |
| 4,642,250 | A | 2/1987 | Spector |
| 4,684,771 | A | 8/1987 | Wuthrich |
| 4,688,900 | A | 8/1987 | Doane et al. |
| 4,747,413 | A | 5/1988 | Bloch |
| 4,890,902 | A | 1/1990 | Doane et al. |
| 4,896,946 | A | 1/1990 | Suzuki et al. |
| 4,948,232 | A | 8/1990 | Lange |
| 5,007,872 | A | 4/1991 | Tang |
| 5,061,553 | A | 10/1991 | Olsen, Jr. |
| 5,161,479 | A | 11/1992 | Mahr |
| 5,172,108 | A | 12/1992 | Wakabayashi et al. |
| 5,200,845 | A | 4/1993 | Crooker et al. |
| 5,360,503 | A | 11/1994 | Coffy |

(Continued)

FOREIGN PATENT DOCUMENTS

WO 2005/072447 8/2005

(Continued)

OTHER PUBLICATIONS

*Reflective display with photoconductive layer and abistable reflective cholesteric mixture*, Hidefumi Yoshida et al., Journal SID 5/3, 1997, pp. 269-274.

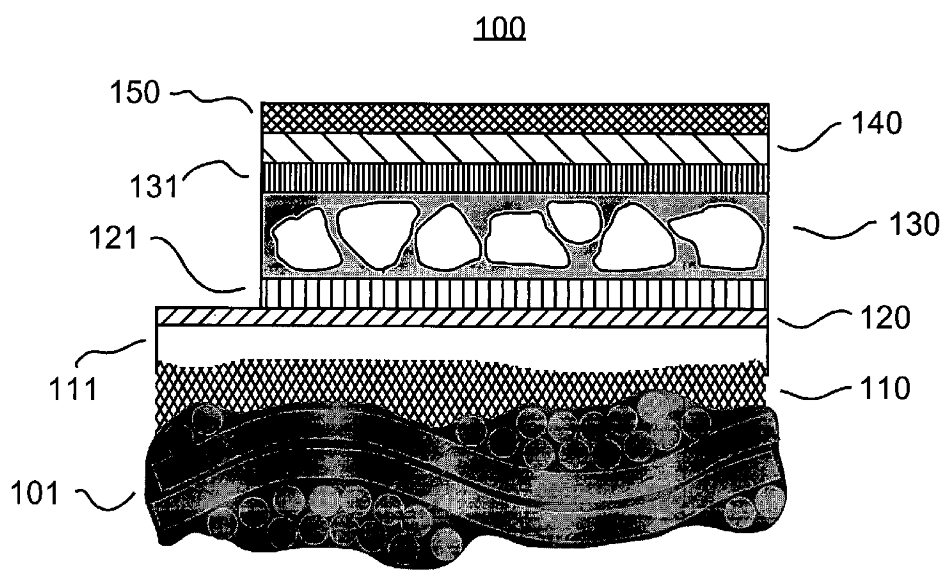
(Continued)

*Primary Examiner*—Nitin Patel
(74) *Attorney, Agent, or Firm*—Pearne & Gordon LLP

(57) **ABSTRACT**

A flexible liquid crystal display is provided wherein an addressable liquid crystal layer is disposed on a single flexible substrate so that the display itself will exhibit flexibility. The substrate is preferably a flexible non-transparent material and more preferably a drapable material such as fabric.

**81 Claims, 10 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 5,376,699 | A | 12/1994 | Sage | |
| 5,437,811 | A | 8/1995 | Doane et al. | |
| 5,453,863 | A | 9/1995 | West et al. | |
| 5,493,430 | A | 2/1996 | Lee et al. | |
| 5,530,457 | A | 6/1996 | Helgeson | |
| 5,625,477 | A | 4/1997 | Wu et al. | |
| 5,636,044 | A | 6/1997 | Yuan et al. | |
| 5,644,330 | A | 7/1997 | Catchpole et al. | |
| 5,668,614 | A | 9/1997 | Chien et al. | |
| 5,691,795 | A | 11/1997 | Doane et al. | |
| 5,734,155 | A | 3/1998 | Rostoker | |
| 5,748,277 | A | 5/1998 | Huang et al. | |
| 5,751,257 | A | 5/1998 | Sutherland | |
| 5,815,136 | A | 9/1998 | Ikeda et al. | |
| 5,847,798 | A | 12/1998 | Yang et al. | |
| 5,889,572 | A | 3/1999 | Takahashi et al. | |
| 5,981,408 | A | 11/1999 | Nakagawa et al. | |
| 5,996,897 | A | 12/1999 | Prancz | |
| 6,034,752 | A | 3/2000 | Khan et al. | |
| 6,061,107 | A | 5/2000 | Yang et al. | |
| 6,072,619 | A | 6/2000 | Kiryuschev et al. | |
| 6,096,666 | A | 8/2000 | Jachimowicz et al. | |
| 6,133,895 | A | 10/2000 | Huang | |
| 6,154,190 | A | 11/2000 | Yang et al. | |
| 6,224,964 | B1 * | 5/2001 | Kawai et al. | 428/32.81 |
| 6,253,190 | B1 | 6/2001 | Sutherland | |
| 6,268,839 | B1 | 7/2001 | Yang et al. | |
| 6,268,841 | B1 | 7/2001 | Cairns et al. | |
| 6,269,342 | B1 | 7/2001 | Brick et al. | |
| 6,270,783 | B1 | 8/2001 | Slavtcheff et al. | |
| 6,271,898 | B1 | 8/2001 | Clikeman et al. | |
| 6,277,439 | B1 | 8/2001 | Painter | |
| 6,278,429 | B1 | 8/2001 | Ruth et al. | |
| 6,307,605 | B1 | 10/2001 | Bailey | |
| 6,316,278 | B1 | 11/2001 | Jacobsen et al. | |
| 6,320,563 | B1 | 11/2001 | Yang et al. | |
| 6,359,673 | B1 | 3/2002 | Stephenson | |
| 6,377,321 | B1 | 4/2002 | Khan et al. | |
| 6,423,368 | B1 | 7/2002 | Stephenson et al. | |
| 6,433,849 | B1 | 8/2002 | Lowe | |
| 6,452,590 | B1 | 9/2002 | Awamoto et al. | |
| 6,459,467 | B1 | 10/2002 | Hashimoto et al. | |
| 6,468,638 | B2 | 10/2002 | Jacobsen et al. | |
| 6,483,563 | B2 | 11/2002 | Khan et al. | |
| 6,532,052 | B1 | 3/2003 | Khan et al. | |
| 6,556,262 | B1 | 4/2003 | Stephenson et al. | |
| 6,585,849 | B2 | 7/2003 | Smith et al. | |
| 6,603,259 | B1 | 8/2003 | Kiryuschev et al. | |
| 6,608,438 | B2 | 8/2003 | Topelberg et al. | |
| 6,618,114 | B1 | 9/2003 | Freeman | |
| 6,624,565 | B2 | 9/2003 | Topelberg | |
| 6,628,256 | B2 | 9/2003 | Nishimura | |
| 6,654,080 | B1 | 11/2003 | Khan et al. | |
| 6,655,788 | B1 * | 12/2003 | Freeman | 347/58 |
| 6,657,620 | B2 | 12/2003 | Oishi et al. | |
| 6,697,191 | B2 | 2/2004 | Kiryuschev et al. | |
| 6,710,760 | B1 | 3/2004 | Johnson et al. | |
| 6,727,197 | B1 | 4/2004 | Wilson et al. | |
| 6,788,362 | B2 | 9/2004 | Stephenson et al. | |
| 6,819,310 | B2 | 11/2004 | Huang et al. | |
| 6,850,217 | B2 | 2/2005 | Huang et al. | |
| 6,864,435 | B2 | 3/2005 | Hermanns et al. | |
| 6,902,454 | B1 * | 6/2005 | Petruchik | 445/24 |
| 7,009,666 | B2 | 3/2006 | Khan et al. | |
| 2001/0015712 | A1 | 8/2001 | Hashimoto | |
| 2002/0030776 | A1 | 3/2002 | Khan et al. | |
| 2002/0030786 | A1 | 3/2002 | Stephenson | |
| 2002/0186182 | A1 | 12/2002 | Stephenson et al. | |
| 2003/0011549 | A1 | 1/2003 | Murahashi et al. | |
| 2003/0016329 | A1 | 1/2003 | Smith et al. | |
| 2003/0019575 | A1 | 1/2003 | Smith et al. | |
| 2003/0031845 | A1 * | 2/2003 | Umeya et al. | 428/212 |
| 2003/0034945 | A1 | 2/2003 | Mi et al. | |
| 2003/0063245 | A1 | 4/2003 | Bowley et al. | |
| 2003/0071791 | A1 | 4/2003 | Hanson et al. | |
| 2003/0085380 | A1 | 5/2003 | Schuhmacher et al. | |
| 2003/0117548 | A1 | 6/2003 | Stephenson | |
| 2003/0155151 | A1 | 8/2003 | Hermanns et al. | |
| 2003/0160912 | A1 | 8/2003 | Stephenson | |
| 2003/0169221 | A1 | 9/2003 | Stephenson et al. | |
| 2003/0184569 | A1 | 10/2003 | Koga et al. | |
| 2003/0202136 | A1 | 10/2003 | Stephenson et al. | |
| 2003/0206147 | A1 | 11/2003 | Mi et al. | |
| 2003/0222139 | A1 | 12/2003 | Stephenson et al. | |
| 2004/0032545 | A1 | 2/2004 | Stephenson et al. | |
| 2004/0080477 | A1 | 4/2004 | Capurso et al. | |
| 2005/0001797 | A1 | 1/2005 | Miller, IV et al. | |
| 2005/0007336 | A1 | 1/2005 | Albert et al. | |
| 2005/0083284 | A1 | 4/2005 | Huang et al. | |
| 2005/0195354 | A1 | 9/2005 | Doane et al. | |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| WO | 2005/072455 | 8/2005 |
| WO | 2005/081779 | 9/2005 |

OTHER PUBLICATIONS

*Photostable Tilted-Perpendicular Alignment of Liquid Crystals for Light Valves*, Anna Lackner et al., Proceedings of the SID, vol. 31/4, 1990, pp. 321-326.

*Transparent Phase Images in Photoactivated Liquid Crystals*, J.S. Margerum et al., Applied Physics Letter, vol. 19, No. 7, Oct. 1, 1971, pp. 216-218.

*Development of a Flexible Electronic Display Using Photographic* Technology, Stanley Stephenson et al., SID 04 Digest, pp. 774-777.

*A Fully Flexible Colour Display*. Peter Slikkerveer et al., SID 04 Digest, pp. 770-773.

*Robust Flexible LCD's with Paintable* Technology, Joost P.A. Vogels et al., SID 04 Digest, pp. 767-769.

*Invited Paper: What is Electronic Paper? The Expectations*,Makoto Omodani, SID 04 Digest, pp. 128-131.

*Effect of Woven Fabric Anisotropy on Drape Behaviour*, Sidabraite, et al., ISSN 1392-1320, Materials Science, vol. 9, No. 1. 2003, pp. 111-115.

*The Characterisation of the Static and Dynamic Drape of Fabrics*, G.K. Stylios et al., J. Text. Inst., 1997, 88 Part 1, No. 4, pp. 465-475.

*Modelling the Fused Panel for a Numerical Stimulation of Drape*, Jevsnik et al., Fibers & Textiles in Eastern Europe, Jan./Mar. 2004, vol. 12, No. 1, 0047-52.

*Mechanics of Elastic Performance of Textile Materials*, Chauncey Chu et al., Textile Research Journal, Aug. 1950, pp. 539-548.

*The Dependence of Fabric Drape on Bending and Shear Stiffness*, G.E. Cusick, J. Textile Institute. 36, 11, 1965, pp. T597-T-607.

*Liquid Crystal Dispersions*, Paul S. Drzaic., World Scientific, Series on Liquid Crystals, vol. 1., pp. xi-xv, 1995.

*Plastic VGA Reflective Cholesteric LCDs with Dynamic Drive*, G.M. Podojil et al., SID proceedings, 1998, pp. 51-54.

*Reflective Color Display Using Cholesteric Liquid Crystals*, K. Hashimoto et al., SIC 98 Digest, pp. 897-900.

*Robust Flexible LCDs with Paintable Technology*, J.P.A. Vogels et al., Society for Information Display, 2004 Proceedings. pp. 767-769.

*Black and White Photo-addressable Electronic Paper using Encapsulated Cholester Liquid Crystal and Organic Photoconductor*, T. Kakinuma et al., IDW 2002, pp. 1345-1348.

*Characterization of "Peas in a Pod" , a Novel Idea for Electronic Paper*, S. Maeda et al., IDW 2002, pp. 1353-1356.

*Holographic Polymer-Dispersed Liquid Crystals* (*H-PDLCs*), T.J. Bunning et al., Annu. Rev. Mater. Sci 2000, 30:83-115, pp. 83-115.

*Reflective display with photoconductive layer and bistable reflective cholesteric mixture*, H. Yoshida, Journal of SID 5/3 1997, pp. 269-274.

*Reflective Multicolor Display Using Cholesteric Liquid Crystals*, M. Okada et al., Proc, SID 97 Digest, pp. 1019-1022.

*Multiple Color High Resolution Reflective Cholesteric Liquid Crystal Display*, D. Davis et al., Proc IDRC (242) 1997.
*Full Color (4096 Colors) Reflective Cholesteric Liquid Crystal Display*, X. Huang et al., Proceedings of Asia Display 98, pp. 883-886 (1998).
Doane, J.W., Liquid Crystals: Applications and Uses, Ed. B. Bahadur, World Scientific Publishers, Ch. 14 (1990).
Jing-Jou Tang et al.,*A 30-V Row/Column Driver for PSCT LCD Using High-Voltage BiMOS Process*, Online Article, dated 1999.
http://www/us.semiconductors.philips.com/pip/PCF8578.html. LCD/row/column driver for dot matrix graphic displays, printed Jul. 8, 2003, pp. 1-3.
40CH Segment/Driver for Dot Matrix LCD, KS0065B, Samsung Electronics, 12 pages.
Doane, J. William, Khan, Asad; *Cholesteric Liquid Crystal for Flexible Displays*, in *Flexible Flat Panel Displays*, Ed. G. Crawford) John Wiley & Sons, England, Chapter 17 (2005) pp. 331-354.
Doane, J. William, "Polymer Dispersed Liquid Crystal Displays", in *Liquid Crystals: Applications & Uses*, Ed. Birendra Bahadur (World Scientific Pub. 1990), Chapter 14, pp. 361-395.
Luo, F.C., "*Active Matrix LC Displays*", in *Liquid Crystals: Applications & Uses*, (ed. B. Bahadur), World Scientific, Singapore, Chapter 15, pp. 397-436.

* cited by examiner

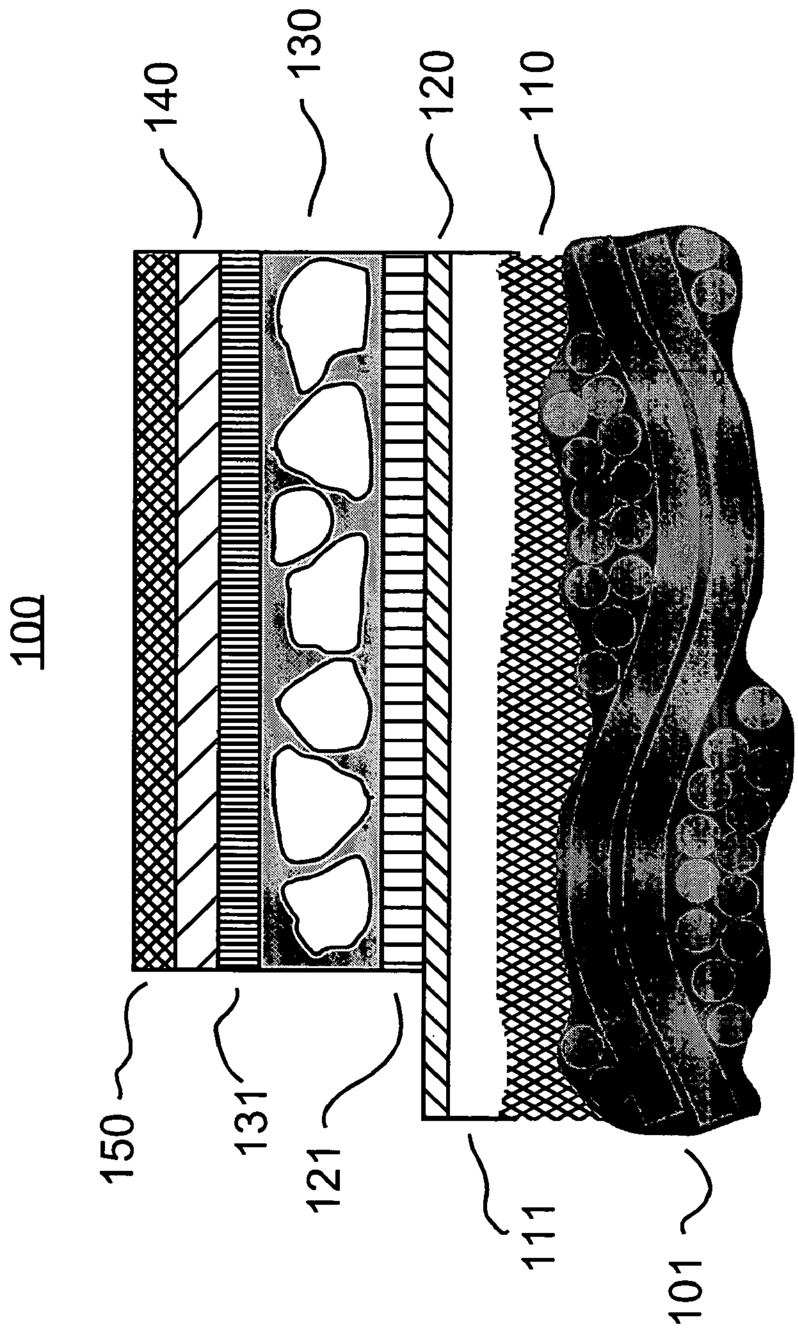



Fig. 1

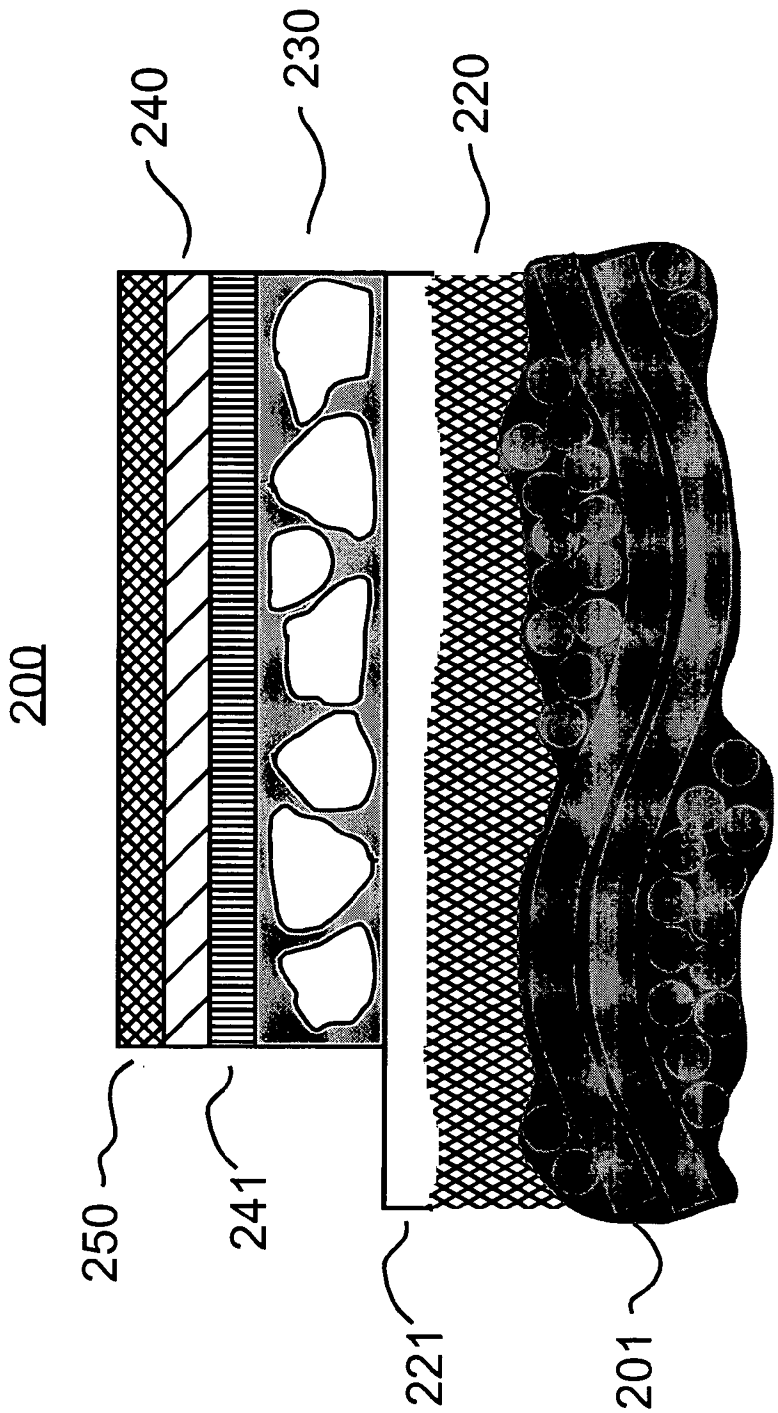



Fig. 2

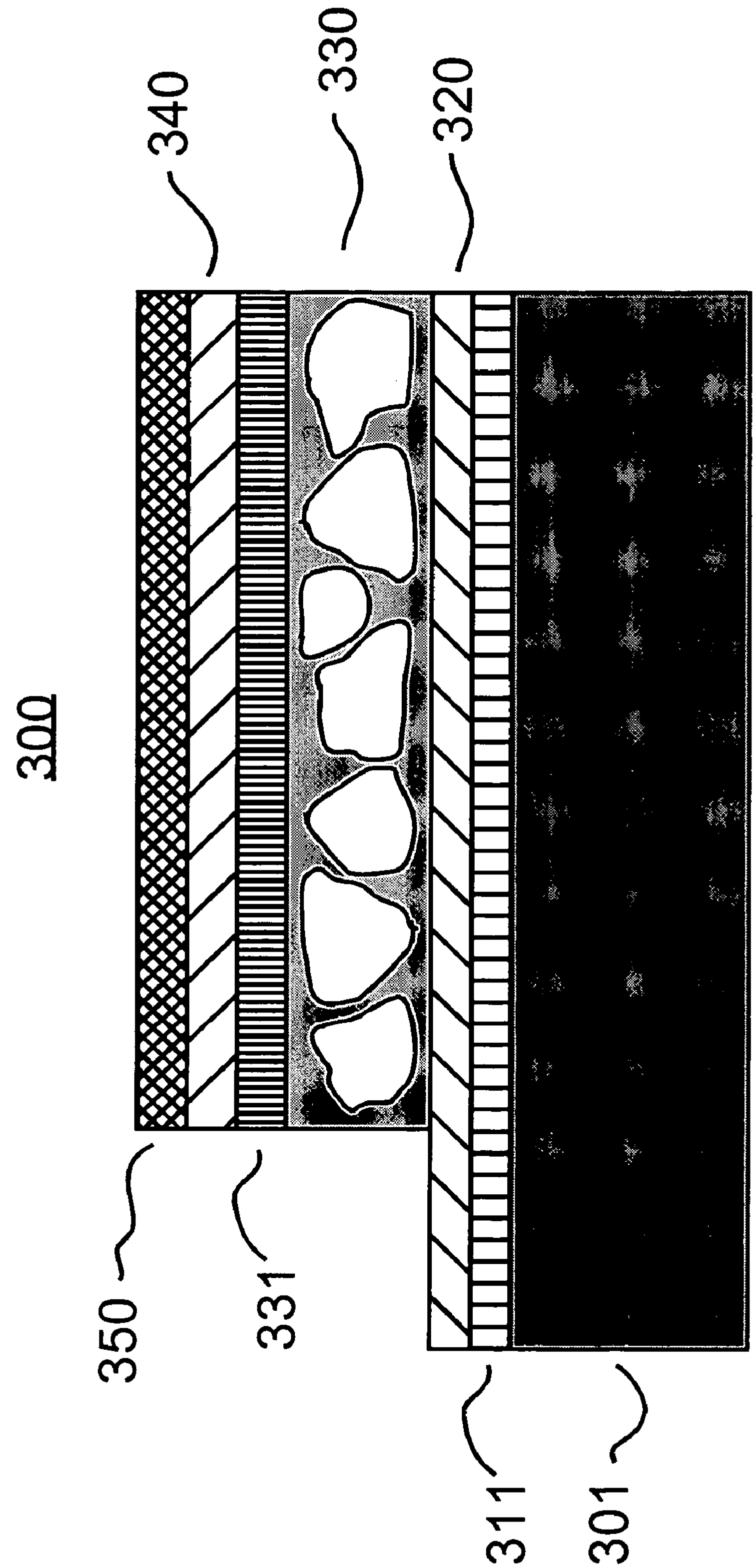



Fig. 3

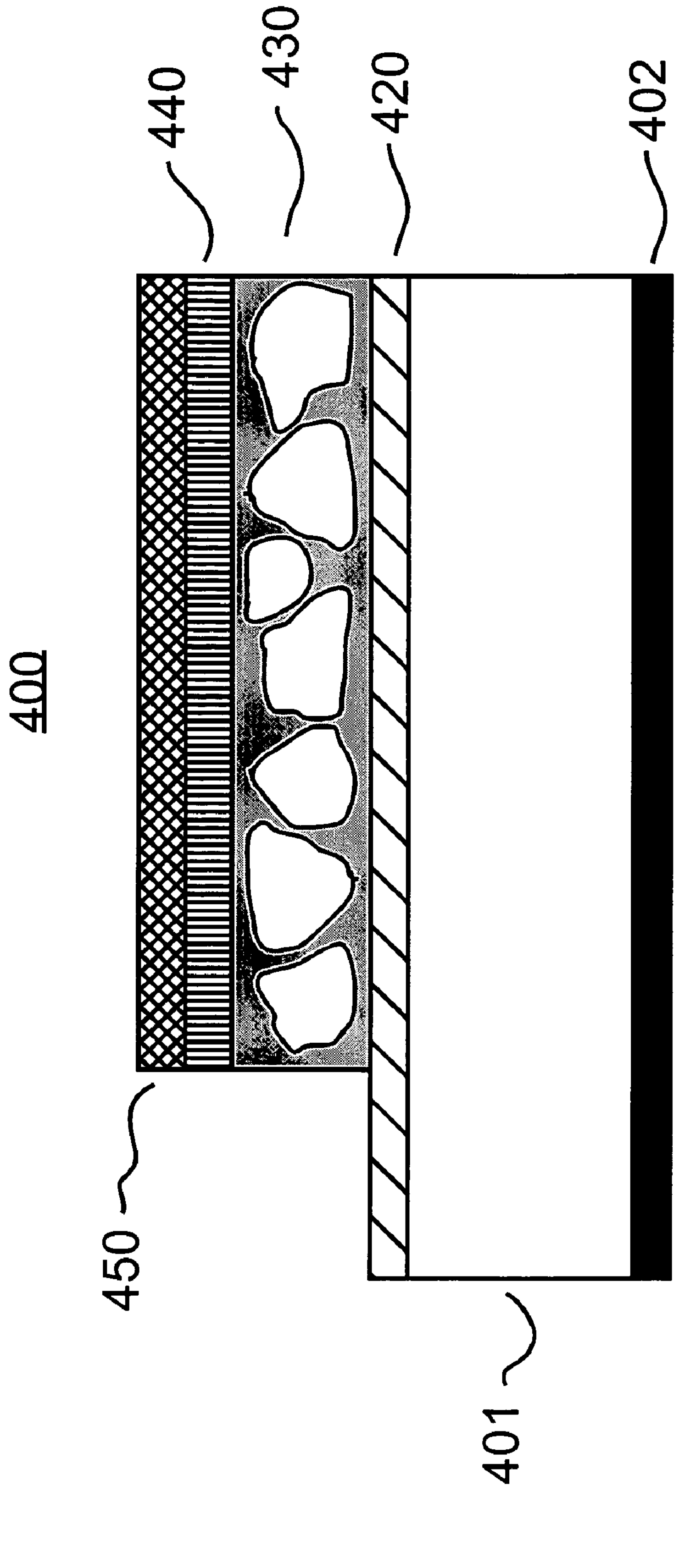



Fig. 4

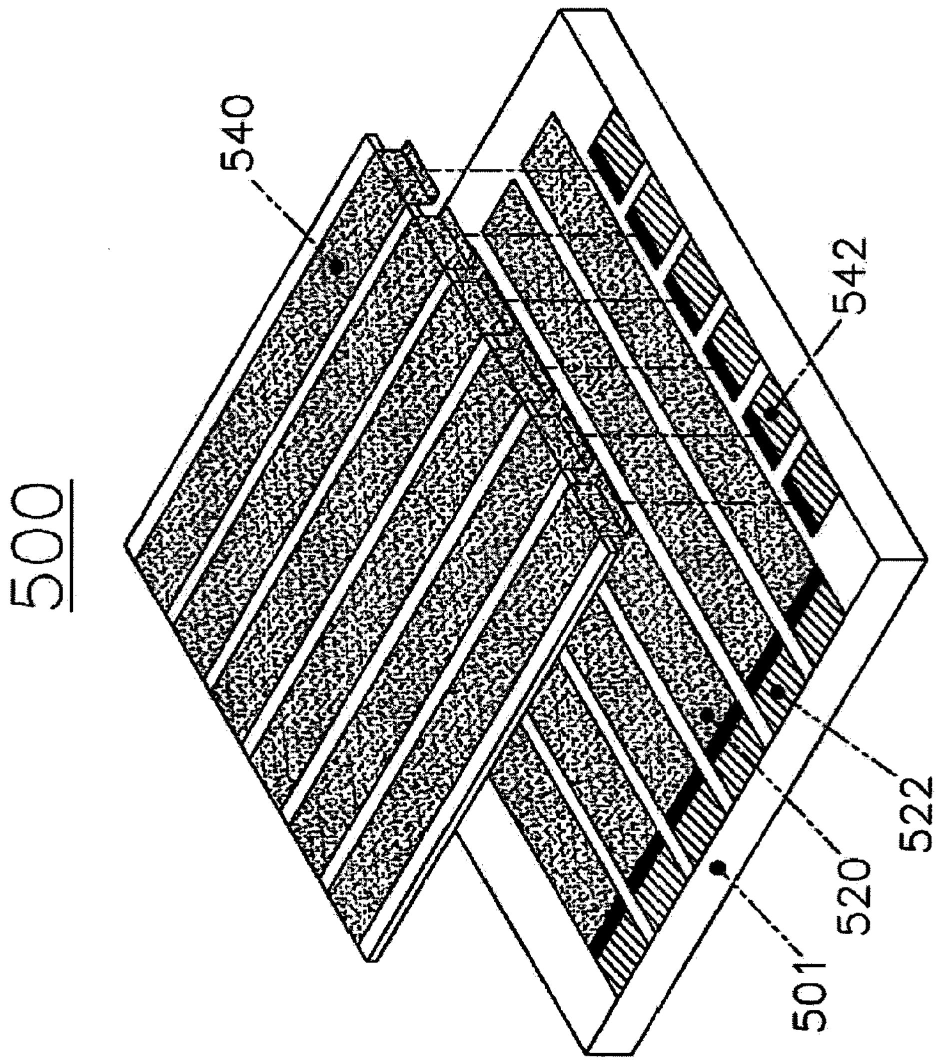



Fig. 5

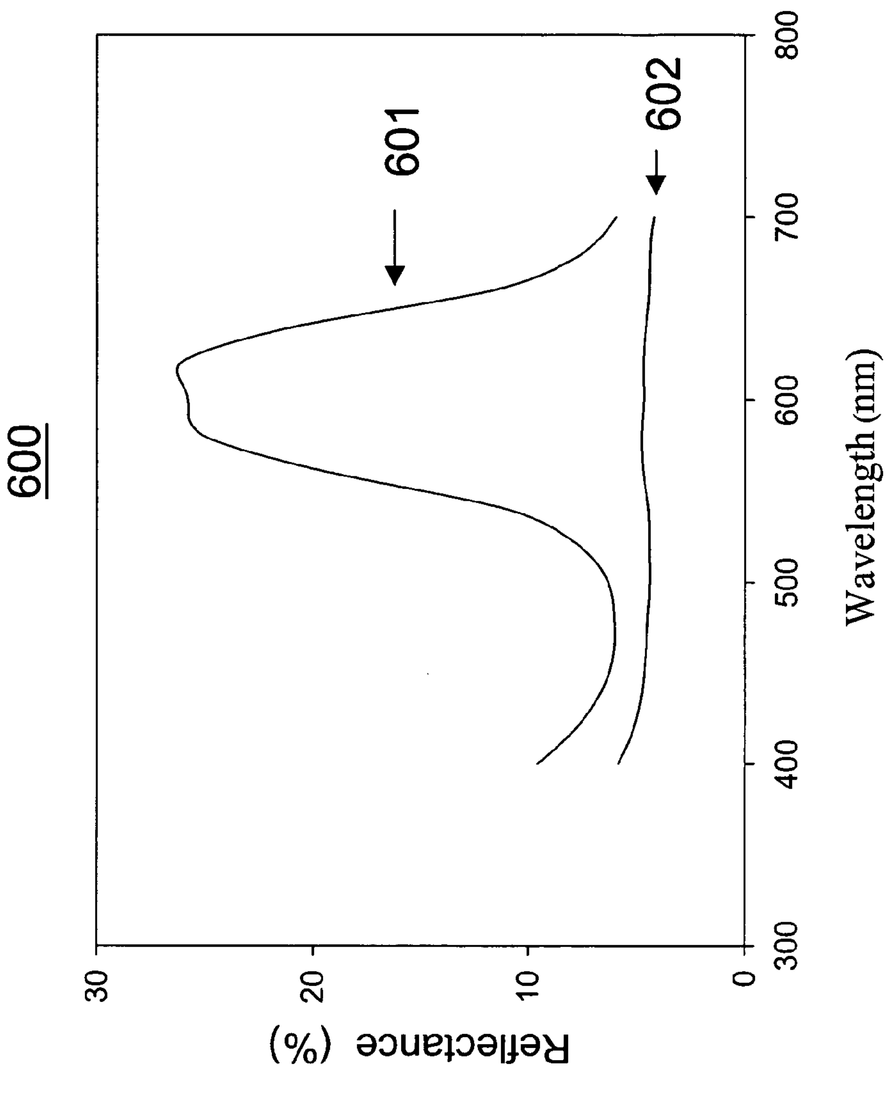

600
601
602
Reflectance (%)
Wavelength (nm)
0
10
20
30
300
400
500
600
700
800

Fig. 6

650

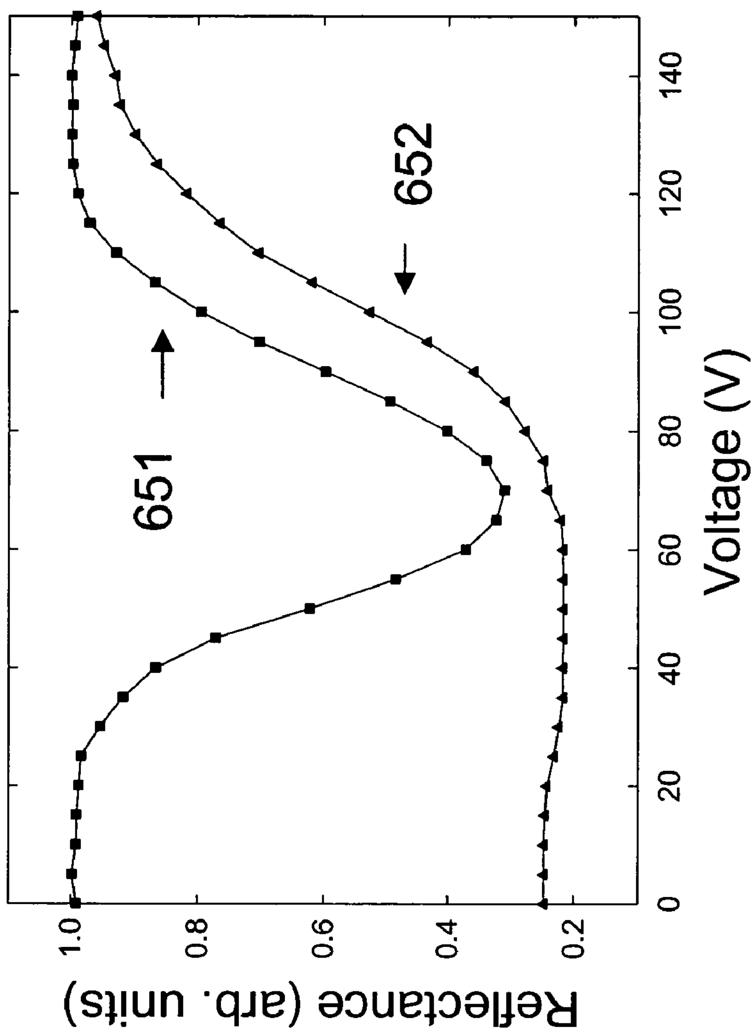

Reflectance (arb. units)
1.0
0.8
0.6
0.4
0.2
Voltage (V)
0
20
40
60
80
100
120
140
651
652

Fig. 7

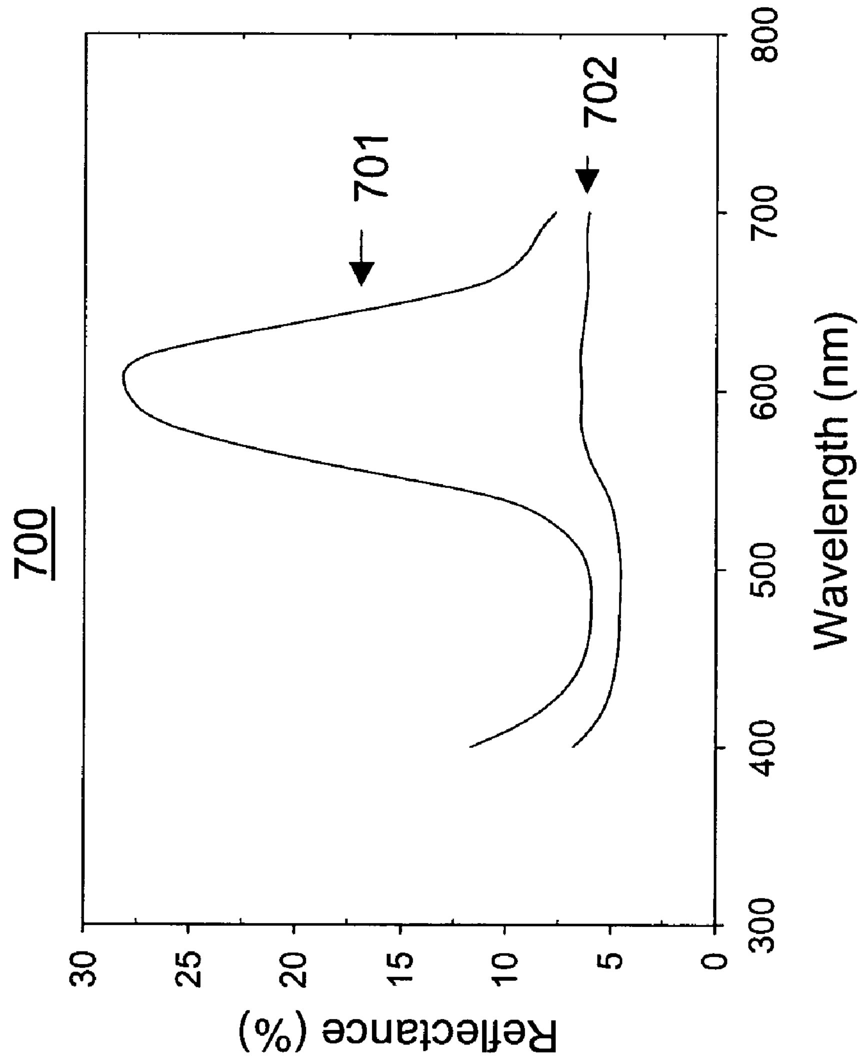

700
701
702
Reflectance (%)
Wavelength (nm)
0
5
10
15
20
25
30
300
400
500
600
700
800

Fig. 8

750

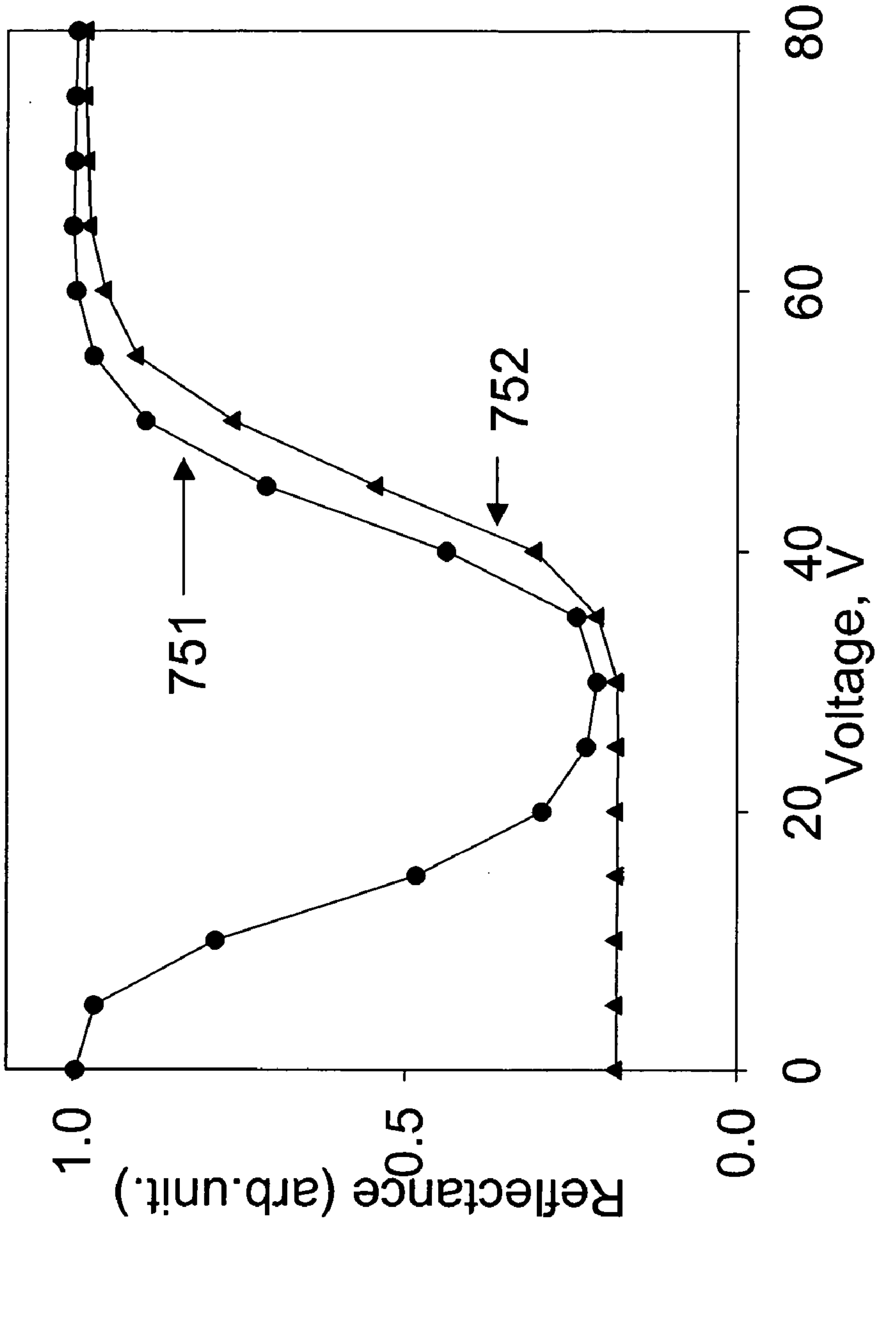



Fig. 9

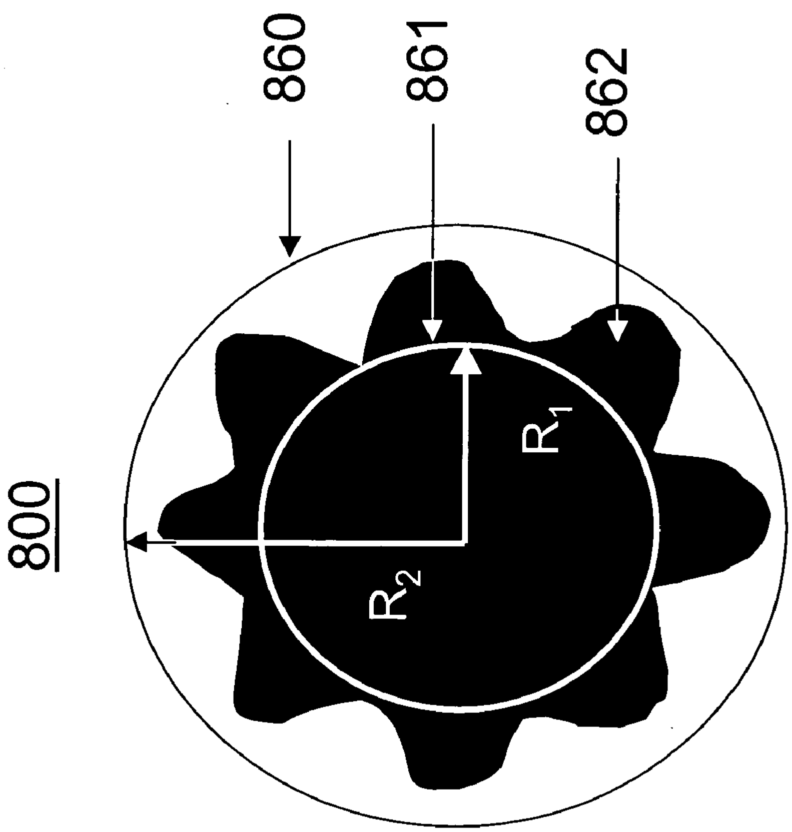



Fig. 10

# LIQUID CRYSTAL DISPLAY

## RELATED APPLICATIONS

This regular application claims the benefit of co-pending provisional applications 60/565,586, filed 04/27/2004 and 60/539,873, filed Jan. 28, 2004.

This application was made in part with United States Government support under cooperative agreement No. DAAB07-03-C-J406 awarded by the Department of Defense. The government may have certain rights in this invention.

## BACKGROUND OF THE INVENTION

A revolution in the information display technology began in the early 1970s with the invention of the liquid crystal display (LCD). Because the LCD is a flat-panel display of light weight and low power which provides a visual read out that conforms to the small size, weight and battery demands of a handheld electronic device, this display technology enabled a new broad class of handheld and other portable products. Commercially, the LCD first appeared in volume as a digital readout on wrist watches, then on instruments and, later, enabled the laptop computer, personal data assistant and many other digital devices. Today LCD technology is even replacing cathode ray tubes in televisions and PCs.

Nearly every commercial LCD display manufactured and sold today is on glass substrates. Glass offers many features suitable for the manufacture of LCDs. It can be processed at high temperatures, it is rigid and suitably rugged for batch processing methods used in high volume manufacturing, its surface can be made very smooth and uniform over large areas and it has desirable optical properties such as high transparency. There are many applications, however, where glass is far from being the ideal substrate material. Glass substrates cannot be made very flexible and are not very rugged, being unsuitable for web manufacturing and subject to easy breakage. As a result there is a large worldwide effort to develop displays on more flexible and rugged substrates that can not only conform to three-dimensional configurations but which can also be repeatedly flexed. A display is desired that has the flexibility of a thin plastic sheet, paper or fabric, so that it can be draped, rolled up or folded like paper or cloth. This would not only make the display more portable and easier to carry, it would expand its potential applications well beyond those of the typical flat panel information displays known today: A display worn on the sleeve; the back of a bicyclists coat that shows changing direction signals; textile that changes its color or design are but a few examples.

While the ability of an electrically addressable liquid crystal display to be flexible and deform like cloth or paper would be advantageous for any LCD technology, it is especially advantageous in applications suited to cholesteric liquid crystal displays. Cholesteric displays can be made highly reflective such that they can be seen in bright daylight or a dimly lit room without the aid of a heavy and power consuming backlight. Since cholesteric liquid crystals can be made to be bistable they require power only when being addressed, further adding to the power savings associated with such displays. Cholesteric liquid crystalline materials are unique in their optical and electro-optical features. Of principal significance, they can be tailored to Bragg reflect light at a pre-selected wavelength and bandwidth. This feature comes about because these materials posses a helical structure in which the liquid crystal (LC) director twists around a helical axis. The distance over which the director rotates 360° is referred to as the pitch and is denoted by P. The reflection band of a cholesteric liquid crystal is centered at the wavelength, $\lambda_O=0.5(n_e+n_o)P$ and has the bandwidth, $\Delta\lambda=(n_e-n_o)P$ which is usually about 100 nm where $n_e$ and $n_o$ are the extra-ordinary and ordinary refractive indices of the LC, respectively. The reflected light is circularly polarized with the same handedness as the helical structure of the LC. If the incident light is not polarized, it will be decomposed into two circularly polarized components with opposite handedness and one of the components reflected. The cholesteric material can be electrically switched to either one of two stable textures, planar or focal conic, or to a homeotropically aligned state if a suitably high electric field is maintained. In the planar texture the helical axis is oriented perpendicular to the substrate to Bragg reflect light in a selected wavelength band whereas in the focal conic texture it is oriented, on the average, parallel to the substrate so that the material is transparent to all wavelengths except for weak light scattering, negligible on an adjacent dark background. These bistable structures can be electronically switched between each other at rapid rates on the order of milliseconds. Gray scale is also available in that only a portion of a pixel can be switched to the reflective state thereby controlling the reflective intensity.



The bistable cholesteric reflective display technology was introduced in the early 1990's as a low power, sunlight readable technology intended primarily for use on handheld devices. Such portable devices demand long battery lifetimes requiring the display to consume very little power. Cholesteric displays are ideal for this application as the bistability feature avoids the need for refreshing power and high reflectivity avoids the need for power-consuming backlights. These combined features can extend battery life times from hours to months over displays that do not have these features. Reflective displays are also easily read in very bright sunlight where backlit displays are ineffective. Because of the high reflective brightness of a cholesteric display and its exceptional contrast, a cholesteric display can be easily read in a dimly lit room. The wide view angle offered by a cholesteric display allows several persons to see the display image at the same time from different positions. In the case of cholesteric materials possessing positive dielectric anisotropy, modes of operation other than a bistable mode are possible by applying a field to untwist the cholesteric material into a transparent, homeotropic texture. Quick removal of the field transforms the material into the reflective planar texture. The more fundamental aspects of such modem cholesteric displays are disclosed in, for example, U.S. Pat. Nos. 5,437,811 and 5,453,863, incorporated herein by reference.

Bistable cholesteric liquid crystal displays have several important electronic drive features that other bistable reflective technologies do not. Of extreme importance for addressing a matrix display of many pixels is the characteristic of a voltage threshold. A threshold voltage is essential for multiplexing a row/column matrix without the need of an expensive active matrix (transistor at each pixel). Bistability with a voltage threshold allows very high-resolution displays to be produced with low-cost passive matrix technology.

In addition to bistable cholesteric displays with liquid crystalline materials having a positive dielectric anisotropy, it is possible to fabricate a cholesteric display with liquid crystalline materials having a negative dielectric anisotropy as, for example, described in the U.S. Pat. No. 3,680,950 to Haas et al., or 5,200,845 to Crooker et al., incorporated herein by reference. These "negative materials" like the "positive" materials are chiral nematic liquid crystals that are prepared from nematic materials that have been twisted into a helical molecular arrangement by the addition of chiral compound or collection of chiral compounds. The negative and positive materials are prepared from nematic liquid crystals with either a negative or positive dielectric anisotropy respectively.

Negative type cholesteric displays can operate in a bistable mode where the material is switched into the stable planar (e.g., color reflective) texture with an AC pulse or into the stable focal conic (e.g., transparent) texture with a DC pulse as described by U.S. Pat. No. 3,680,950. There are other modes of operation such as has been disclosed by Crooker where a droplet dispersion of negative cholesteric materials is switched into the planar, color reflective texture with an applied electric field, but relaxes back into a transparent texture when the field is removed.

Some cholesteric materials possess a dielectric anisotropy that can be negative under an applied electric field of one frequency but positive at another frequency. This feature can be used to drive a bistable display using a dual frequency drive scheme as described in U.S. Pat. No. 6,320,563, incorporated herein by reference.

Another important feature of cholesteric materials is that the layers reflecting red, green, and blue (RGB) colors as well as IR night vision can be stacked (layered) on top of each other without optically interfering with each other. This makes maximum use of the display surface for reflection and hence brightness. This feature is not held by traditional displays were the display is broken into pixels of different colors and only one third of the incident light is reflected. Using all available light is important for observing a reflective display in a dimly lit room without a backlight. Gray scale capability allows stacked RGB, high-resolution displays with full-color capability where as many as 4096 colors have been demonstrated. Because a cholesteric display cell does not require polarizers, low cost birefringent plastic substrates such a PET can be used. Other features, such as wide viewing-angles and wide operating temperature ranges as well as fast response times make the cholesteric bistable reflective technology, the technology of choice for many low power applications.

Cholesteric liquid crystals are particularly well suited for flexible substrates. Such cholesteric displays have been reported by Minolta Co. Ltd. and by Kent Displays, Inc. involving two plastic substrates filled with cholesteric liquid crystal materials (Society for Information Display Proceedings, 1998, pp 897–900 and 51–54, respectively). While the substrates themselves are flexible, the assembled displays are much less flexible because of the lamination of two substrates together. Minolta has developed procedures for manufacturing flexible displays with two substrates as seen in U.S. Pat. No. 6,459,467.

Greater flexibility can be achieved if only one substrate is used and the display materials are coated or printed on the substrate. Cholesteric liquid crystals are made suitable for standard coating and printing techniques by forming them into polymer droplet dispersions. As droplet dispersions, the materials are made insensitive to pressure and shear such that an image on a bistable cholesteric display is not readily erased by flexing the substrate. Recently, Stephenson et al., at Kodak fabricated flexible bistable reflective displays with polymer dispersions of cholesteric liquid crystals on a single transparent plastic substrate using photographic methods (U.S. Published Application No. 2003/0202136 A1 and U.S. Pat. No. 6,788,362 B2). This process involves a sequence of depositions on transparent polyester plastic whereby the end product is a display where the images are viewed through the substrate. Such a process requires substrate materials that are transparent such as a clear plastic sheet.

In view of the foregoing, it is desirable to provide a reflective display that does not require a transparent substrate, making available a broader range of substrate materials such as fabrics made of fibers that can be deformed such as by bending, rolling, draping or folding. These added features offer many advantages and open up many new display applications. Use of flexible and drapable substrates can bring to the market place new displays that have the physical deformability of fabric so that they can be an integral part of clothing and have the feel and appearance of cloth because they can be draped and folded.

## SUMMARY OF THE INVENTION

In view of the foregoing, it is therefore an object of the invention to provide an electrically addressable liquid crystal display having the physical deformability or drapability of textile or cloth which may incorporate, inter alia, any of the aforementioned liquid crystal materials and technologies. This invention also brings advantages in manufacturing where the display including the electrodes is made of organic materials that are coated or printed on the substrate. Conducting polymers are used instead of the traditional inorganic materials such as indium tin oxide (ITO) for the electrodes. On some fabrics, preparation layers are used to color, smooth or planarize the surface, adjust the resistivity, index match and other features. Polymer dispersions of cholesteric liquid crystals can be made from a wide variety of different methods as is suitable for various manufacturing processes or display function.

In one aspect of the invention there is provided a drapable electrically addressable liquid crystal display comprising a drapable substrate material, a layer of. liquid crystal material, a first conducting electrode disposed on a first side of said liquid crystal layer proximal said substrate, and a second conducting electrode disposed on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry.

In another aspect of the invention, a flexible reflective liquid crystal display is provided which comprises a non-transparent flexible substrate material, a layer of liquid crystal material, a first conducting electrode disposed on a first side of said liquid crystal layer proximal said substrate, and a second conducting electrode disposed on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry.

In a preferred aspect of the invention there is provided an electrically addressable liquid crystal display comprising, as a substrate, paper or a textile fabricated from natural or synthetic fibers, a layer of liquid crystal material, a first conducting electrode disposed on a first side of said liquid layer proximal said substrate, and a second conducting electrode disposed on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry. Where drapable substrates are employed, the substrates will preferably have a drape coefficient less than about 98%. Drape coefficients of less than about 95% or further less than about 90% will be desirable depending upon the application.

In preferred embodiments of each the foregoing aspects of the invention one side of said substrate is smoother than the opposite side of said substrate. In one embodiment, one side of said substrate is made smoother by deposition of a layer of material thereon, preferably by interposing a planarization layer between the substrate and the first electrode.

Further preferred embodiments of each of the foregoing aspects of the invention will include an insulation layer disposed between at least one of the electrodes and the liquid crystal layer and, more preferably still, a protective coating disposed as un uppermost layer of at least a portion of the display.

The electrodes for use in connection with the foregoing aspects of the invention are preferably formed of a conducting polymer or carbon nanotube material. The second electrode is substantially optically transmissive. In some embodiments the first electrode will be comprised at least in part of the substrate. Similarly, the liquid crystal layer for use in connection with the foregoing aspects of the invention preferably comprises cholesteric liquid crystal material and, more preferably, a dispersion of droplets of the liquid crystal material. Preferred dispersions are selected from an emulsion, a phase separated liquid crystal material, or a microencapsulated liquid crystal material. Still more preferably, the dispersion is a polyurethane latex emulsion which comprises a mix of liquid crystal and latex in a ratio of from about 2:1 to about 6:1. Preferred cholesteric liquid crystal materials will have a positive dielectric anisotropy and a pitch length effective to reflect light in the visible or infrared spectrum.

In aspects of the invention employing an electrode matrix, the displays will preferably include a plurality of conducting electrodes arranged in substantially parallel lines on a first side of said liquid crystal layer proximal said substrate, and a plurality of conducting electrodes arranged in substantially parallel lines on an opposite side of said liquid crystal layer, said lines of electrodes on opposite sides of said liquid crystal layer being oriented substantially perpendicular to each other.

For some preferred applications, the displays will further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material. Preferably, these embodiments will include at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material, and conducting electrodes disposed on opposite sides thereof, whereby the additional layer is independently electrically addressable. In other aspects of the invention, the display can further include a layer of photoconductive material interposed between the liquid crystal layer and the first electrode or the first electrode can comprise an active matrix backplane.

A greater understanding of these and other aspects of the invention will be had from the following detailed description and accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic cross-sectional illustration of a display configuration according to the invention wherein the display elements are coated, printed or laminated sequentially as layers on a fabric substrate.

FIG. **2** is a diagrammatic cross-sectional illustration of another display configuration according to the invention wherein some display layers share functionality.

FIG. **3** is a diagrammatic cross-sectional illustration of another display configuration according to the invention wherein the display elements are coated, printed or laminated sequentially as layers on a non-fibrous and non-transparent substrate.

FIG. **4** is a diagrammatic cross-sectional illustration of another display configuration according to the invention wherein the display elements are coated printed or laminated sequentially as layers on a non-fibrous and non-transparent substrate prepared, in part, from transparent materials.

FIG. **5** is a three-dimensional diagrammatic sketch of a preferred display configuration according to the invention illustrating an exploded view of how the row and column electrodes are connected to tabs on the substrate.

FIG. **6** is a graph of the spectral reflectivity of the two states of the cholesteric display of Example 1.

FIG. **7** is the electro-optic response of the display of Example 1.

FIG. **8** is a graph of the spectral reflectivity of the two states of the cholesteric display in Example 12.

FIG. **9** is the electro-optic response of the display of Example 12.

FIG. **10** is diagrammatic sketch illustrating the parameters in the determination of the drape coefficient for substrates suitable for use in the preferred embodiments of the invention.

## DESCRIPTION OF THE INVENTION

This invention involves a substantial advance in addressable liquid crystal displays wherein, by forming the displays on or integrally with a drapable substrate, the display itself is drapable. Such substrates include textiles or fabrics made of natural or man-made fibers such as cloth or paper, as well as non-fiberous materials such as flexible or even drapable thin polymeric sheets or films. Advantageously, the substrate need not be transparent. With deformable substrates, cholesteric or other liquid crystal displays are made flexible, rugged and can even be sewn into or onto clothing to provide a wearable display. In fact, the display itself can form the material used to make the clothing or other fabric construct. A display with the drapability of cloth provides a new dimension to display technology enabling display applications that were not previously possible. Such displays can conform to three dimensional structures or flex and fold with a garment or other fabric construct containing the display. To this end, the displays according to the invention are operatively deformable, meaning that they will function even though they are or have been deformed. In preferred applications, the displays according to the invention will be operatively drapable such that they can have folds and possess a measurable drape coefficient.

The formability of a fabric or other drapable substrate material can be defined as its ability to re-form from a two-dimensional shape to a simple or complex three-dimensional shape. The drape coefficient is used to describe the degree of 3-D deformation when the fabric specimen is draped over a drapemeter as described, for example, in the publication: "Effect of Woven Fabric Anisotropy on Drape Behavior," ISSN 1392-1320, *Materials Science* (Medziagotyra), Vol. 9, No. 1, pp. 111–115 (2003) by V. Sidabraitre and V. Masteikaite, or "Modeling the Fused Panel for a Numerical Simulation of Drape" *Fibers and Textiles*, Vol. 12, pages 47–52 (2004), by S. Jevsnik and J. Gersak, incorporated herein by reference. Drapability is a phenomenon that occurs when a material such as a curtain, flag, table cloth or flared skirt hangs from an object. The drape coefficient, DC, describes any deformation between draped and undraped material. In terms of percentage, it is described by the ratio: $DC=100(S_P-\pi R_1^2)/(\pi R_2^2-\pi R_1^2)$ were $R_2$ is the radius of a circular cut of non-deformed fabric; $R_1$, the radius of a horizontal disc holding the fabric, and $S_P$ the projected area of the draped specimen, including the part covered by the horizontal disc. The value of DC varies between zero and

100%. Since the value of DC can depend on the values selected for $R_1$ and $R_2$ of the drapemeter, we follow others in taking $R_1$=9 cm and $R_2$=15 cm. The larger the value of the drape coefficient, the stiffer the fabric and more difficult to reform. Alternatively, the lower the value of DC, the easier to reform and adapt to shapes. Some examples of desirable fabric substrate materials include silk, cotton, nylon, rayon, polyester, Kevlar, or similar materials made of fibrous material formed by woven and non-woven means having the deformability of cloth. Some examples of fabrics having the desired drapability are shown in Table I, which shows measured values of the drape coefficient, DC, for various fabric materials made with $R_2$=15 cm and $R_1$=9 cm. The data on the materials identified with an aserisk (*) were obtained from the publication "The Dependence of Fabric Drape on Bending and Shear Stiffness, *J. Textile Institute*, Vol. 56, pp. 596–606 (1965) by G. E. Cusick, incorporated herein by reference. The other materials were obtained from Jo-Ann Fabrics, Cuyahoga Falls, Ohio and Hudson, Ohio, and the DC values measured.

TABLE I

| Fabric | Weight ($g/m^2$) | Thickness (mm) | DC(%) |
|---|---|---|---|
| *Woven dress fabric, spun viscose rayon | 231 | 0.36 | 67.8 |
| *Woven dress fabrics, spun viscose rayon | 142 | 0.41 | 36.9 |
| *Plain woven 1.5 den spun viscose rayon | 196 | 0.45 | 32.6 |
| *Plain woven continuous-filament acetate and rayon | 226 | 0.46 | 24.7 |
| * Woven dress fabric cotton | 115 | 0.20 | 75.5 |
| * Woven dress fabric cotton | 105 | 0.31 | 97.2 |
| * Plain woven, continuous-filament polyester fiber | 96 | 0.20 | 49.9 |
| Polyester from Jo-Ann Fabrics | 186 | 0.3 | 14 |
| Polyester-65%, nylon 35% from Jo-Ann Fabrics | 116 | 0.17 | 49 |
| Polyester, satin from Jo-Ann Fabrics | 128 | 0.21 | 52 |

As will be apparent to those of ordinary skill in the art in view of the present disclosure, any deformable material having the desired flexibility or drapability and capable of supporting the display elements as disclosed herein will be suitable for use in the invention. In some preferred embodiments, the fabric substrate may be a composite or, more preferably, a fiber reinforced composite such as cotton and polyisoprene. An example of such composites is a raincoat where the cotton provides the feel and drapability of cloth and polyisoprene provides water resistance. Another example is rayon and neoprene used as a light shield against laser light such as that obtained by Thorlabs, Inc. (NJ) catalog # BK5. Composites can be useful substrate materials for many of the preferred displays of the invention in that they may require less planarization for the display elements.

In many preferred embodiments, the substrate material is non transparent. While black is a preferred color, other colors such as dark blue, green or some other color may be used to additively mix with the reflective color of the cholesteric liquid crystal to provide the desired color of text or other image addressed on the display. The substrate material itself may be substantially clear or transparent but the substrate made non-transparent by adding a black coating or dye to render it opaque, translucent or non-transparent as required for the background of the display. The image on a reflective cholesteric display is viewed against the background. It is therefore important that the background absorb unwanted light and not provide light that competes with or washes out light reflected from the cholesteric liquid crystal. Most fabrics are non-transparent. There are many examples of deformable sheet materials that are not made of fibers such as polymer films. If the sheet is thin enough, these films may also be drapable. An example of a polymer film that is non-transparent and very drapable is black static cling polyvinyl chloride sheet material from Graphix Plastics, Cleveland Ohio. Other examples of non-fiberous and drapable plastic sheets having the desired drapability are shown in Table II, which shows measured values of the drape coefficient, DC, for various non-fiberous sheet materials ($R_1$=9 cm and $R_2$=5 cm). The value of the drape coefficient was measured by photographing from above, the drape of the specimen of radius $R_2$ draped over a pedestal of radius $R_1$ under a weighed disk of the same radius. The areas of the projected image of the drape in the circle of radius $R_2$ were obtained from the digital photograph. In all cases, the drape showed the characteristic folds.

TABLE II

| Sheet Material | Weight ($g/m^2$) | Thickness (mm) | DC(%) |
|---|---|---|---|
| Black polyvinyl chloride from Graphix Plastics | 189 | 0.15 | 52 |
| Clear DuraLar (general purpose polyester) | 18.1 | 0.013 | 68 |
| Clear DuraLar (general purposed polyester) | 32.9 | 0.025 | 95 |
| Clear DuraLar (general purpose polyester) | 73.7 | 0.050 | 98 |

Sheet materials which are too thick do not exhibit drape but may bend or be flexed about one axis such as, for example, being rolled up. An example is 5 mil (0.125 mm thick) Clear DuraLar (polyester) or 5 mil thick Teijin Limited polycarbonate ITO coated foil (SS120-B30). Such 2-D deformation materials can be rolled up but do not reflect the nature of drape. It should be noted, however, that these and similar films will be suitable for certain embodiments of the invention where drapability is not required. For example, where only a flexible display is desired, such films can be rendered black or otherwise non-transparent for use as a substrate by coating it with a black Krylon paint.

It will be apparent from the following that while the principal advantages of the invention are realized by the presentation of a deformable liquid crystal display, a principal contributor to the realization of this advantage is the provision of an electrically addressable liquid crystal display on a single substrate. Electrically addressable displays on the market today employ at least two substrates which, as noted above, are generally rigid, with the liquid crystal sandwiched between them. These displays are, in general, manufactured by batch processing methods. In accordance with the preferred embodiments of the present invention, a display element on a single substrate is fabricated by a sequence of layers as may be placed on the substrate by coating, printing or lamination techniques suitable for the web processing methods necessary for low cost, high volume production. Fundamentally, these layers consist of a first conductive layer followed by a layer of an electrically responsive droplet dispersion such as a polymer dispersed cholesteric liquid crystal, followed next by a transparent conductive layer. Coating on textiles or other fabrics may require a planarization coating to at least partially smooth the surface. This may be followed by a preparation coating or sequence of such coatings to further smooth the surface of the fabric as well as adjust its color, resistivity, wetting and adhesive properties with respect to the first conductive layer. Insulation coatings are often needed between the cholesteric dispersion and electrodes to avoid electrical shorts between the electrodes. A durable protective layer is coated to finalize construction of the display element. In some cases an isolation layer is required between some of the coatings to avoid damage by subsequent coatings, such as may be caused by a chemical reaction between coating solvents or other components. Likewise, preparation coatings between various layers may be necessary to promote wetting and adhesion of the subsequent coat. In some embodiments, the coatings often serve multiple functions, such as where the first conductive coat may also serve as a preparation coat to smooth the surface.

The electro-optic layer can further consist of several coatings of cholesteric dispersions with different reflective colors or twist handedness as desired for multiple colors or high brightness. For color, enhanced brightness or infrared applications such as those described in U.S. Pat. No. 6,654,080, incorporated herein by reference, stacks of coatings arranged as disclosed therein can be employed in accordance with the instant invention. The coating of the upper conductive electrodes with a protective coat avoids the need to laminate an upper substrate. Such display configurations on a single substrate improve the flexibility of the display as well as its brightness and contrast. Such displays according to the invention exhibit improved ruggedness because the protective coat can be more difficult to delaminate than an upper laminated substrate.

While the invention will be described herein primarily in conjunction with the preferred use of cholesteric liquid crystals, any liquid crystal material that can be adapted to use in connection with the foregoing substrates will be suitable for use in accordance with the present invention. Such materials include, by way of example only, nematic, chiral nematic (cholesteric), smectic and ferroelectric smectic liquid crystal materials. They include materials which are bistable and those which are not bistable. They include cholesteric or chiral nematic liquid crystals having positive or negative dielectric anisotropy or a combination of negative and positive with a crossover frequency suitable for dual frequency addressing. They include cholesteric materials having pitch lengths reflecting in the visible spectrum as well as those having pitches reflecting outside the visible spectrum, including ultraviolet and infrared. Preferred liquid crystal materials for use in the present invention are bistable cholesteric (chiral nematic) liquid crystals having positive dielectric anisotropy. Especially preferred materials are nematic materials with a high birefringence and dielectric anisotropy with a chiral additive to twist the material to a pitch length to reflect in the visible spectrum such as BL061, BL048 and BL131 from EM Industries of Hawthorne, N.Y. These and other suitable materials will be apparent to those of ordinary skill in the art in view of the present disclosure.

As will be apparent to those of ordinary skill in the art in view of the instant disclosure, the liquid crystal material will preferably be present in the displays of the invention in the form of liquid crystalline layers comprised of a liquid crystal dispersion and, most preferably, a cholesteric droplet dispersion. There are many different approaches to the formation of a layer of liquid crystal droplets, some of which have been used for cholesteric liquid crystals. To form such a liquid crystal layer, the liquid crystal can be microencapsulated, formed into a layer of phase separated liquid crystal droplets, or formed into emulsified droplets of liquid crystal.

More specifically, one process suitable for forming liquid crystal layers for use in the invention is phase separation, which is basically a process that involves mixing the cholesteric liquid crystalline material with a pre-polymer solution then polymerizing the polymer under suitable conditions to form a dispersion of droplets in a polymer binder. Polymerization and, hence, droplet formation, occurs after the material mixture has been coated, either onto a temporary or interim substrate, or onto the display substrate itself. There are basically three types of polymerization techniques that can be used depending on the polymer (or monomer): (1) thermally induced phase separation (TIPS); (2) polymerization induced phase separation (PIPS); and, (3) solvent induced phase separation (SIPS).

The thermally induced phase separation (TIPS) process has been used to show that a cholesteric material will maintain its bistability and electro-optical features when encapsulated into a droplet structure as disclosed in, for example, U.S. Pat. No. 6,061,107, incorporated herein by reference. The TIPS system is a binary mixture of a liquid crystal and a thermoplastic polymer. At high temperatures, the polymer is melted and the materials are in solution. As temperature is lowered, the liquid crystal phase separates to form droplets as the polymer solidifies. The droplet size can be controlled by the cooling rate with smaller droplets being formed at faster cooling rates. TIPS is advantageous in controlling droplet size because cooling rates are easily adjusted. Furthermore, the system can be thermally cycled many times and different droplet sizes can be obtained in the same sample using different cooling rates. There are many thermoplastic polymers that can be used for this process. Some examples are PMMA (poly methyl methacrylate), which provides a tangential anchoring condition for the elongated liquid crystal molecules and PIEMB (poly isobutyl methacrylate), which provides a perpendicular anchoring condition. Other polymers suitable for use in this and the embodiments that follow would be apparent to those of ordinary skill in the art in view of the present disclosure.

Polymerization induced phase separation (PIPS) starts with a homogeneous mixture of a prepolymer (monomer) and a liquid crystal. As the monomers are polymerized, the liquid crystal phase separates from the polymer. The polymerization can be thermal-initiated or photo-initiated. In thermal-initiated polymerization, the monomers are typically combinations of epoxy resins and thiol curing agent, such as Epon 828 (Shell Chemical) or Capcure 3800 (Miller Stephenson Company). The mixture, coated at room temperature, can then be cured at an elevated temperature. In general, smaller droplets are formed at higher temperatures or higher concentrations of epoxy resins because of the higher reaction rate. In photo-initiated polymerization, monomers with acrylate or methyacrylate end groups, such as Norland 65 (which is a combination of acrylate monomers and photo-initiators), are used. Some photo-initiators are also needed. In sample preparation, the mixture is printed or coated then cured under the irradiation of UV light. Smaller droplets are formed under higher uv irradiation.

In the SIPS method, the initial material is a mixture of a liquid crystal and a thermoplastic dissolved in a common solvent. When the concentration of the solvent is sufficiently high, the components are homogeneously mixed. As the solvent evaporates, the system phase separates. The droplet size of the liquid crystal depends on the solvent evaporation rate with smaller droplets obtained at faster evaporation rates.

In accordance with the foregoing, those of ordinary skill in the art will be able to select suitable materials and methods for producing phase separated liquid crystal droplet layers for use in the present invention. In some cases, it may be preferable to use a combination of the PIPS, SIPS and TIPS processes. The PIPS, SIPS and TIPS methods and materials are well known in the art as disclosed in, for example, U.S. Pat. Nos. 4,688,900 and 4,684,771, incorporated herein by reference.

Another very different encapsulation process involves emulsification of a cholesteric liquid crystal in water with a waterborne polymer. Encapsulation of cholesteric liquid crystals by emulsification was practiced even before the invention of bistable cholesteric displays. As early as 1970, cholesteric materials were emulsified for making cholesteric thermal and electrical responsive coatings as discussed in U.S. Pat. No. 3,600,060, incorporated herein by reference. More recently, emulsification methods have been refined by Stevenson et al., at Kodak to make cholesteric droplets that are very uniform in size, as disclosed in U.S. Pat. 6,423,368 B1, incorporated herein by reference. The most common emulsification procedure basically involves a liquid crystal being dispersed in an aqueous bath containing a water-soluble binder material such as de-ionized gelatin, polyvinyl alcohol (PVA) or latex. Water acts as a solvent and dissolves the polymer to form a viscous solution. This aqueous solution does not dissolve the liquid crystal, and they phase separate. When a propeller blade at a sufficiently high speed stirs this system, the micron size liquid crystal droplets are formed. Smaller liquid crystal droplets form at higher stirring speeds as disclosed in P. Drzaic, *Liquid Crystal Dispersions*, World Scientific Publishing Co., Singapore (1995), incorporated by reference. The molecular weight of the water-soluble polymer is also a factor affecting the droplet size. After the droplets are formed, the emulsion is coated on a substrate and the water is allowed to evaporate. There are many different emulsification procedures. In preferred embodiments, one or more of PVA, gelatin and latex, preferably urethane based latex, are used to form the binder. Especially preferred polyurethane latex materials are NeoRez R967, and Witcobond W232 or W786. The emulsification method has the advantage that the droplet dispersions may contain a very high percentage of cholesteric material. As with the phase separated liquid crystal layers, those of ordinary skill in the art will be able to select suitable materials and methods for providing emulsified liquid crystal droplet layers for use in accordance with the present invention in view of the instant disclosure.

Microencapsulation is a yet another process for preparing droplet dispersions as seen, for example, in U.S. Pat. No. 6,271,898, incorporated herein by reference. While this procedure can be more complex and material sensitive, it can nonetheless provide more control over droplet size and molecular anchoring conditions for the cholesteric liquid crystal. In this case the liquid crystal droplet is coated by a shell isolating it from the binder. It may be possible to process the droplet particles in the form of a wet cake or slurry which is later dispersed in a suitable binder for coating. Other types of dispersions may be a regular array of polymer pockets filled with liquid crystalline material and sealed on the top by a phase separation process as disclosed in, for example, D. J. Broer et al, Society for Information Display 2004 Proceedings, pp 767.

In some embodiments, the substrate material will be formed by applying coated or printed layers directly on a deformable polymeric sheet that has a relatively smooth surface on or into which to incorporate the display elements. Alternatively, a fabric can be manufactured to have a smooth surface, such as with a neoprene coating that serves to partially planarize the surface of the fabric. However, in many embodiments of the invention the display will be formed on or integrally with substrates having rough surfaces such as cloth and similar fabric or textile materials. In embodiments where the surface of the substrate is undesirably rough, the substrate will require some degree of planarization in order to provide a smoother surface onto which the first electrode may be deposited. Smoothing out the surface helps to maintain a constant thickness for the cholesteric or other electro-optic layer. Planarization can be achieved in any number of ways, from the application of an organic layer, application of heat and/or mechanical pressure or the chemical modification of the surface. For example, one might smooth a substrate surface by application of a polymer coating followed by application of physical stress and heat, such as from a hot roll laminator. Alternatively, one can chemically treat the surface to melt or otherwise bring about a physical change in its degree of smoothness. Of course, as will be apparent to those of ordinary skill in the art, the degree of smoothness necessary is relative as long as it serves to help maintain a uniform thickness or gap between the electrodes so as to provide a uniform electric field and, consequently, drive uniformity across the entire display. Planarization need not render the substrate surface perfectly smooth or flat. In fact, in many embodiments the electrodes and liquid crystal layers of the displays of the invention will follow the minute contours of a fabric substrate, with the planarization layer or other planarization means functioning to eliminate only the most dramatic fluctuations in the substrate surface. Thus, these and other suitable means of planarizing (i.e., smoothing out) the substrate surface will be apparent to those of ordinary skill in the art in view of the instant disclosure.

A preferred manner of planarizing the substrate surface in accordance with the invention is the addition of a planarization layer. A planarization layer is a coating of material which, when applied to the substrate, will tend to smooth out the most dramatic fluctuations in the substrate so as to provide a generally smooth, though not necessarily flat, surface onto which to deposit the conducting electrodes. Preferred materials for use as a planarization layer in accordance with the invention are gelatin, neoprene and latex materials such NeoRez R967 available from NeoResins, Mass. The planarization layer also may be a polymeric sheet such as PET laminated onto the substrate.

As noted, the liquid crystal layer will, in the preferred embodiments, be bounded by conducting electrodes. The electrodes need not be identical. For example, in many embodiments, the electrode on the non-viewing side of the liquid crystal will be black or some other color, while the electrode on the view side will be transparent. In other embodiments, the electrodes on both sides of the liquid crystal layer will be transparent. In other embodiments still, an electrode or array of electrodes can be formed integrally with the substrate or the substrate itself can form one of the electrodes. An advantage to being able to use fabric substrates is that it enables greater flexibility in the manner in which the display can be configured. There are potentially many methods of applying and patterning the conductors. The conductors may be printed in some specified pattern using ink jet, screen or off-set printing. Alternatively the conducting materials may by sprayed or coated onto the fabric using a mask, stencil or pretreating the surface to form a chemical mask which allows the electrode material to only adhere to certain areas. In some cases it may be desirable to first lay down a uniform conducting coat and subsequently pattern the layer by chemically or mechanically deactivating regions of conductive material. In fact, it is contemplated that even the substrate itself can be manufactured as the conductor. For example, some flexible plastic materials are manufactured with an indium tin oxide (ITO) coating that may be patterned for use as electrodes. Suitable electrode materials for application to the substrates of the invention will be apparent to those of ordinary skill in the art in view of the instant disclosure and include conducting polymers, carbon nanotubes, metal or carbon conductive inks, ITO and the like. Electrode materials which are self leveling and which can be used in suitable thicknesses to obviate the need for a planarization layer are particularly desirable. Examples of materials for use as conducting electrodes in accordance with the present invention include Agfa conducting polymers ELP-3040, S300, and S2500 available from Agfa-Gevaert N.V., Belguim; Carbon Nanotube materials are available from EiKos,Inc., Franklin Mass.

The aforementioned electrodes can be patterned, formed into pixels of varying shapes or sizes, aligned into rows and columns so as to form a passive matrix and so on, all as will be apparent to those of ordinary skill in the art in view of the instant disclosure. Any means for addressing the liquid crystal known in the art and adaptable to a display having the deformability of the instant invention can be employed. In the preferred electrically addressable displays, the means for addressing the liquid crystal will be drive and control electronics operatively linked to the electrodes for application of driving voltages across the liquid crystal material in accordance with any suitable drive scheme known to those of ordinary skill in the art. Examples of suitable drive schemes include, but are not limited to, the conventional drive scheme disclosed in U.S. Pat. No. 5,644,330 implemented with either bipolar or unipolar drive chips, the dynamic drive scheme disclosed in U.S. Pat. Nos. 5,748,277 or 6,154,190 for faster or lower temperature response, or the cumulative drive scheme disclosed in U.S. Pat. No. 6,133,895, for video response, all of which are incorporated herein by reference. Alternatively, the means for addressing can be an optical method whereby the image is written on the display with white light or laser light in a manner such as disclosed in H. Yoshida et al., Journal of the SID, Vol. 5/3, 269–274, (1997), also incorporated herein by reference. Of course, in these embodiments, the displays can be fabricated without patterned electrodes.

In a preferred configuration, a high resolution display device in accordance with the invention is configured where the first conducting polymer is printed or otherwise patterned in the form of parallel strips to form rows of parallel conducting electrodes. The droplet dispersion is then coated on top of the rows of conductors, followed by a transparent conductor which is then printed, or otherwise coated and patterned on top of the droplet dispersion in the form of conductive strips (columns) in a direction perpendicular to the rows of conductors that are under the dispersion. In this way, a row and column matrix of electrodes is formed with the cholesteric dispersion in between. Voltage pulses are then multiplexed in such a way to selectively address each pixel of the display formed by the intersection of each row and column. When a high-resolution image is addressed on the fabric and the voltage removed, the image will be retained indefinitely until readdressed to form another image.

In carrying out the invention, it will often be desirable to employ an insulation layer or layers between the electrodes in order to insulate the conductors from each other and thereby minimize the potential for shorting. Accordingly, for purposes of the instant invention it is desirable to select materials that can be coated, printed, sprayed or otherwise laid down in a layer before and/or after the electro-optically responsive liquid crystal layer. The insulation layer must not significantly detract from the deformability or optics of the display. In accordance with the preferred embodiments of the invention, materials such as gelatin or latex are employed. Some particularly preferred insulating materials are polyurethane latex materials such as WITCOBOND W232 (available from Crompton Corporation, CT). Although an insulation layer such as gelatin is optional, experiments show that it leads to a decrease in the switching voltage on the order of 10–15 volts (f=250 Hz) when the liquid crystal layer is a cholesteric droplet dispersion. Without being bound by theory, this may be because the gelatin layer is enhancing the dielectric properties of the emulsion through the increase of the dielectric constant.

As noted above, the use of one or more durable protective coatings obviates the need to laminate a second substrate, thereby enhancing both the flexibility and durability of the display. Desirable protective coatings will be materials that will provide a tough, scratch and ware resistant coating over at least a portion, and preferably all, of the uppermost surface of the display, but not materially interfere with the optics of the system. Likewise, the most desirable materials will maintain the deformability of the system. Those of ordinary skill in the art will be able to select suitable materials in view of the instant disclosure. Preferred materials include acrylic or silicone paints, UV curable adhesives, PVA, latex materials and the like. Because some protective coatings will include solvents or other components which may be harmful to the electrodes or other elements of the display, in carrying out the invention it may be desirable to select an isolation layer material that will protect the other display elements from harmful components of the protective coat, or to include an additional protective material as an isolation layer interposed between the protective coat and the other display elements.

As will be apparent to those of ordinary skill in the art, displays according to the invention can be formed in many different configurations using some or all of the foregoing component layers. For example, the display materials may only appear on one side of the fabric leaving the other side untouched, or the display may be partially imbibed into and integrally formed with the substrate. Of course, the minimum requirements for the electrically addressable displays of the invention are the incorporation of a liquid crystal layer between a pair of conducting electrodes onto or into the substrate. Beyond this, there are multiple possible configurations and combinations which can effectively take advantage of the flexibility and/or drapability of the substrates according to the invention as will be apparent to those of ordinary skill in the art in view of the present disclosure.

The fabrication of these display devices involves printing, coating or other deposition means to incorporate the liquid crystal material, display electrodes as well as any insulating, isolation or other coatings into or onto a substrate in a manner that will allow the display to deform with the substrate. In view of the instant disclosure those of ordinary skill in the art will be able to select and employ suitable coating, printing and deposition techniques including, but not limited to, air brushing, ink jet, spin coating and spray printing, optionally in conjunction with various masks or stencils known in the art, screen printing, photolithography, chemical masking and so on, depending upon the particular substrates and display elements used. It is contemplated that any contact or non-contact method of applying coatings and conductors known in the art will be suitable for use in accordance with the instant disclosure.

In carrying out the invention it will also be possible to prepare a display on a remote substrate and then transfer it to the desired substrate such as a drapable fabric. In this case, a sequence of multiple coatings involving droplet dispersions, conductive coatings, and any desirable insulation coatings, isolation coatings, etc. that are needed to formulate a complete display device are coated on a temporary substrate from which the coated sequence can be removed upon drying or curing. The removed film now is a display element in itself without any substrate. The display film can then be laminated onto any object or material to which electrodes can be applied for connection to drive electronics. The casting or base layer of the display film may be used for printing all or a portion of the drive electronics as the printed electronic technology permits.

A multiple color reflective display can be fabricated by replacing the single cholesteric dispersion layer with two or more dispersion layers, each of a different reflective color layered on top of one another with conducting electrodes in between. A full color display can be made by layering red, R, green, G, and blue, B. With only one electrode layer between each color, the display is electronically addressed by a shared electrode addressing scheme possible with bistable cholesteric dispersions. Added brightness may be achieved if each of the R, G and B layers contains a stacked left twist and right twist dispersion layer. An infrared reflective display is possible where at least one of the droplet dispersion layers reflects in the infrared, such as might be used for night vision purposes. A multiple color display can also be prepared with a single dispersion layer wherein each pixel is divided into different primary colors such as red, green and blue, for additive color mixing. The patterned colors can be achieved as described, for example, U.S. Pat. No. 5,668,614, incorporated herein by reference.Sep. 16, 2004

Still further, a self-powered display may be achieved by using a solar panel as the substrate or a component of the substrate whereby light that is not reflected by the cholesteric material can be absorbed in the solar panel for conversion into electrical power for powering the display. It is also conceived that an active matrix substrate could be employed to create an actively driven cholesteric display, whereby the various display elements are sequentially layered on the active backplane. Further still, an optically addressed display is achieved by placing a photoconductive sheet over the lower conducting electrode. With a continuous voltage applied to the electrodes, light impinging the display film will locally alter the resistivity of the photoconductor and drive the display film. Such a display construction avoids the need of patterning the electrodes. The display can be addressed by an image suitably focused on the film, or written with a scanned laser beam as described in the publication "Reflective Display with Photoconductive Layer and Bistable Reflective Cholesteric Mixture" *Journal of the SID*, Vol. 5/3, pages 269–274 (1997) by J. Yoshida et al., incorporated herein by reference. Of course, other veneered stacks are possible depending on desired display

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. **1**–**5** illustrate various preferred display configurations according to the invention. FIG. **1** is a profile illustration of a cholesteric reflective display on a highly drapable fabric. The display **100** is a stack of layers that are coated, printed or laminated on a fabric substrate **101** made of fibrous material. The substrate **101** may be drapable and either opaque or transparent, consisting of natural or man-made fibers. The fabric material **101** may be of woven or non-woven fibers or may be a composite such as a fiber-reinforced thermoplastic material.

Because the surface of fabric is often very rough, it may be necessary to have a planarization layer **110**. The planarization layer may be coated, laminated or may be made to be an integral part of the fabric. In addition to at least partially smoothing out the surface, the planarization layer may serve several other purposes, such as adjusting the wetting and adhesion characteristics for the next layer of the sequence, adjusting the color, refractive index or other optical property of the film and so on. Layer **111** is a preparation layer that overlays layer **110** if more planarization is required or if **110** does not present a suitable surface for the first conducting electrode **120**. Coating is a preferred means of casting layer **111** over **110** and more than one coating may be required for unusually rough surfaces. Layer **111** may also serve as an insulating layer if the previous layer **110** is conductive. As shown, however, the next layer **120** is the first or lower conducting electrode. Normally, in the case of fabric substrates, the substrate is opaque. In this case the conducting electrode **120** can likewise be opaque, although it should not be reflective. Carbon based materials, such as conducting polymers are suitable as long at they provide sufficient conductivity; for example, less than 1000 Ohms/square resistivity, a parameter also controlled by the thickness of the layer. Carbon based materials are often desirable in that, often, they can be screen, inkjet or otherwise printed to form a desired electrode pattern.

If printing the conducting layer is not an option, it may be coated as a continuous sheet and then subsequently patterned. For example, a conducting polymer can be first coated then patterned by printing a deactivating agent with the desired pattern over the conducting polymer. An insulating layer **121** is coated over the conducting polymer in cases where the liquid crystal layer **130** does not provide sufficient insulation between the upper conductor **140** and the lower conductor **120** to prevent shorting.

The next layer in the sequence is the liquid crystal layer **130** which, as described above, can be a dispersion or an array of polymer walls filled with liquid crystal. As described above, a liquid crystal dispersion material can be made from any of several different processes such as, an emulsion, phase separation, or microencapsulation process. Preferred processes are dispersions prepared from latex emulsion, a PIPS phase separation or gelatin microencapsulation process as these materials can be easily coated or printed. If bistability is desired, the droplet size of the cholesteric dispersion should be large enough to allow a stable focal conic and planar texture, typically greater than 1.0 micron. The thickness of this coating determines the drive voltage of the display as well as the display brightness. To optimize brightness, it is desired that this layer be at least 4.0 microns in thickness. However, to maintain moderate to low drive voltages it is desirably less than 15 microns depending on the physical properties of the liquid crystal material. As a possible alternate to a dispersion, an array of polymer walls filled with liquid crystal can be employed, although this would require more coatings and processing.

An isolation coating **131** is coated over the liquid crystal layer in cases where it is needed to prevent material from the second or upper conducting layer from penetrating into the liquid crystal layer. Layer **131** may also serve as an insulation layer or as a wetting and adhesion layer for the transparent or upper conducting electrode. A transparent conducting layer **140** is then printed or coated and suitably patterned to serve as the upper electrode. Transparent conducting polymers or carbon nanotubes are preferred materials suitable for this purpose. The transparency to conductivity ratio depends on the thickness of the coating. If the response speed of the display is not an issue, a resistivity as high as a few thousand Ohms/square has been found suitable to drive cholesteric dispersions. Finally, in order to improve the ruggedness of the display and to protect the display elements from the environment, the transparent conductor **140** is overlaid with a flexible protective layer **150**. The protective layer **150** may be applied in one or more layers by coating, printing, laminating or a combination thereof.

In FIG. **2** there is shown an illustration of a cholesteric reflective display on a drapable fabric, where the number of layers is advantageously reduced by combining the functionality of the electrodes and planarization layers. The display **200** is a stack of layers that are coated, printed or laminated on a fabric substrate made of fibrous or other deformable material. The substrate **201** may be a drapable fabric consisting of natural or man-made fibers which is either opaque or transparent. The fabric material may be of woven or non-woven fibers or may be a composite such as a fiber-reinforced thermoplastic material. In this embodiment, the planarization layer **220** is conductive to serve both as an electrode and a planarization layer, as well as to prepare the surface for the insulating layer **221** where needed. The conductive layer **220** may be coated, laminated or may be made to be an integral part of the fabric. The transparent conducting materials such as conducting polymers or carbon nanotubes may be printed to a suitable pattern. The conductive layer can be patterned by local deactivation with UV or printing a deactivating solution such as, for example, bleach, to locally deactivate a conducting polymer. Following a coating or printing of the insulation layer **221** the liquid crystal containing layer **230** is cast as illustrated. This layer maybe a droplet dispersion, such as a polymer dispersed cholesteric liquid crystal, or an array of confining polymer cups to hold the liquid crystalline material. The transparent conducting electrode **240** completes the electro-optic component of the display stack which is then over coated or laminated with a protective layer, **250**.

FIG. **3** is a profile illustration of a cholesteric reflective display **300** on a flexible non-fiberous and non-transparent sheet substrate **301**, such as a thermoplastic, composite or cross-linked polymeric material. A preparation layer **311** is often required to provide improved planarization of the surface, adjust the color and light absorption of the substrate and present a suitable surface for wetting and attaching the lower conducting electrode layer **320**. A layer of cholesteric materials **330** suitably confined such as in polymer dispersion, is then cast onto the conductive layer followed by an isolation layer **331** coated over layer **330**. The isolation layer provides a surface on which to coat or print the transparent conducting electrode layer **340**, as well as to insulate from shorts and protect the liquid crystal layer. A protective layer **350** is then coated to protect the electro-optic elements below it from the environment.

FIG. **4** is a profile view of a cholesteric display **400** where the non-transparent substrate **401** is made from transparent material such as polyester (PET) or polycarbonate (PC) coated on the lower side with and ink or paint **402** to prevent light from passing through the film. The ink or paint coating is preferably black. The upper side of the transparent material contains the conducting layer **420** which, in this case, may be indium tin oxide (ITO) that is pre-coated and pre-etched. A cholesteric liquid crystal dispersion **430** then is coated over the conducting electrode layer **420** followed by a printing of the transparent electrode layer **440** and protective coating **450**.

FIG. **5** is a three-dimensional drawing **500** of a passive matrix configuration illustrating, in an exploded view, how the conducting transparent electrodes **540** patterned as rows, are electrically connected to conducting tabs **542** attached to the substrate **501**. The column electrodes **520** are electrically connected to tabs **522**, which also are attached to the substrate **501**. The tabs are used for interconnecting drive electronics, not shown. Since the tabs for both of the columns **520** and the rows **540** are disposed on the substrate **501**, attaching the drive electronics is greatly simplify. It will be apparent that the intermediate layers of the display, including the cholesteric dispersion layer, are not shown in the exploded view.

It will be apparent that the foregoing description in connection with FIGS. **1**–**5** is intended to illustrate the preferred cell configurations using components necessary for an electrically addressable display according to the invention. In each of the foregoing embodiments, it may be necessary or desirable to include any or all of the additional display components described above, and to coat a durable protective coat or series of coatings on top of the upper transparent conductor to insure a rugged display that is protected against the environment. Thus, although the most basic electro-optic elements of the preferred displays of the invention are a deformable substrate, a liquid crystal layer and a pair of electrodes, preferred display configurations shown in FIG. **1**–**5** include planarization layers to smooth the surface of the fabric or other substrate, preparation layers that serve multiple purposes as needed to further smooth the surface, adjust the surfaces wetting and adhesion characteristics for coating the next layer in the sequence, and/or to adjust the optical characteristics needed in the display, insulation layers to prevent electrical shorts between the lower conductor and upper transparent conductor, and isolation layers as needed to prevent chemical interaction between layers or suitably adjust wetting and adhesion characteristics.

FIGS. **6**–**9** show the measured optical and electro-optical characteristics of fabricated displays described in the Examples. FIG. **6** shows the reflectance versus wavelength measured from the cholesteric display on a fabric substrate of Example 1. The spectral reflectance from the planar texture **601** and from the focal conic texture **602** is shown in the experimental plot **600**. FIG. **7** is the electro-optic response curve showing the reflectance versus the voltage measured from the display on fabric of Example 1. Curve **651** shows the response of a voltage pulse when the sample is initially in the reflective planar texture while curve 652 shows the response of a voltage pulse when the sample is initially in the focal conic state.

FIG. **8** shows the reflectance versus wavelength measured from the cholesteric display on a plastic substrate of Example 12. The spectral reflectance from the planar texture **701** and from the focal conic texture **702** is shown in the experimental plot **700**. FIG. **9** is the electro-optic response curve showing the reflectance versus the voltage measured from the display on a plastic substrate of Example 12. Curve **751** shows the response of a voltage pulse when the sample is initially in the reflective planar texture while curve **752** shows the response of a voltage pulse when the sample is initially in the focal conic state.

FIG. **10** is a diagrammatic illustration of the parameters used in the determination of the drape coefficient. In illustration **800**, a fabric sheet is cut on a flat surface to a circle

860 of radius $R_2$. The shaded area 862 represents a projection, $S_P$ as viewed from above, of fabric draped over a pedestal in the shape of a disk 861 of radius $R_1$. The drape coefficient is calculated from the equation $100 (S_p-\pi R_1^2) / (\pi R_2^2-\pi R_1^2)$.

EXAMPLE 1

An operable 4×1 pixel cholesteric display was made by coating and printing the various display elements on a fabric substrate. The fabric substrate was a black woven rayon fabric (150 micron thick) coated with neoprene available from Thor Labs (Newton, N.J.). The neoprene coating served to partially planarize the fabric surface. The fabric was rinsed with the mixture of water and isopropanol (90:10%) to make the surface hydrophilic. A preparation layer of aqueous polyurethane dispersion, NeoRez R967 available from NeoResins, MA was deposited on the fabric with a Meyer rod # 8 (available from Chemsultants International, Mentor, Ohio) technique and allowed to dry at room temperature. The dry thickness of the preparation layer was approximately 10–12 microns. The preparation layer serves to further smooth the rather rough neoprene surface and to provide a chemical barrier for the next casting layer. A layer of conductive polymer (ELP-3040 available from Agfa-Gevaert, Belgium) was screen printed on the preparation layer as 4 pixels 25 mm wide, 18 mm long spaced 2 mm apart to serve as the electrodes of the passive matrix display. After coating the conducting polymer, it was cured at 100° C. for 10 minutes. The sheet resistivity of the conductive polymer layer was 800 Ω/sq. A thin insulation layer (1–2 μm) of the polyurethane dispersion NeoRez R967 was cast on the conductive layer using a doctor blade technique. A layer of encapsulated cholesteric liquid crystal in polymer binder was formed from a water-based emulsion and coated on the insulation layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. The thickness of encapsulated liquid crystal layer was approximately 8–10 μm. The ratio between liquid crystal and binder was from 4:1 to 5:1. The emulsion was prepared from 0.4 g of yellow CLC KLC 19 (EM Industries of Hawthorne, NY) and 0.27 g of NeoRez R967. To improve the display contrast, a small amount (0.3–0.4 wt %) of 4-hexylamino-4'-nitro-azobenzene dye was added to the liquid crystal before emulsification. The mixture was emulsified with a homogenizer (PowerGen 700) at 1000 rpm for 3–4 min at room temperature. The emulsified CLC formed droplets which are about 3–15 μm in diameter. The second conductive electrode was formed from a highly transparent conductive polymer, Dipcoat, available from Agfa. A thin layer of the conductive polymer was deposited using air brushing over a mask and cured at room temperature. The mask provided a continuous top electrode for the passive matrix display. The bistable cholesteric material could be addressed to the planar (yellow reflective) texture by application of 125 volts or to the focal conic (non-reflective texture) with application of 70 volts with frequency of 50 Hz and pulse width of 20 ms. The electro-optical curves are shown in FIG. 7. The data for reflectance vs. wavelength is presented in FIG. 6 with a contrast ratio of 12:1 and brightness of 26%.

EXAMPLE 2

An operable 4×1 pixel cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 1 except that for the display protection, a clear coat of polyurethane dispersion WITCOBOND W232 (available from Crompton Corporation, CT) was deposited on the top of the second conductive electrode using a doctor blade. The use of the transparent layer of WITCOBOND W232 with thickness approximately of 5–10 microns as a clear coat allowed one to increase the transmission due to the refractive index matching.

EXAMPLE 3

An operable 4×1 pixel cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 1 except that the second conductive electrode was made of the transparent conductive polymer 2500 available from Agfa. A thin layer of the conductive polymer was deposited using air brushing over a mask and cured at 45° C. for 3 min.

EXAMPLE 4

An operable single pixel cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 1 except the following. The first conductive electrode was made of the conductive polymer ELP-3040 and formed as one pixel electrode and was deposited with a Meyer rod #12. Two coatings of conductive polymers were deposited to reach desirable conductivity of the electrode. The preparation layer was coated from 5 wt % aqueous solution of Hi-Pure gelatin (available from Norland Products Inc.) using the Meyer rod #12 and dried at room temperature for 30 min. The second conductive electrode of conductive polymer Dipcoat was spin coated at 2000 rpm for 60 s and cured at room temperature for an hour. The bistable cholesteric material could be addressed to the planar (yellow reflective) texture by application of 170 volts or to the focal conic (non-reflective texture) with application of 60 volts with frequency of 250 Hz. The display film had a brightness of 31% at a wavelength of 590 nm.

EXAMPLE 5

An operable 4×1 pixel cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 4 except the following. The first conductive electrode of ELP-3040 was screen printed and patterned to form the row of 4 pixels as described in the Example 1. The bistable cholesteric material could be addressed to the planar (yellow reflective) texture by application of 150 volts or to the focal conic (non-reflective texture) with application of 50 volts with frequency of 1 Hz. The display film had a brightness of 27% at a wavelength of 610 nm.

EXAMPLE 6

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 1 except that first and second conductive electrodes were patterned to provide a 256 pixel display. The first electrode, made of conductive polymer ELP-3040, was screen printed on the preparation layer as 5 mm wide, 15 cm long strips spaced 1 mm apart to serve as the column electrodes of the passive matrix display. The second conductive electrode made of conductive polymer Dipcoat was deposited using air brushing over a mask and cured at room temperature. The mask was patterned to provide 5 mm wide, 15 cm long strips spaced 1 mm apart to form the row electrodes of the passive matrix display. Attached to the drive electronics and driven with an image using a cumulative drive scheme as disclosed in U.S. Pat. No. 6,133,895, the bistable cholesteric material could be addressed to the planar (yellow reflective) texture by application of 140 volts or to the focal conic (non-reflective texture) with application of 105 volts.

EXAMPLE 7

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 6 except that for display protection, a clear coat of polyurethane dispersion WITCOBOND W232 was deposited on the top of the second conductive electrode using a doctor blade.

EXAMPLE 8

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials layers are the same as in the Example 6 except that an insulation layer between the first conductive electrode and encapsulated liquid crystal layer was made of the polyurethane dispersion WITCOBOND W232.

EXAMPLE 9

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a fabric substrate. The sequence of the layers and materials are the same as in the Example 6 except that a second insulation layer was introduced between the encapsulated liquid crystal layer and the second transparent conductive electrode. The clear layer of polyurethane dispersion WITCOBOND W232 was deposited on the top of the encapsulated liquid crystal layer using a doctor blade. The thickness of this layer was approximately 2–3 microns. Also, this display does not have a top clear coat layer.

EXAMPLE 10

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a plastic substrate. The plastic substrate was a PET sheet with thickness of 137 microns available from Teijin (Japan). In order to establish a black background for the reflective display a black paint (KRYLON) was first coated on the back side of the substrate by spraying and dried at room temperature. A layer of conductive polymer (ELP-3040 available from Agfa-Gevaert, Belgium) was screen printed on the other side of the plastic substrate as 5 mm wide, 15 cm long strips spaced lmm apart to serve as the column electrodes of the passive matrix display. After coating, the conducting polymer was cured at 100° C. for 10 minutes. A thin insulation layer (1–2 μm) of the polyurethane dispersion WITCOBOND W232 (available from Crompton Corporation, CT) was cast on the conductive layer using a doctor blade technique. A layer of encapsulated cholesteric liquid crystal in the form of a water-based emulsion in a polymer binder was coated on the insulation layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. The thickness of encapsulated liquid crystal layer was approximately 8–10 μm. The emulsion was prepared from 0.4 g of yellow CLC KLC19 (EM Industries of Hawthorne, N.Y.) and 0.27 g of NeoRez R967 and was emulsified with a homogenizer (PowerGen 700) at 1000 rpm for 3–4 min. at room temperature. The content of liquid crystal and binder in the encapsulated layer was 78% and 22%, respectively. The emulsified CLC formed droplets which are about 3-15 μm in diameter. A second conductive electrode was formed of the highly transparent conductive polymer Dipcoat, available from Agfa. A thin layer of the conductive polymer was deposited using air brushing over a mask and cured at room temperature. The mask was patterned to provide 5 mm wide, 15 cm long strips spaced 1 mm apart to form the row electrodes of the passive matrix display. Connected to the drive circuitry for multiplexing and addressed to an image using a cumulative drive scheme as disclosed in U.S. Pat. No. 6,133,895, the bistable cholesteric material could be switched to the planar (yellow reflective) texture by application of 95 volts or to the focal conic (non-reflective texture) with application of 65 volts.

EXAMPLE 11

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a plastic substrate. The sequence of the layers and materials are the same as in the Example 10 except that a second insulation layer was introduced between encapsulated liquid crystal layer and the second transparent conductive electrode. The clear layer of polyurethane dispersion WITCOBOND W232 was deposited on the top of the encapsulated liquid crystal layer using a doctor blade. The thickness of this layer was approximately 2–3 microns.

EXAMPLE 12

An operable 2×6 pixel cholesteric display was made by coating and printing the various display elements on a plastic substrate. The plastic substrate was. a 137 micron thick PET sheet coated with an ITO conductive layer (available from Tijin, Japan). The ITO patterning was made by etching. Each pixel was 20 mm wide and 13 mm long and serves as the electrode of the passive matrix display. In order to establish a black background for the reflective display a black paint (KRYLON) was first coated on the back side of the substrate by spraying and dried at room temperature. A water-based emulsion of cholesteric liquid crystal in polymer binder was coated on the ITO layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. The thickness of encapsulated liquid crystal layer was approximately 8–10 μm. The emulsion was prepared from 0.4 g of green CLC KLC19 (EM Industries of Hawthorne, N.Y.) and 0.27 g of NeoRez R967 and was emulsified with a homogenizer (PowerGen 700) at 1000 rpm for 3–4 min at room temperature. The content of liquid crystal and binder in the encapsulated layer was 78% and 22%, respectively. The emulsified CLC formed droplets which are about 3–15 μm in diameter. A second conductive electrode of highly transparent conductive polymer, Dipcoat available from Agfa, was deposited using air brushing over a mask and cured at room temperature. The mask provides a solid electrode of the passive matrix display. The bistable cholesteric material could be addressed to the planar (yellow reflective) texture by application of 60 volts or to the focal conic (non-reflective texture) with application of 35 volts. The display film has a contrast ratio of 16:1 and brightness of 28%. The electro-optical curves are shown in FIG. **9**. The data for reflectance vs. wavelength is presented in FIG. **8** with a contrast ratio of 16:1 and brightness of 28%.

EXAMPLE 13

An operable 2×6 pixel cholesteric display was made by coating and printing the various display elements on a plastic substrate. The materials and sequence of the layers are the same as in the Example 12 except that a clear coat of the polyurethane dispersion WITCOBOND W232 was used for protection of the display. A thin transparent layer of polyurethane dispersion was deposited on the top of the second conductive electrode using a doctor blade. The thickness of this layer was approximately 2–3 microns.

EXAMPLE 14

An operable 2×6 pixel cholesteric display was made by coating and printing the various display elements on a plastic substrate. The materials and sequence of the layers are the same as in the Example 12 except that the encapsulated liquid crystal was CLC with a reflective band in the blue region of the spectrum. The bistable cholesteric material could be addressed to the planar (blue reflective) texture by application of 80 volts or to the focal conic (non-reflective texture) with application of 50 volts.

EXAMPLE 15

An operable 2×6 pixel cholesteric display was made by coating and printing the various display elements on a plastic substrate. The materials and sequence of the layers are the same as in the Example 12 except that the encapsulated liquid crystal was CLC with a reflective band in the yellow region of the spectrum. The bistable cholesteric material could be addressed to the planar (yellow-green reflective) texture by application of 70 volts or to the focal conic (non-reflective texture) with application of 40 volts.

EXAMPLE 16

An operable 2×6 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a plastic substrate. The materials and sequence of the layers are the same as in the Example 12 except that the encapsulated liquid crystal was CLC mixed with 1 wt % of BAB6. The purpose of the BAB6 additive was to improve contrast ratio and brightness. The assembled display was cured under UV light for 30 min under an applied electric field which switches the CLC into homeotropic state. The bistable cholesteric material could be addressed to the planar (green reflective) texture by application of 115 volts or to the focal conic (non-reflective texture) with application of 70 volts per pixel. The display film has a contrast ratio of 25:1 and brightness of 30%.

EXAMPLE 17

An operable 2×6 pixel cholesteric display was made by coating and printing the various display elements on a plastic substrate. The materials and sequence of the layers are the same as in the Example 16 except that the assembled display was cured under UV light for 30 min. in the absence of an electric field. The bistable cholesteric material could be addressed to the planar (green reflective) texture by application of 110 volts or to the focal conic (non-reflective texture) with application of 65 volts per pixel. The display film has contrast ratio of 19:1 and brightness of 30%.

EXAMPLE 18

An operable 4×1 pixel cholesteric display was made by coating and printing the various display elements on a black plastic substrate. The plastic substrate was a black PET sheet with thickness of 125 microns. A layer of conductive polymer ELP-3040 was screen printed on the plastic substrate as a 3.5×10 cm strip to serve as the solid electrode for the passive matrix display. After casting the conducting polymer was cured at 100° C. for 10 minutes. A water-based emulsion of CLC in NeoRez R967 binder was coated from water-based emulsion on the conductive polymer layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. A second conductive electrode was formed from the conductive polymer Dipcoat deposited as a thin layer using air brushing over a mask and cured at room temperature. The mask provides a 4×1 pixelated electrode.

EXAMPLE 19

An operable 16×16 pixel passive matrix cholesteric display was made by coating and printing the various display elements on a plastic substrate. Black paint for background and the first conductive layer were deposited as described in the Example 10. A layer of microencapsulated CLC in NeoRez R967 binder was coated from water-based slurry on the conductive polymer layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. Each individual droplet of CLC (KLC2 from EM Industries) was encapsulated in an individual shell consisting of cross-linked gelatin using a coacervation process (produced by Liquid Crystal Resources, Inc., IL). 5 wt % of latex binder was added to microencapsulated liquid crystal slurry to provide binder between individual droplets. The coating was very rugged and scratch resistant and does not require any protection layers. The bistable cholesteric material could be addressed to the planar (green reflective) texture by application of 60 volts or to the focal conic (non-reflective texture) with application of 35 volts using a cumulative drive scheme with frequency of 10 Hz and pulse width of 100 ms.

EXAMPLE 20

An operable 2×2 pixel cholesteric display was made by coating and printing the various display elements on a white paper substrate. In order to establish a black background for the reflective display a black paint (KRYLON) was first coated on the paper substrate by spraying and dried at room temperature. A first conductive electrode made of conductive polymer Dipcoat was air brushed over a mask and cured at room temperature for an hour. The mask provides 2 strips 15 mm wide, 50 mm long separated apart by 2 mm distance. A layer of encapsulated yellow CLC in NeoRez R967 binder was coated from water-based emulsion on the conductive polymer layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. A second conductive electrode of Dipcoat conductive polymer was deposited as a thin transparent layer using air brushing over a mask and cured at room temperature. The mask provides two strips 15 mm wide, 50 mm long separated apart by 2 mm distance. The display film has contrast ratio of 18:1 and brightness of 32%.

EXAMPLE 21

An operable 2×6 pixel cholesteric display with two electro-active layers was made by coating and printing the various display elements on a plastic substrate. The plastic substrate with patterned ITO layer, encapsulated CLC layer and the second conductive electrode were the same as in the Example 12. The CLC helixes were right handed (RH). The thin insulation layer of UV curable optical adhesives NOA 72 (available from Norland Products) was spin coated (at 3000 rpm) on the top of second conductive layer. The insulation layer was cured by exposure to UV lamp with intensity of several milliwatts per square centimeter for 4 min. A second layer of encapsulated cholesteric liquid crystal in polyurethane binder (NeoRez R967) was coated from water-based emulsion on the insulation layer using a doctor blade. The CLC helixes were left handed (LH). The thickness of encapsulated liquid crystal layer was approximately 8–10 μm. A third conductive transparent electrode made of conductive polymer Dipcoat was deposited over a mask using air brushing and cured at room temperature. The mask provides a solid electrode of the passive matrix display. Finally, the top clear coat of NOA 72 was spin coated (at 3000 rpm) on the third conductive electrode. Each encapsulated CLC layer can be addressed separately.

EXAMPLE 22

An operable 2×6 pixel cholesteric display with two electro-active layers was made by coating and printing the various display elements on a plastic substrate. The plastic substrate with patterned ITO layer was the same as in the Example 12. The encapsulated blue CLC layer in PVA binder was deposited from aqueous emulsion with a doctor blade technique as described previously. To prepare the emulsion, approximately 0.350 g of CLC, 0.250 g of 20% PVA aqueous solution, and 0.100 g of monohydric alcohol were emulsified with a homogenizer (PowerGen 700) at 1000 rpm for 3–4 min at room temperature. Encapsulating material, PVA (Celveol 205 with an 88% hydrolization, from Celanese Chemicals) was initially purified using Soxhlet extraction method. Emulsified CLC formed droplets which are about 2–10 μm in diameter. The thickness of encapsulated liquid crystal layer was approximately 10–12 μm. The thin insulation layer of UV curable NOA 72 was spin coated (at 3000 rpm) on the top of the encapsulated layer. The insulation layer was cured by exposure to UV lamp with intensity of several milliwatts per square centimeter for 4 min. A second conductive transparent electrode made of conductive polymer Dipcoat was deposited over a mask using air brushing and cured at room temperature. The mask provides a solid electrode of the passive matrix display. A second layer of yellow encapsulated cholesteric liquid crystal in PVA binder was coated from water-based emulsion on the second conductive electrode using a doctor blade. The thickness of encapsulated liquid crystal layer was approximately 10–12 μm. A second conductive transparent electrode made from conductive polymer Dipcoat was deposited over a mask using air brushing and cured at room temperature. The mask provides a solid electrode of the passive matrix display. The second insulation layer of UV curable NOA 72 was spin coated on the top of the second encapsulated CLC layer. A third conductive transparent electrode made of conductive polymer Dipcoat was deposited over a mask using air brushing and cured at room temperature. The mask provides a solid electrode of the passive matrix display. Each encapsulated CLC layer can be addressed separately.

EXAMPLE 22

An operable cholesteric layer was fabricated on fabric using droplet dispersions by the PIPS method. The first step was to pass a piece of black rayon fabric coated with neoprene through a laminator at 100° C. and then clean it with methanol to prepare the surface. Next, a layer of conductive polymer, Agfa EL-P 3040 was screen printed onto the neoprene and cured at 130° C. for 2 minutes to form the bottom electrode. An open-face Polymerization Induced Phase Separation (PIPS) mixture consisting of 75% KCL19 cholesteric liquid crystal and 25% pre-polymer mixture was cast onto the fabric using a #12 Meyer rod. The pre-polymer mixture had the following composition: 40% 2-Ethylhexyl Methacrylate, 31% Isobomyl Methacrylate, 18% Pentafluoropropyl Acrylate, 9% Trimethylol Propane Triacrylate, and 2% Irgacure 651, the photoinitiator. The film was then irradiated for 10 minutes with UV light (ELC4001, Electrolite Corp., 3.75 mW/cm$^2$) while contained in a clear Tupperwear container (Rubbermaid StainShield, 2.1 QT) being purged with a $N_2$ gas stream. The purpose of the $N_2$ stream was twofold; 1.) to enable polymerization of the acrylate monomers by purging the atmosphere with an inert gas thereby prohibiting the scavenging of radicals via $O_2$ [K. Studer, C. Decker, E. Beck, R. Schwalm, Progress in Organic Coatings 48 92–100 (2003)], 2.) to keep the black fabric cool while undergoing high intensity UV irradiation. During the curing process, the pre-polymer mixture polymerizes causing the liquid crystal to phase separate into droplets. After curing, the film was rinsed with Isopropyl Alcohol to remove any non-encapsulated liquid crystal present on the surface. After rinsing, the sample is dried using compressed air. Finally, the surface was segmented into 3 pixels using Scotch tape (3M) strips and 5 layers of Dipcoat conductive polymer (700) were airbrushed onto the surface of the film and allowed to dry in air for 15 minutes. After drying, the tape was removed and the pixels were individually switchable. The sample was switched at 170 Volts (f=20 Hz) to the planar state and at 100 Volts (f=20 Hz) to the focal conic state. In the planar state, the maximum reflectivity is 23% at 500 nm whereas the focal conic state has a reflectivity of 8.25% at 500 nm. The sample was very flexible—easily rolling around a pencil or conforming to a rounded surface without changing the bistable liquid crystal texture.

EXAMPLE 24

An operable cholesteric layer was fabricated on the polymer planarized fabric of Example 23 using droplet dispersions by the PIPS method. The first step was to clean the neoprene pre-planarization layer that is coated on the fabric with Isopropyl Alcohol to prepare the surface. Next, a polymer planarization layer was added to smooth out the neoprene layer. The polymer planarization layer consists of a mixture of 82% 2-Ethylhexyl Methacrylate 10% Pentafluoropropyl Methacrylate, 6% Trimethylol Propane Triacrylate, and 2% Irgacure 651. If the fabric substrate is not planarized, the weave of the substrate will cause nonuniformities in the planar texture across the pixel as thin spots will switch at a lower voltage than thicker spots. A layer of conductive polymer, Agfa EL-P 3040 with 1.0% adhesion promoter (PLM158) and 0.5% wetting agent (TPR156), was screen printed through a 4-pixel mask onto the substrate and cured at 85° C. for 40 minutes to form the bottom electrode. An open-faced PIPS mixture consisting of 75% KCL19 cholesteric liquid crystal and 25% pre-polymer mixture was cast onto the fabric using a #12 Meyer rod and cured as in Example 23. After curing, the film was rinsed with Isopropyl Alcohol to remove any non-encapsulated liquid crystal present on the surface. After rinsing, the sample is dried using a $N_2$ stream. Finally 15 layers of Dipcoat conductive polymer were airbrushed onto the surface of the PIPS film and allowed to dry in air for 15 minutes. The sample was switched at 130 Volts (f=20 Hz) to the planar state and at 60 Volts (f=20 Hz) to the focal conic state. The sample was very flexible—easily rolling around a pencil or conforming to a rounded surface without changing the bistable liquid crystal texture.

## EXAMPLE 25

An operable cholesteric layer was fabricated on planarized fabric using droplet dispersions by the PIPS method in the same method as in Example 24 with the exception that an insulation layer was added between the first conductive layer and the open-faced PIPS layer. The method of preparation is identical to Example 24 up to and including the first conductive layer. In order to prevent top to bottom shorts from the bottom layer of conductive polymer to the top layer of conductive polymer, an insulation layer was applied over the first conductive layer. The insulation layer consists of a thin (~5 micron) layer of pre-polymer (50% Bisphenol A Glycerolate Diacrylate, 48% Isopropanol, and 2% Irgacure) that is cast using a number 2.5 wire-wound rod and is UV-polymerized in a nitrogen environment for 10 minutes. The polymeric composition of the insulation layer is not that critical so long as it wets the surface of the conductive polymer and the planarization layer. The subsequent PIPS layer and remaining layers were added to the insulation layer as described in Example 24. The sample was switched at 150 Volts (f=20 Hz) to the planar state and at 70 Volts (f=20 Hz) to the focal conic state. The sample was very flexible—easily rolling around a pencil or conforming to a rounded surface without changing the bistable liquid crystal texture.

## EXAMPLE 26

An operable cholesteric layer was fabricated on planarized fabric using droplet dispersions by the PIPS method in the same method as in Example 25 with the exception that an isolation layer was added between the polymer planarization layer and the first conductive layer. The method of preparation is identical to Example 24 up to and including the polymer planarization layer. To enhance the wetting of the conductive polymer to the planarization layer, a thin isolation layer was used consisting of 50% Bisphenol A Glycerolate Diacrylate, 48% Isopropanol, and 2% Irgacure. This layer was cast using a number 2.5 wire-wound rod and UV cured for 15 minutes in an $N_2$ environment. A layer of conductive polymer, Agfa EL-P 3040, was deposited over the isolation layer by screen printing through a 4-pixel mask onto the substrate and cured at 85° C. for 40 minutes to form the bottom electrode. The remainder of the sample was prepared identically to Example 25 from the insulation layer forward. The sample was switched at 150 Volts (f=20 Hz) to the planar state and at 70 Volts (f=20 Hz) to the focal conic state. The sample was very flexible—easily rolling around a pencil or conforming to a rounded surface without changing the bistable liquid crystal texture.

## EXAMPLE 27

A sheet of the bare rayon/neoprene fabric substrate material of Thor Labs (Newton, N.J.) used in Examples 1–9 and 22–26 was cut to a circle of diameter of 30 cm then draped over a pedestal of diameter of 18 cm and the projection photographed and area measured. A drape coefficient of 53% was measured for the bare fabric substrate. The substrate was then coated with the same layers as Example 1 and the drape coefficient again measured and found to be 59%, only slightly larger than the bare substrate.

What is claimed is:

**1**. A drapable electrically addressable liquid crystal display comprising a substrate material, a layer of liquid crystal material, a first conducting electrode disposed on a first side of said liquid crystal layer proximal said substrate, and a second conducting electrode disposed on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry wherein said substrate is selected from a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper and display has a drape coefficient less than 100%.

**2**. The display of claim **1** further including a planarization layer interposed between said substrate and said first electrode.

**3**. The display of claim **1** further including an insulation layer disposed between at least one of said electrodes and said liquid crystal layer.

**4**. The display of claim **1** further including a protective coating disposed as un uppermost layer of at least a portion of said display.

**5**. The display of claim **1** wherein one side of said substrate is smoother than an opposite side of said substrate.

**6**. The display of claim **5** wherein said one side of said substrate is made smoother by deposition of a layer of material thereon.

**7**. The display of claim **1** wherein at least one of said electrodes is a conducting polymer or carbon nanotube material.

**8**. The display of claim **1** wherein said second electrode is substantially optically transmissive.

**9**. The display of claim **1** wherein said liquid crystal lays comprises cholesteric liquid crystal material.

**10**. The display of claim **9** wherein said liquid crystal layer comprises a dispersion of droplets of said liquid crystal material.

**11**. The display of claim **10** wherein said dispersion is selected from an emulsion, a phase separated liquid crystal material, or a microencapsulated liquid crystal material.

**12**. The display of claim **11** wherein said dispersion is a polyurethane latex emulsion.

**13**. The display of claim **12** wherein said emulsion comprises a mix of liquid crystal and latex in a ratio of from about 2:1 to about 6:1.

**14**. The display of claim **9** wherein said liquid crystal has a positive dielectric anisotropy and a pitch length effective to reflect light in the visible or infrared spectrum.

**15**. The display according to claim **1** further comprising a layer polyurethane latex interposed between said substrate and said, first electrode.

**16**. The display of claim **1** wherein said first electrode is comprised of said substrate.

17. The display of claim 1 including a plurality of conducting electrodes arranged in substantially parallel lines on a first side of said liquid crystal layer proximal said substrate, and a plurality of conducting electrodes arranged in substantially parallel lines on an opposite side of said liquid crystal layer, said lines of electrodes on opposite sides of said liquid crystal layer being oriented substantially perpendicular to each other.

18. The display of claim 1 further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material.

19. The display of claim 1 further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material, and including conducting electrodes disposed on opposite sides thereof, whereby said additional layer is independently electrically addressable.

20. The display of claim 1 wherein said display has a drape coefficient less than about 98%.

21. The display of claim 1 wherein said display has a drape coefficient less than about 95%.

22. The display of claim 1 operatively linked to electronic drive circuitry.

23. The display according to claim 1 further including a layer at photoconductive material interposed between said liquid crystal layer and said first electrode.

24. The display according to claim 1 wherein said first electrode comprises an active matrix backplane. said first electrode comprises an active matrix backplane.

25. A flexible or drapable reflective liquid crystal display comprising a non-transparent flexible or drapable substrate material, a layer of liquid crystal material, a first conducting electrode coated, printed or laminated on a first side of said liquid crystal layer proximal said substrate, and a second conducting electrode coated, printed or laminated on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry wherein said substrate is selected from a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper.

26. The display of claim 25 wherein said substrate is itself non-transparent.

27. The display of claim 25 wherein said substrate includes a layer of non-transparent material disposed thereon to render it non-transparent.

28. The display of claim 25 further including a planarization layer interposed between said substrate and said first electrode.

29. The display of claim 25 further including an insulation layer disposed between at least one of said electrodes and said liquid crystal layer.

30. The display of claim 25 further including a protective coating disposed as an uppermost layer of at least a portion of said display.

31. The display of claim 25 wherein one side of said substrate is smoother than an opposite side of said substrate.

32. The display of claim 31 wherein said one side of said substrate is made smoother by deposition of a layer of material thereon.

33. The display of claim 25 wherein at least one of said electrodes is a conducting polymer or carbon nanotube material.

34. The display of claim 25 wherein said second electrode is substantially optically transmissive.

35. The display of claim 25 wherein said liquid crystal layer comprises cholesteric liquid crystal material.

36. The display of claim 35 wherein said liquid crystal layer comprises a dispersion of droplets of said liquid crystal material.

37. The display of claim 36 wherein said dispersion is selected from an emulsion, a phase separated liquid crystal material, or a microencapsulated liquid crystal material.

38. The display of claim 37 wherein said dispersion is a polyurethane latex emulsion.

39. The display of claim 38 wherein said emulsion comprises a mix of liquid crystal and latex in a ratio of from about 2:1 to about 6:1.

40. The display of claim 35 wherein said liquid crystal has a positive dielectric anisotropy and a pitch length effective to reflect light in the visible or infrared spectrum.

41. The display according to claim 25 further comprising a layer of polyurethane latex interposed between said substrate and said first electrode.

42. The display of claim 25 wherein said first electrode is comprised of said substrate.

43. The display of claim 25 including a plurality of conducting electrodes arranged in substantially parallel lines on a first side of said liquid crystal layer proximal said substrate, and a plurality of conducting electrodes arranged in substantially parallel lines on an opposite side of said liquid crystal layer, said lines of electrodes on opposite sides of said liquid crystal layer being oriented substantially perpendicular to each other.

44. The display of claim 25 further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material.

45. The display of claim 25 further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material, and including conducting electrodes disposed on opposite sides thereof, whereby said additional layer is independently electrically addressable.

46. The display of claim 25 operatively linked to electronic drive circuitry.

47. The display according to claim 25 further including a layer of photoconductive material interposed between said liquid crystal layer and said first electrode.

48. The display according to claim 25 wherein said first electrode comprises an active matrix backplane.

49. The display of claim 25 having no frame structure adapted to maintain any individual layers of said display in sliding apposition.

50. The display of claim 25 wherein said substrate is drapable.

51. The display of claim 50 wherein said display has a drape coefficient less than about 98%.

52. The display of claim 50 wherein said display has a drape coefficient less than about 95%.

53. An electrically addressable liquid crystal display comprising, as a substrate, paper, a sheet of polymeric material or textile fabricated from natural or synthetic fibers a layer of liquid crystal material, a first conducting electrode coated, printed or laminated on a first side of said liquid layer proximal said substrate and a second conducting electrode coated, printed or laminated on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry and display has a drape coefficient less than 100%.

54. The display of claim 53 further including a planarization layer interposed between said substrate and said first electrode.

55. The display of claim 53 further including an insulation layer disposed between at least one of said electrodes and said liquid crystal layer.

**56**. The display of claim **53** further including a protective coating disposed as un uppermost layer of at least a portion of said display.

**57**. The display of claim **53** wherein one side of said substrate is smoother than an opposite side of said substrate.

**58**. The display of claim **57** wherein said one side of said substrate is made smoother by deposition of a layer of material thereon.

**59**. The display of claim **53** wherein at least one of said electrodes is a conducting polymer or carbon nanotube material.

**60**. The display of claim **53** wherein said second electrode is substantially optically transmissive.

**61**. The display of claim **50** wherein said liquid crystal layer comprises cholesteric liquid crystal material.

**62**. The display of claim **61** wherein said liquid crystal layer comprises a dispersion of droplets of said liquid crystal material.

**63**. The display of claim **62** wherein said dispersion is selected from an emulsion, a phase separated liquid crystal material, or a microencapsulated liquid crystal material.

**64**. The display of claim **63** wherein said dispersion is a polyurethane latex emulsion.

**65**. The display of claim **64** wherein said emulsion comprises a mix of liquid crystal and latex in a ratio of from about 2:1 to about 6:1.

**66**. The display of claim **61** wherein said liquid crystal has a positive dielectric anisotropy and a pitch length effective to reflect light in the visible or infrared spectrum.

**67**. The display according to claim **53** further comprising a layer of polyurethane latex interposed between said substrate and said first electrode.

**68**. The display of claim **53** wherein said first electrode is comprised of said substrate.

**69**. The display of claim **53** including a plurality of conducting electrodes arranged in substantially parallel lines on a first side of said liquid crystal layer proximal said substrate, and a plurality of conducting electrodes arranged in substantially parallel lines on an opposite side of said liquid crystal layer, said lines of electrodes on opposite sides of said liquid crystal layer being oriented substantially perpendicular to each other.

**70**. The display of claim **53** further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material. including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material.

**71**. The display of claim **53** further including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material, and including conducting electrodes disposed on opposite sides thereof, whereby said additional layer is independently electrically addressable.

**72**. The display of claim **53** wherein said display has a drape coefficient less than about 98%.

**73**. The display of claim **53** wherein said display has a drape coefficient less than about 95%.

**74**. The display of claim **53** operatively linked to electronic drive circuitry.

**75**. The display according to claim **53** further including a layer of photoconductive material interposed between said liquid crystal layer and said first electrode.

**76**. The display according to claim **53** wherein said first electrode comprises an active matrix backplane.

**77**. The display of claim **53** having no frame structure adapted to maintain any individual layers of said display in sliding apposition.

**78**. A method of preparing a drapable or flexible liquid crystal display on a drapable or flexible substrate material comprising coating, printing or laminating a first conducting electrode on said substrate, coating printing or laminating a layer of liquid crystal material on said first electrode and coating printing or laminating a second conducting electrode on said liquid crystal layer and adapting said electrode to be connected to electronic drive circuitry wherein said substrate is selected from a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper.

**79**. The method of claim **78** further comprising optionally coating, printing or laminating one or more additional layers selected from a planarization layer, an insulation layer and a protective coating layer on or between one or more of said electrode layers, liquid crystal layer or substrate.

**80**. A drapable liquid crystal display prepared according to the method of claim **76** wherein said substrate is drapable.

**81**. A flexible liquid crystal, display prepared according to the method of claim **78** wherein said substrate is flexible.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 7,236,151 B2
APPLICATION NO. : 11/006100
DATED : June 26, 2007
INVENTOR(S) : Doane et al.



It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Under item (56), References Cited, Other Publications, page 2, column 2, line 20, please delete “stimulation”, and insert therefor --simulation.--

Under item (56), References Cited, Other Publications, page 3, column 2, line 1, please delete “Crystal” and insert therefor --Crystals.--

In the claims, column 28, line 47, claim 9, please delete “lays” and insert therefor --layer--.

In the claims, column 29, line 24, claim 23, please delete “at” and insert thereof --of--.

In the claims, column 32, lines 1-3, please delete “including at least one additional liquid crystal layer disposed adjacent said layer of liquid crystal material.” in its entirety.

Signed and Sealed this

Eighth Day of July, 2008

Jon W. Dudas

JON W. DUDAS
*Director of the United States Patent and Trademark Office*

US007236151C1

(12) **EX PARTE REEXAMINATION CERTIFICATE** (8128th)

**United States Patent** (10) **Number: US 7,236,151 C1**

**Doane et al.** (45) **Certificate Issued: Mar. 29, 2011**

(54) **LIQUID CRYSTAL DISPLAY**

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**Reexamination Request:**
No. 90/010,932, Apr. 14, 2010

**Reexamination Certificate for:**

| | |
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| Patent No.: | **7,236,151** |
| Issued: | **Jun. 26, 2007** |
| Appl. No.: | **11/006,100** |
| Filed: | **Dec. 7, 2004** |

Certificate of Correction issued Jul. 8, 2008.

**Related U.S. Application Data**

(60) Provisional application No. 60/565,586, filed on Apr. 27, 2004, and provisional application No. 60/539,873, filed on Apr. 28, 2004.

(51) **Int. Cl.**
***G09G 3/36*** (2006.01)

(52) **U.S. Cl.** .......................................... **345/87**; 345/107

(58) **Field of Classification Search** ........................ None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,566,935 | A | 1/1986 | Hornbeck | |
| 4,680,579 | A | 7/1987 | Ott | |
| 6,017,468 | A | 1/2000 | Chung et al. | |
| 6,147,741 | A | 11/2000 | Chen et al. | |
| 6,518,944 | B1 | 2/2003 | Doane et al. | |
| 6,723,479 | B2 | 4/2004 | Van De Witte et al. | |
| 6,977,099 | B2 | 12/2005 | Umeya et al. | |
| 7,072,095 | B2 | 7/2006 | Liang et al. | |
| 7,170,481 | B2 | 1/2007 | Doane et al. | |
| 7,236,151 | B2 | 6/2007 | Doane et al. | |
| 2002/0167500 | A1 | 11/2002 | Gelbman | |
| 2003/0214471 | A1 | 11/2003 | Topelberg | |
| 2005/0003144 | A1 | 1/2005 | Buttgen et al. | |
| 2005/0179678 | A1 | 8/2005 | Nose et al. | |
| 2005/0195354 | A1 | 9/2005 | Doane et al. | |
| 2006/0066803 | A1 * | 3/2006 | Aylward et al. | 349/158 |
| 2006/0124899 | A1 | 6/2006 | Welter | |
| 2007/0026163 | A1 | 2/2007 | Schneider et al. | |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| EP | 1058147 | 12/2000 |
| JP | 3168613 | 7/1991 |
| WO | 02/093240 | 11/2002 |
| WO | 2004029708 | 4/2004 |

OTHER PUBLICATIONS

R.D. Sterling et al., "Video–Rate Liquid Crystal Light Valve Using Amorphous Silicon Photoconductor" proceedings of the SID, XXI, 327–329 (1990).

H. Hiji et al., SID Digest of Papers, vol. XXXIV, 1560–1563, (2005).

E. Sackman, J. Chem Phys. Soc., 93, 7088–7090 (1971).

T. Ikeda, J. Mater. Chem., 13, 2037–2057 (2003).

S. Pieraccini et al., Chem., Comm., 598–599 (2003).

S. Pieraccini et al., Chem. Eur. J., 10, 5632–5639 (2004).

B.L. Feringa et al., J. Chem. Soc. Chem. Comm., 288–290, (1993).

B.L. Feringa et al., Chemical Reviews, vol. 100, pp. 1789–1816 (2000).

Li et al., J. Am. Chem. Soc., 9 vol. 129, pp. 12908–12909 (2007).

A. Bobrovsky et al., Polymers for Advanced Technologies, vol. 13, pp. 595–600 (2002).

(Continued)

*Primary Examiner*—Tuan H Nguyen

(57) **ABSTRACT**

A flexible liquid crystal display is provided wherein an addressable liquid crystal layer is disposed on a single flexible substrate so that the display itself will exhibit flexibility. The substrate is preferably a flexible non-transparent material and more preferably a drapable material such as fabric.

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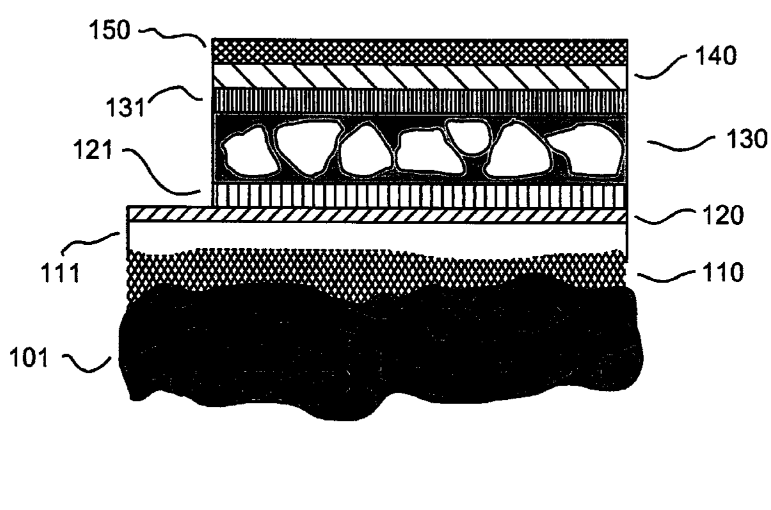

OTHER PUBLICATIONS

M. Brehmer et al., Advanced Materials, 10, 1438–1441 (1998).

P. van de Witte et al., Jornal of Applied Physics, 85, 7517–7521 (1999).

J.W. Doane et al., Proceedings of Japan Diaplay '92 (Hiroshima), pp. 73–76 (1992).

Fundamentals of Liquid Crystal Devices, D–K Yang and S.T. Wu, Chapter 1 (John Wiley & Sons, New York 2006).

Office Action dated Mar. 8, 2006 from Application No. 11/046,487 filed Jan. 28, 2005, which has issued to U.S. Patent No. 7,170,481.

* cited by examiner

# EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

**Matter enclosed in heavy brackets [ ] appeared in the patent, but has been deleted and is no longer a part of the patent; matter printed in italics indicates additions made to the patent.**

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

Claims **3**, **45**, **49**, **51**, **52** and **55** are cancelled.

Claims **1**, **4**, **25**, **29**, **40**, **43**, **46**, **53**, **56** and **78-80** are determined to be patentable as amended.

Claims **2**, **5-11**, **14**, **17-22**, **26-28**, **30-37**, **44**, **50**, **54**, **57-63**, **66**, **69-74** and **81** dependent on an amended claim, are determined to be patentable.

Claims **12**, **13**, **15**, **16**, **23**, **24**, **38**, **39**, **41**, **42**, **47**, **48**, **64**, **65**, **67**, **68** and **75-77** were not reexamined.

**1**. A drapable electrically addressable liquid crystal display comprising a substrate material, a layer of liquid crystal material, a first conducting electrode disposed on a first side of said liquid crystal layer proximal said substrate, and a second conducting electrode disposed on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry*, an electrical insulation layer disposed between and in contact with at least one of said electrodes and said liquid crystal layer,* wherein said substrate is selected from a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper and display has a drape coefficient less than 100%.

**4**. The display of claim **1** further including a protective coating disposed as **[**un**]** *an* uppermost layer of at least a portion of said display.

**25**. A **[**flexible or**]** drapable reflective liquid crystal display comprising a non-transparent **[**flexible or**]** drapable substrate material, a layer of liquid crystal material *dispersed in polymer,* a first conducting electrode coated, printed or laminated on a first side of said liquid crystal layer proximal said substrate, and a second conducting electrode coated, printed or laminated on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry wherein said substrate is selected from a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper.

**29**. The display of claim **25** further including an *electrical* insulation layer disposed between *and in contact with* at least one of said electrodes and said liquid crystal layer.

**40**. The display of claim **35** wherein said liquid crystal has a positive dielectric anisotropy and a pitch length effective to reflect light in the visible **[**or infrared**]** spectrum.



**43**. The display of claim **25** **[**including a plurality of conducting electrodes arranged in substantially parallel lines on a first side of said liquid crystal layer proximal said substrate, and a plurality of conducting electrodes arranged in substantially parallel lines on an opposite side of said liquid crystal layer, said lines of electrodes on opposite sides of said liquid crystal layer being oriented substantially perpendicular to each other**]** *wherein said first conducting electrode is patterned as parallel strips to form rows of conducting electrodes and said second conducting electrode is patterned as parallel strips to form columns of conducting electrodes, said rows of conducting electrodes and said columns of conducting electrodes being perpendicular to each other.*

**46**. The display of claim **25** **[**operatively linked**]** *connected* to **[**electronic **]** drive **[**circuitry**]** *electronics*.

**53**. An electrically addressable liquid crystal display comprising, as a substrate, paper, a sheet of polymeric material or a textile fabricated from natural or synthetic fibers, a layer of liquid crystal material, a first conducting electrode coated, printed or laminated on a first side of said liquid *crystal* layer proximal said substrate, and a second conducting electrode coated, printed or laminated on a second side of said liquid crystal layer distal of said substrate, said electrodes adapted to be connected to electronic drive circuitry*, an electrical insulation layer disposed between and in contact with at least one of said electrodes and said liquid crystal layer,* and *said* display has a drape coefficient less than 100%.

**56**. The display of claim **53** further including a protective coating disposed as **[**un**]** *an* uppermost layer of at least a portion of said display.

**78**. A method a preparing a drapable or flexible liquid crystal on a drapable or flexible substrate material comprising coating, printing or laminating a first conducting electrode on said substrate, coating, printing or laminating a layer of liquid crystal material on said first electrode, coating, printing or laminating a second conducting electrode on said liquid crystal layer*, disposing an electrical insulating layer between and in contact with one of said electrodes and said liquid crystal layer,* and adapting said **[**electrode**]** *electrodes* to be connected to electronic drive circuitry, wherein said substrate is selected from a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper.

**79**. The method of claim **78** further comprising optionally coating, printing or laminating one or more additional layers selected from a planarization layer**[**, an insulation layer**]** and a protective coating layer on or between one or more of said electrode layers, liquid crystal layer or substrate.

**80**. A drapable liquid crystal display prepared according to the method of claim **[**76**]** *78* wherein said substrate is drapable.

* * * * *

US007288014B1

(12) United States Patent
George et al.

(10) Patent No.: US 7,288,014 B1
(45) Date of Patent: Oct. 30, 2007

(54) DESIGN, FABRICATION, TESTING, AND CONDITIONING OF MICRO-COMPONENTS FOR USE IN A LIGHT-EMITTING PANEL

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/756,266**

(22) Filed: **Jan. 14, 2004**

**Related U.S. Application Data**

(63) Continuation-in-part of application No. 10/214,768, filed on Aug. 9, 2002, now Pat. No. 6,822,626, which is a continuation-in-part of application No. 09/697, 358, filed on Oct. 27, 2000, now Pat. No. 6,762,566.

(51) **Int. Cl.**
***H01B 17/49*** (2006.01)

(52) **U.S. Cl.** .......................... **445/24**; 313/582; 438/30

(58) **Field of Classification Search** ................ 313/582; 445/24; 438/30
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,559,190 | A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 | A | 2/1972 | Lay | 313/109.5 |
| 3,704,052 | A | 11/1972 | Coleman | 316/17 |
| 3,755,027 | A | 8/1973 | Gilsing | 156/67 |
| 3,848,248 | A | 11/1974 | MacIntyre, Jr. | 340/324 M |
| 3,969,651 | A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 | A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 | A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 | A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 | A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | 1/1984 | Aboelfotoh | 340/701 |
| 4,534,743 | A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |

(Continued)

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

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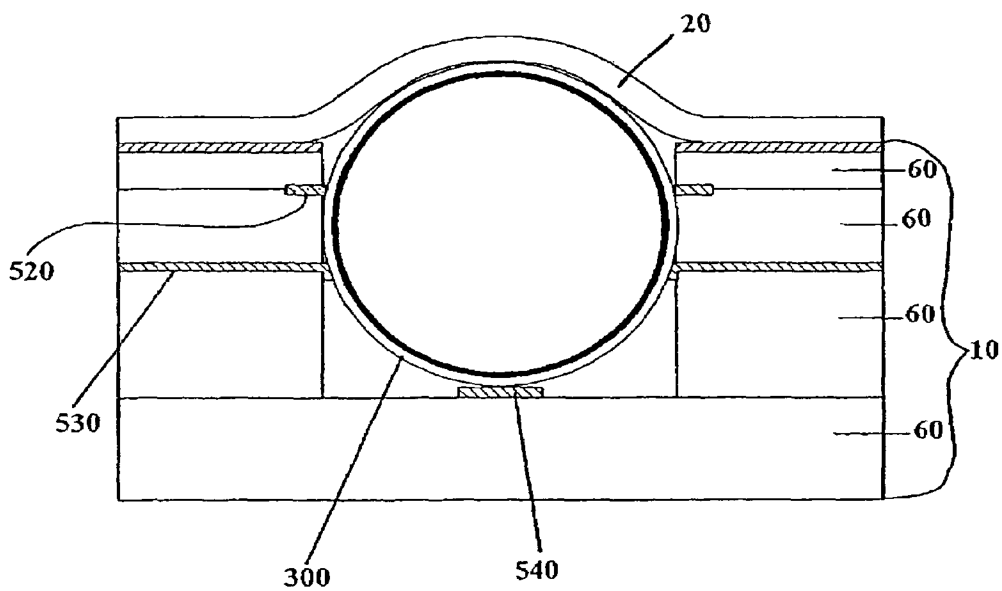
(74) *Attorney, Agent, or Firm*—Kilpatrick Stockton LLP

(57) **ABSTRACT**

A method of forming micro-components is disclosed. The method includes pretesting and conditioning of the micro-components. The micro-components that fail testing or conditioning are discarded, and those remaining are assembled into a panel.

**8 Claims, 15 Drawing Sheets**



U.S. PATENT DOCUMENTS


| | | | | |
|---|---|---|---|---|
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,912,364 | A | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,194,027 | A | 3/1993 | Kruskopf et al. | 445/24 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,008,582 | A * | 12/1999 | Asano et al. | 313/582 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A * | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,120,975 | A * | 9/2000 | Tokai et al. | 430/321 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 * | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 6,545,422 | B1 * | 4/2003 | George et al. | 315/169.3 |
| 6,570,335 | B1 * | 5/2003 | George et al. | 315/169.3 |
| 6,577,062 | B2 * | 6/2003 | Itokawa et al. | 313/582 |
| 6,612,889 | B1 * | 9/2003 | Green et al. | 445/24 |
| 6,620,012 | B1 * | 9/2003 | Johnson et al. | 445/3 |
| 6,646,388 | B2 * | 11/2003 | George et al. | 315/169.3 |
| 6,762,566 | B1 * | 7/2004 | George et al. | 315/169.3 |
| 6,764,367 | B2 * | 7/2004 | Green et al. | 445/24 |
| 6,791,264 | B2 * | 9/2004 | Green et al. | 313/582 |
| 6,796,867 | B2 * | 9/2004 | George et al. | 445/24 |
| 6,801,001 | B2 * | 10/2004 | Drobot et al. | 315/169.3 |
| 6,822,626 | B2 * | 11/2004 | George et al. | 345/60 |
| 6,902,456 | B2 * | 6/2005 | George et al. | 445/24 |
| 6,935,913 | B2 * | 8/2005 | Wyeth et al. | 445/3 |
| 6,975,068 | B2 * | 12/2005 | Green et al. | 313/582 |
| 7,005,793 | B2 * | 2/2006 | George et al. | 313/484 |
| 7,025,648 | B2 * | 4/2006 | Green et al. | 445/24 |
| 7,122,961 | B1 * | 10/2006 | Wedding | 313/582 |
| 7,125,305 | B2 * | 10/2006 | Green et al. | 445/24 |
| 7,137,857 | B2 * | 11/2006 | George et al. | 445/24 |
| 7,140,941 | B2 * | 11/2006 | Green et al. | 445/24 |
| 7,157,854 | B1 * | 1/2007 | Wedding | 313/582 |
| 7,176,628 | B1 * | 2/2007 | Wedding | 313/582 |
| 2001/0008825 | A1 | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0024084 | A1 * | 9/2001 | Kajiwara | 313/486 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |

| | | | | |
|---|---|---|---|---|
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |
| 2003/0090213 | A1* | 5/2003 | George et al. | 315/169.3 |
| 2003/0094891 | A1* | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1* | 9/2003 | Green et al. | 313/582 |
| 2003/0207643 | A1* | 11/2003 | Wyeth et al. | 445/3 |
| 2003/0207644 | A1* | 11/2003 | Green et al. | 445/24 |
| 2003/0207645 | A1* | 11/2003 | George et al. | 445/24 |
| 2003/0214243 | A1* | 11/2003 | Drobot et al. | 315/169.3 |
| 2004/0004445 | A1* | 1/2004 | George et al. | 315/169.3 |
| 2004/0051450 | A1* | 3/2004 | George et al. | 313/512 |
| 2004/0063373 | A1* | 4/2004 | Johnson et al. | 445/24 |
| 2004/0106349 | A1* | 6/2004 | Green et al. | 445/24 |
| 2004/0166762 | A1* | 8/2004 | Green et al. | 445/24 |
| 2004/0175854 | A1* | 9/2004 | George et al. | 438/30 |
| 2005/0095944 | A1* | 5/2005 | George et al. | 445/3 |
| 2005/0206317 | A1* | 9/2005 | George et al. | 313/582 |
| 2006/0097620 | A1* | 5/2006 | George et al. | 313/484 |
| 2006/0205311 | A1* | 9/2006 | Green et al. | 445/24 |
| 2007/0015431 | A1* | 1/2007 | Green et al. | 445/24 |

* cited by examiner

Fig. 1

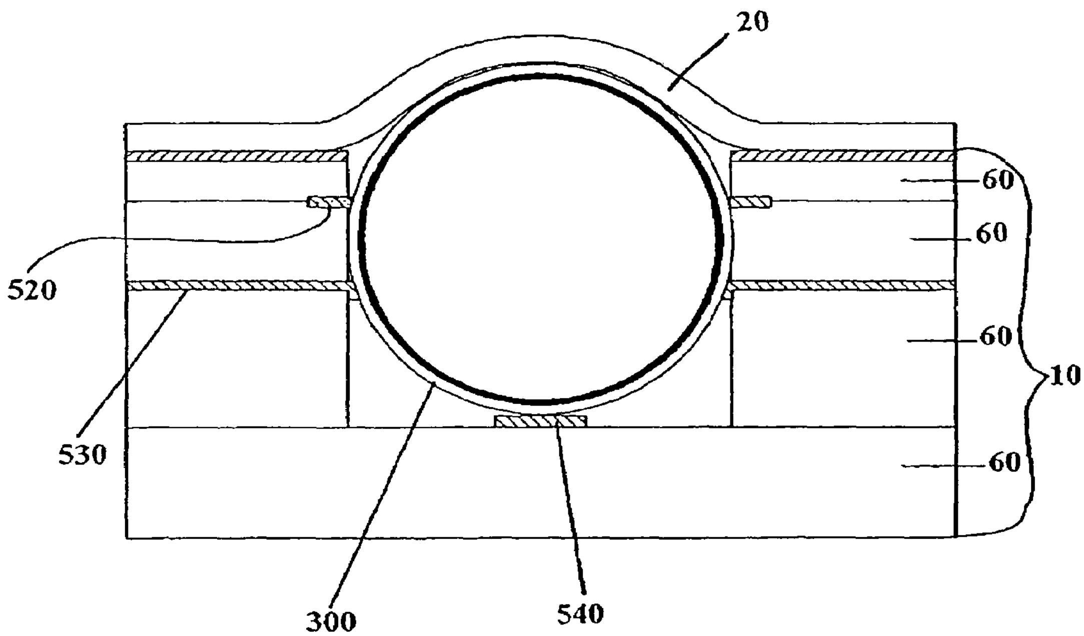
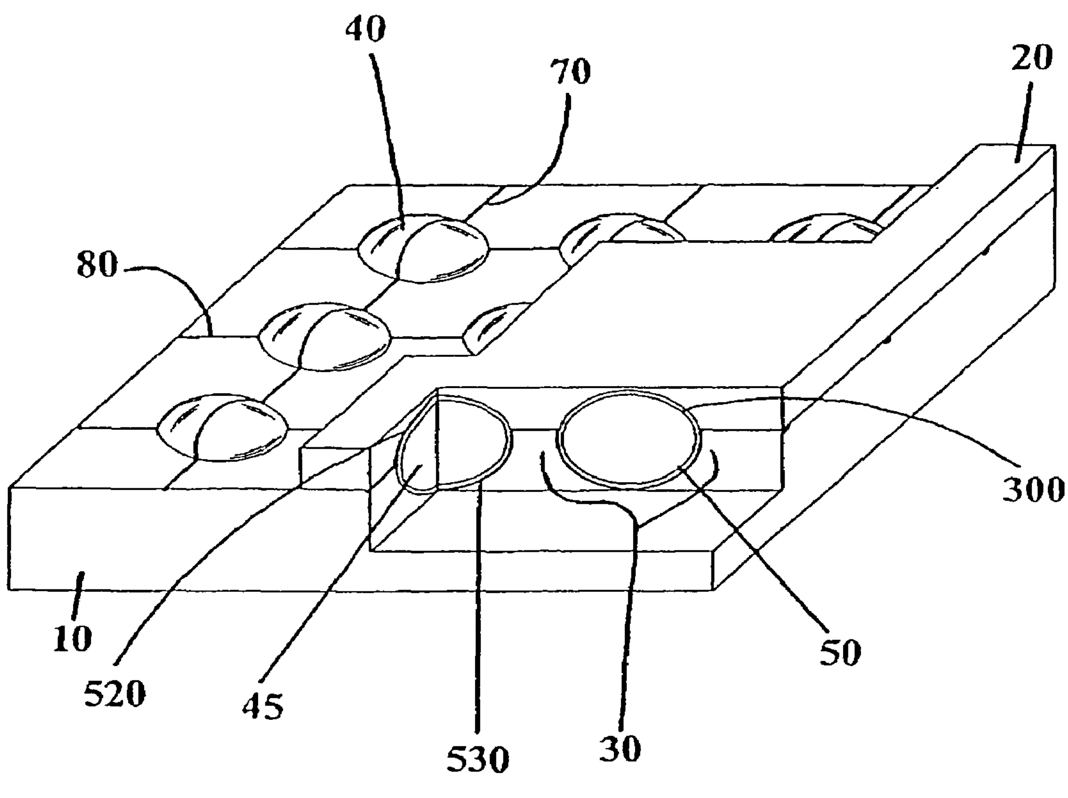


Fig. 2



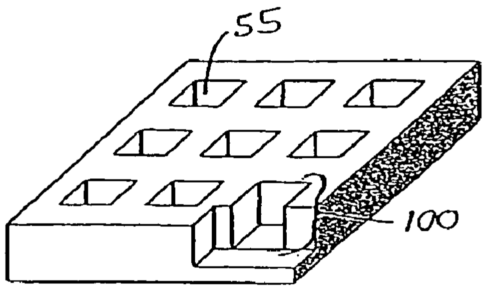



Fig. 3A

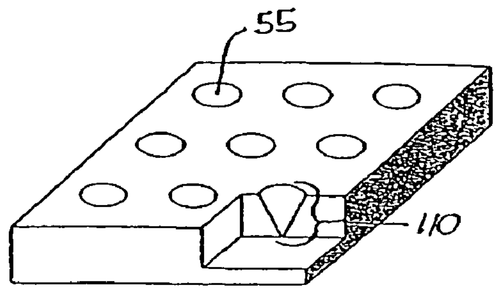



Fig. 3B

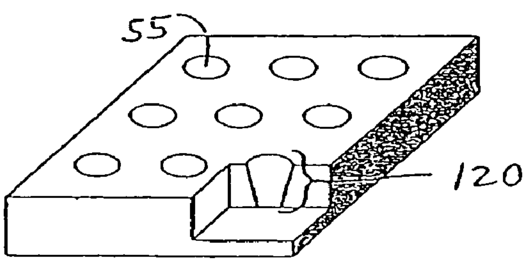



Fig. 3C

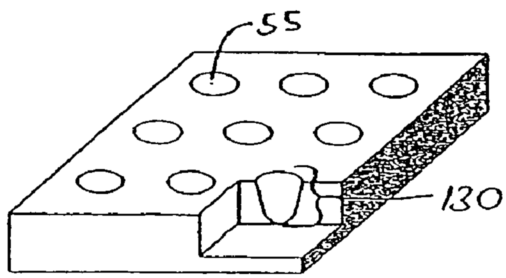



Fig 3D

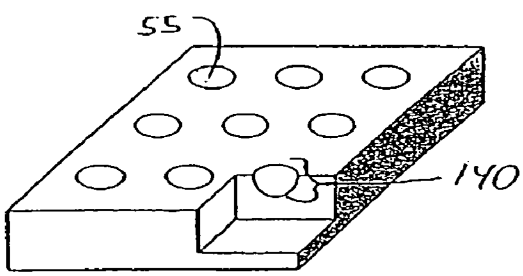



Fig 3E

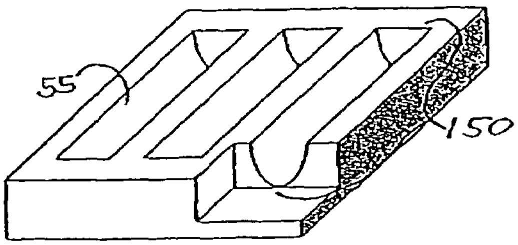



Fig. 3F

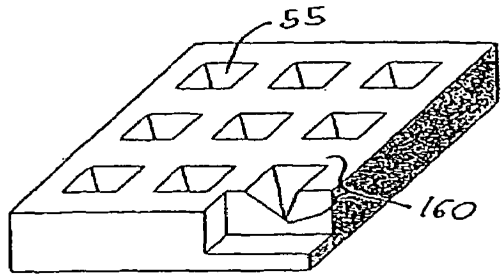



Fig. 3G

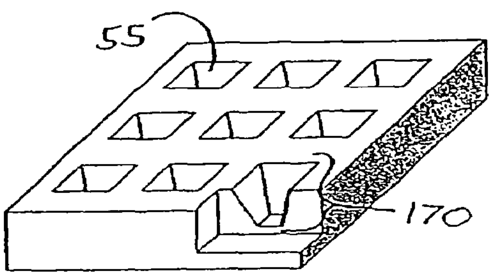



Fig. 3H

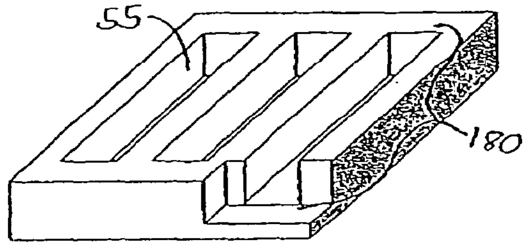



Fig. 3I

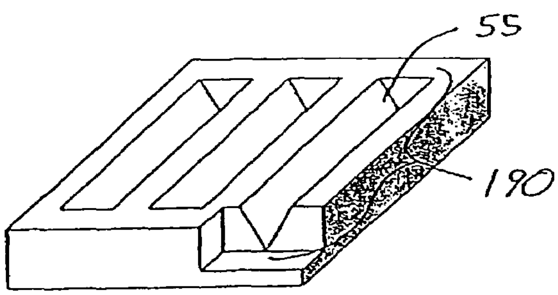



Fig. 3J

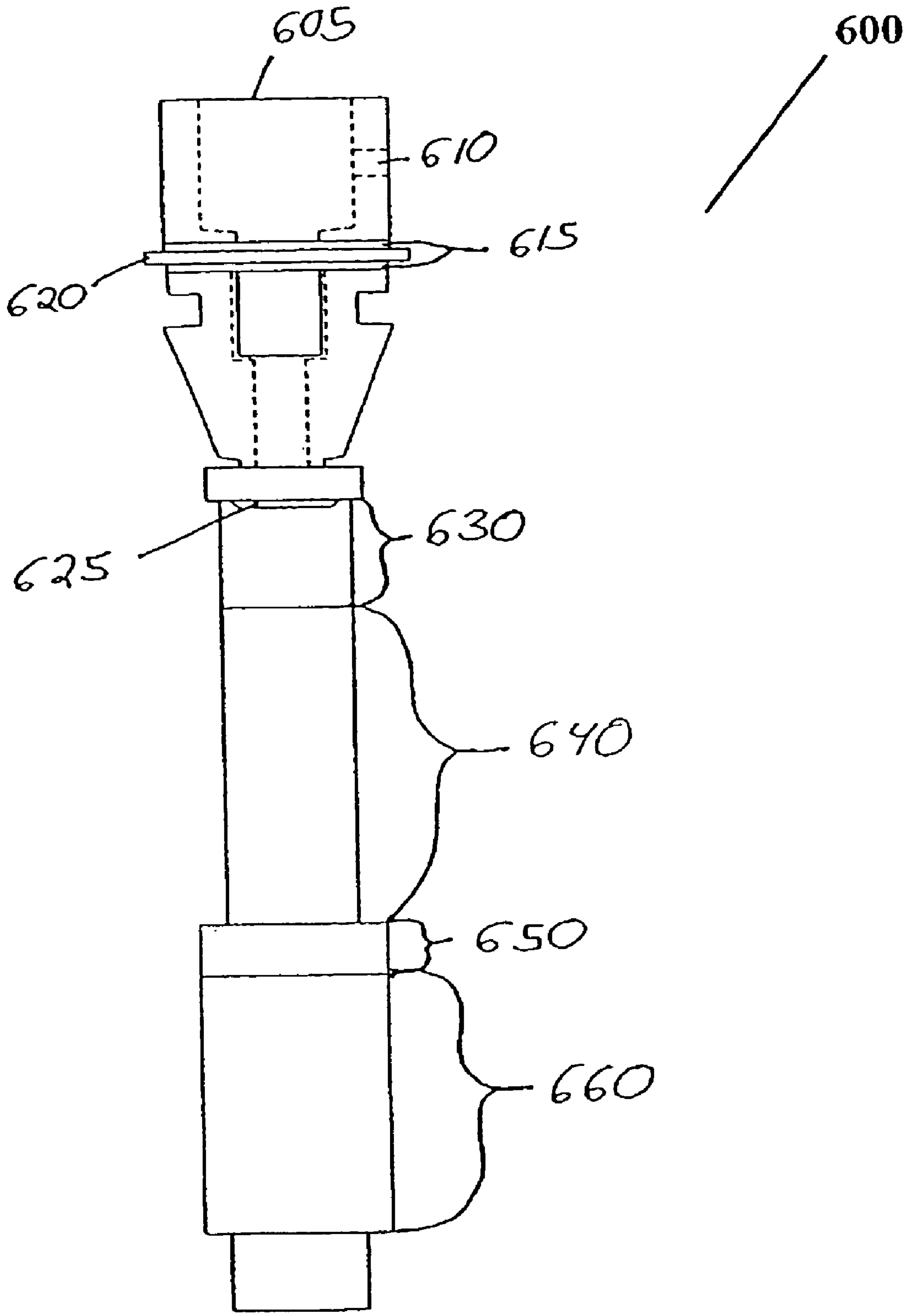



Fig. 4

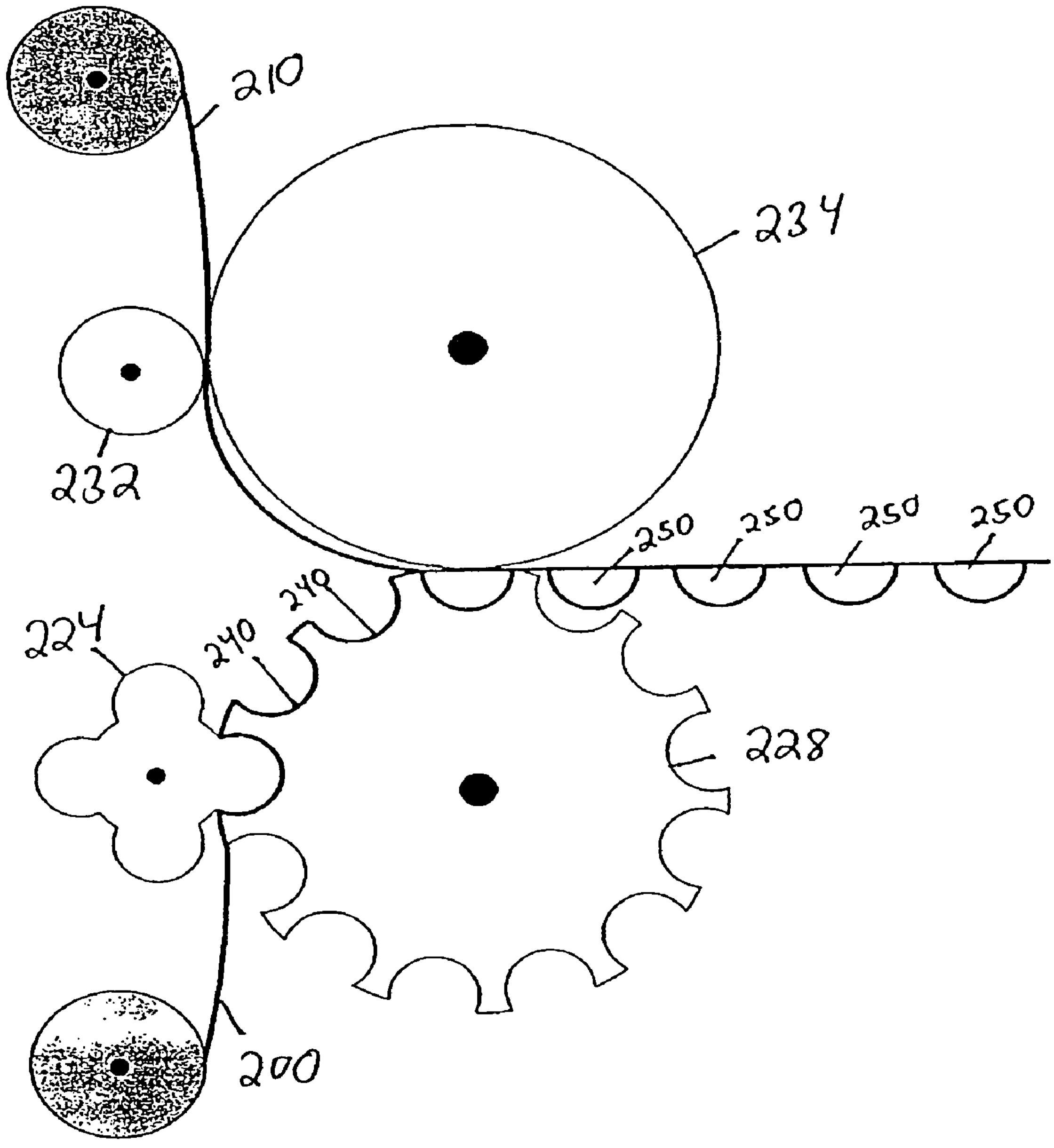
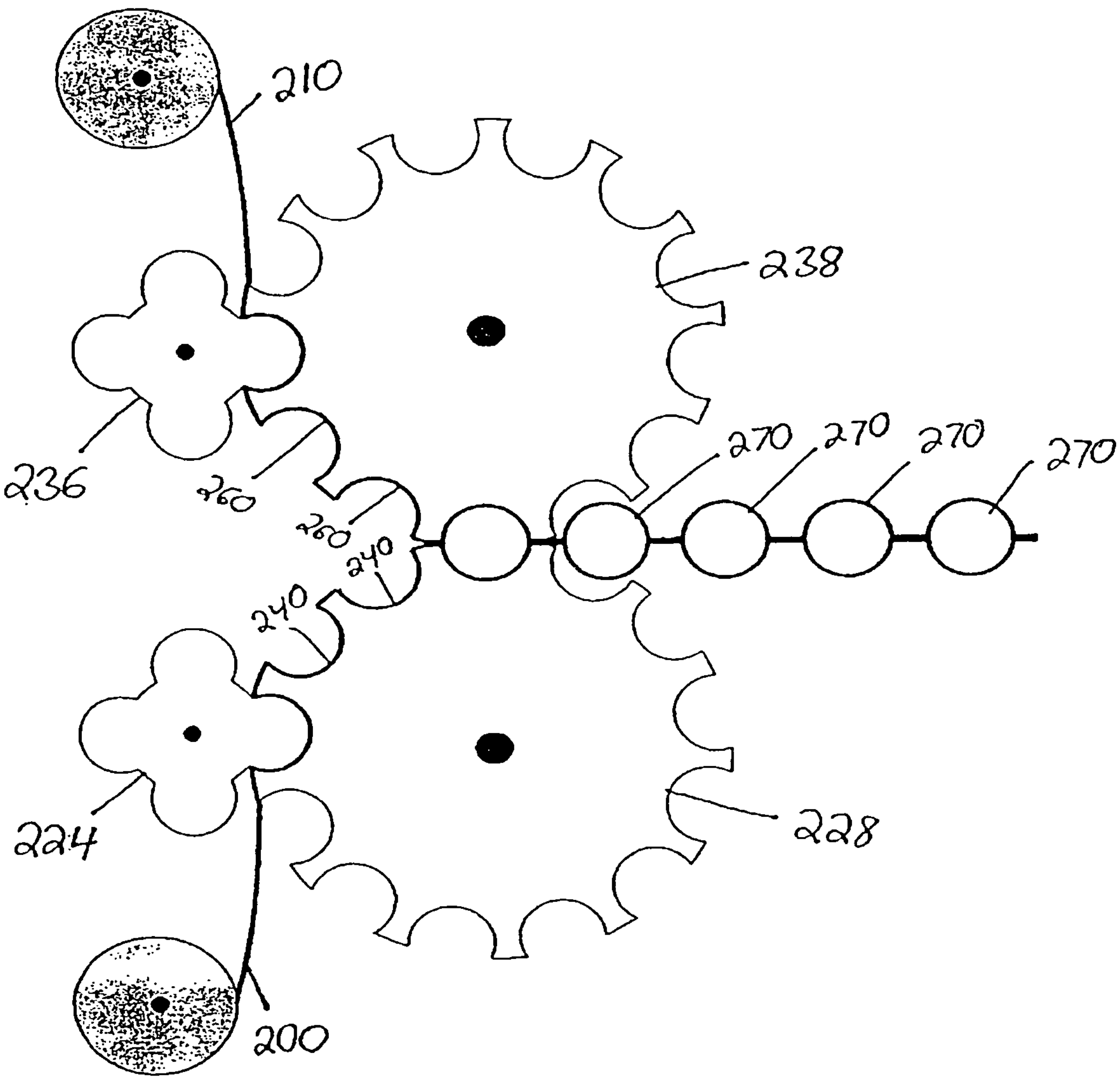
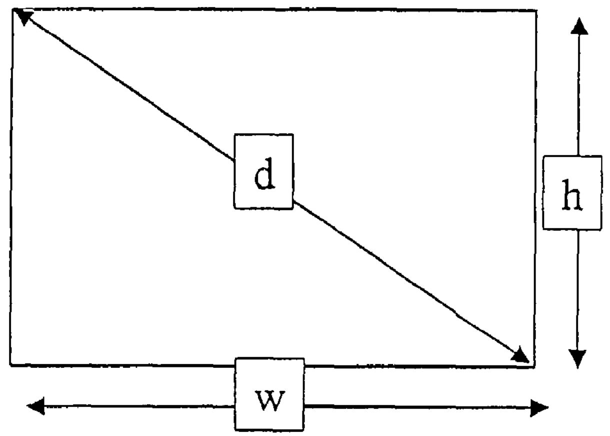



Fig. 5

Fig. 6



Example of Calculation of Pixel Size and Micro-component Size for 42-inch & 60-inch HDTV Displays (16:9 aspect ratio)




- Pixel Size
  - 1024 x 1024 pixels
  - **42" pixel dimensions=508 x 908 μm**
  - **60" pixel dimensions=1292 x 729 μm**
- Microsphere Size
  - 3 microspheres/pixel
  - **42" - 175 μm**
  - **60" - 250 μm**
- Display Size
  - w=d*0.87
  - h=d*0.49
  - **42" diagonal 16 x 9 = 20.6 x 36.6 in**
  - **60" diagonal 16 x 9 = 52.2 x 29.4 in**

Fig. 7

Table showing number of pixels, etc. for various standard display resolutions

| Acronym | Pixels HxV | Aspect | Mpixels |
|---|---|---|---|
| CIF | 352x288 | 4:3 | 0.1 |
| VGA | 640x480 | 4:3 | 0.3 |
| SVGA | 800x600 | 4:3 | 0.5 |
| XGA | 1024x768 | 4:3 | 0.8 |
| HDTV(720p) | 1280x720 | 16:9 | 0.9 |
| SXGA | 1280x1024 | 5:4 | 1.3 |
| SXGA+ | 1400x1050 | 3:4 | 1.5 |
| UXGA | 1600x1200 | 4:3 | 1.9 |
| HDTV(1080i,p) | 1920x1080 | 16:9 | 2.1 |
| WUXGA | 1920x1200 | 16:10 | 2.3 |
| QXGA | 2048x1536 | 4:3 | 3.1 |
| VXGA | 2048x2048 | 1:1 | 4.2 |
| GXGA/QSXGA | 2560x2048 | 5:4 | 5.2 |
| Photo CD (16Base) | 3072x2048 | 3:2 | 6.3 |
| Photo CD (64Base) | 6144x4096 | 3:2 | 25.0 |

Fig. 8

Fig. 9

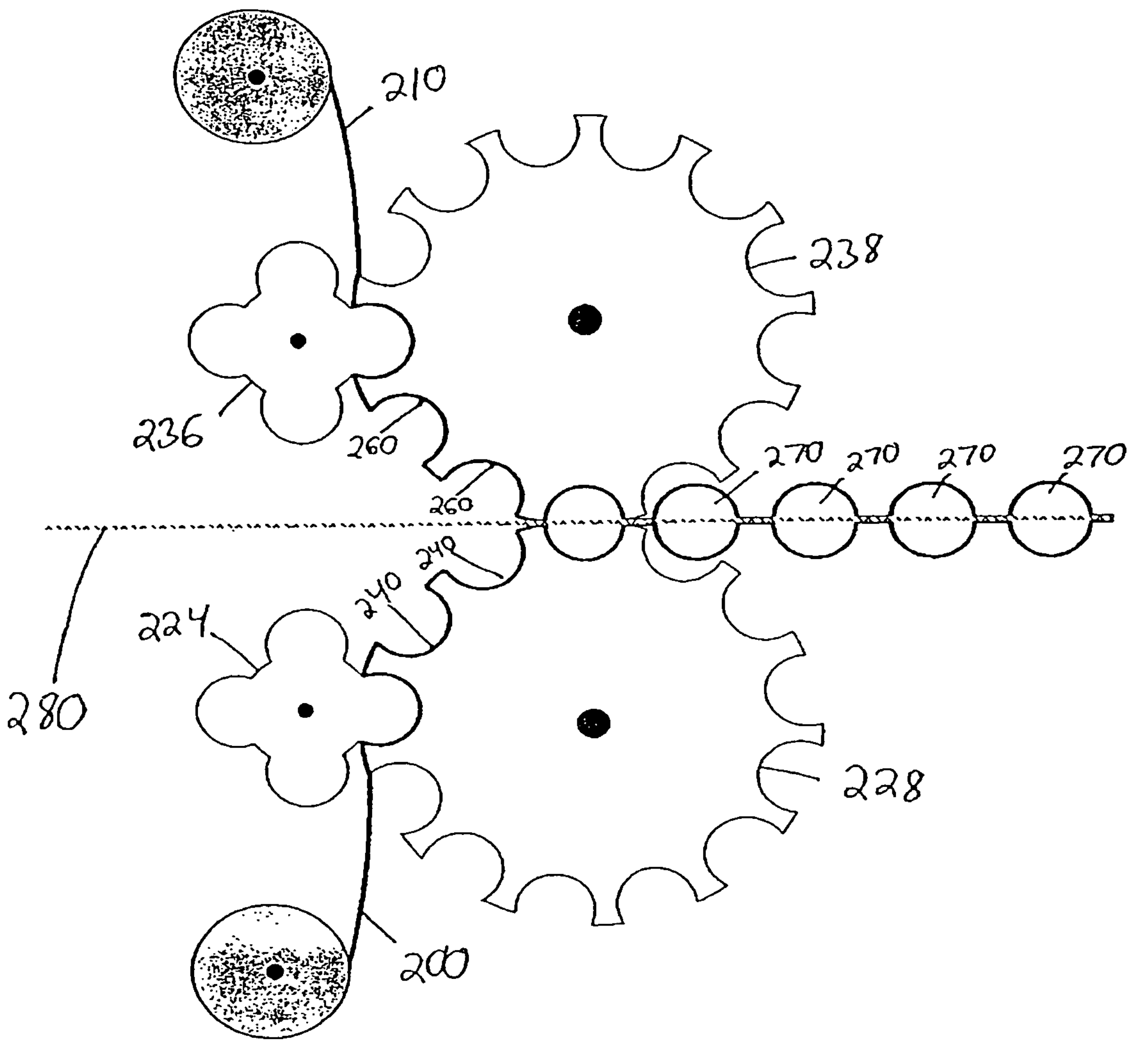
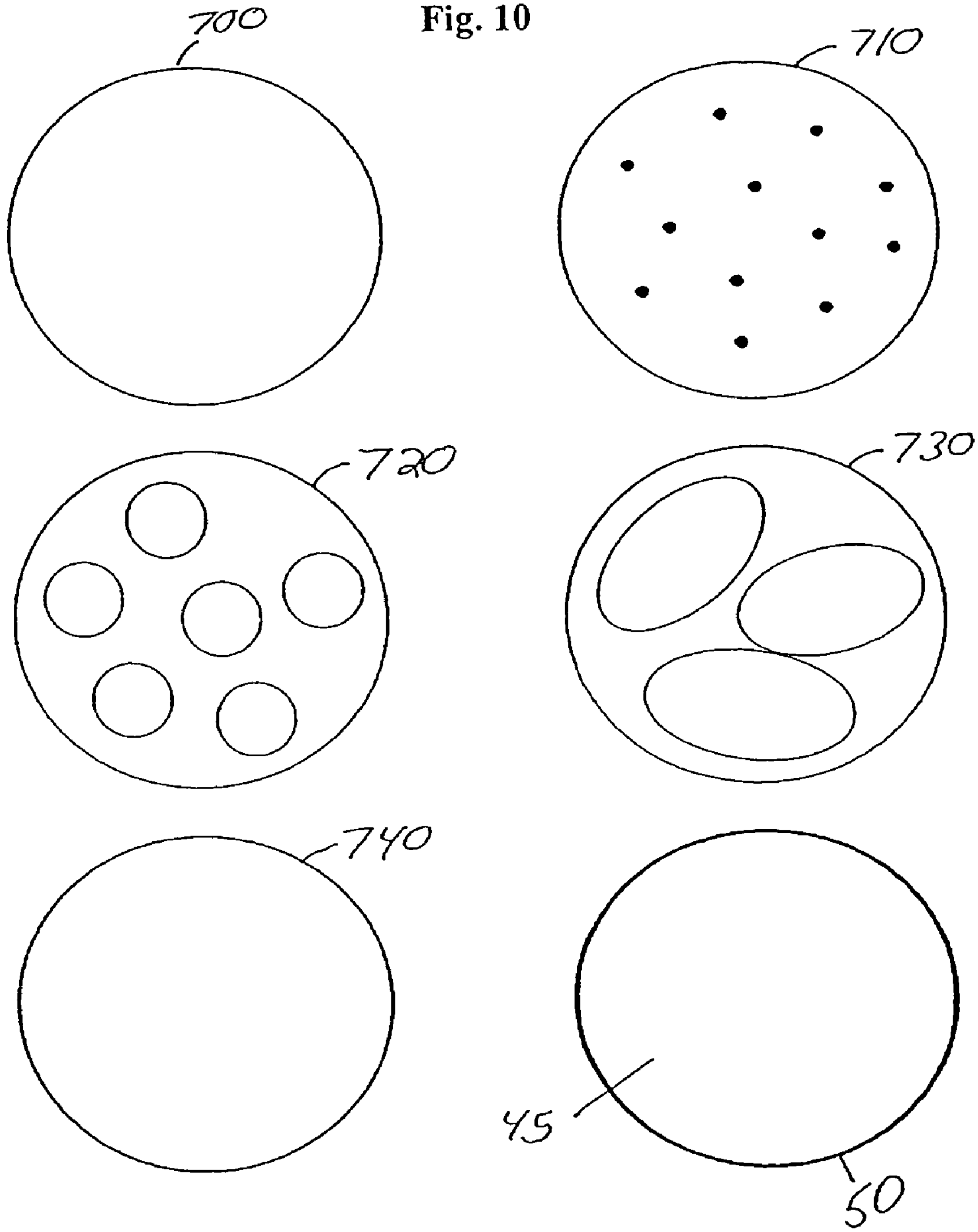


Fig. 10



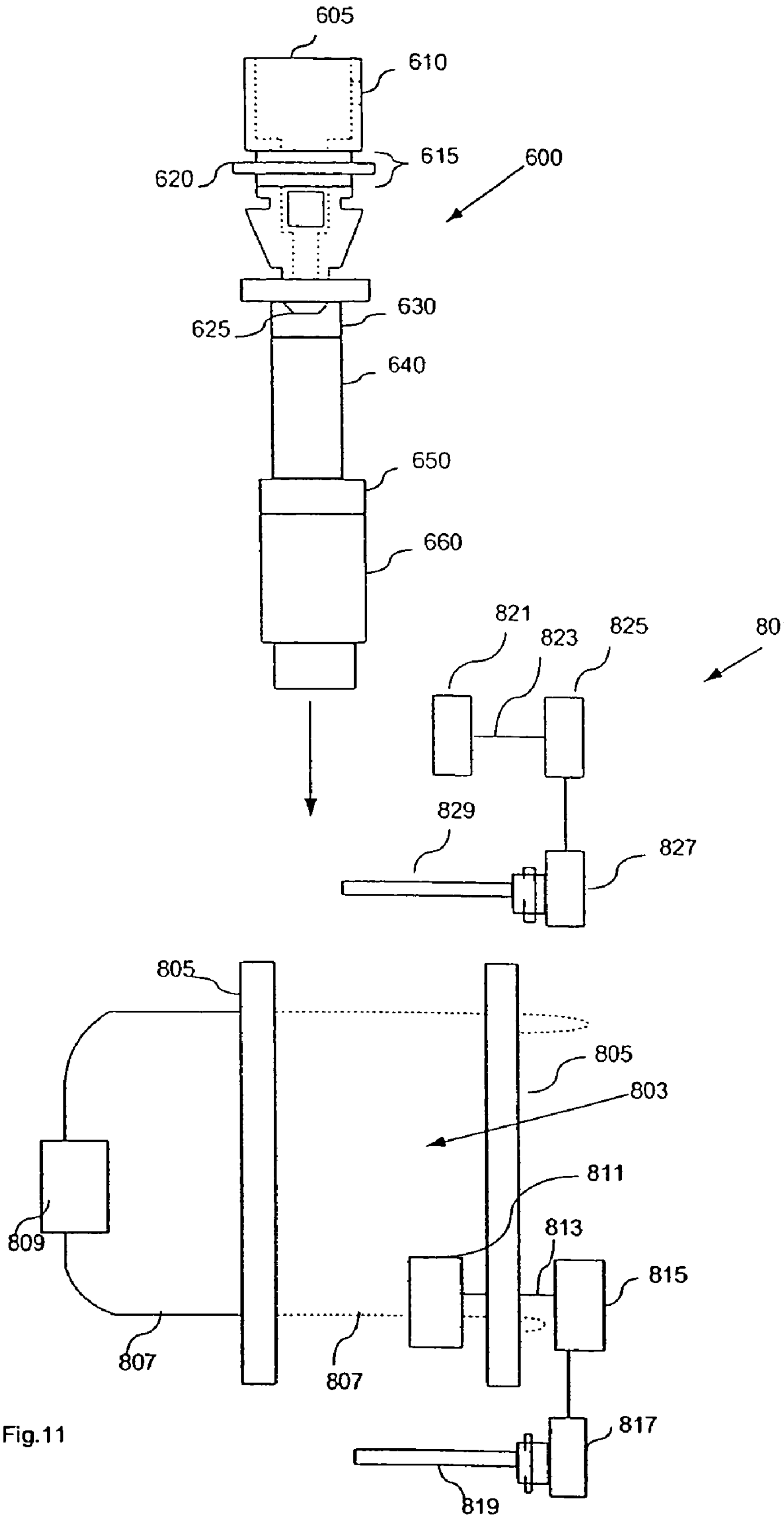

605
610
615
600
620
630
625
640
650
660
821
823
825
801
829
827
805
805
803
811
813
815
809
807
807
817
819

Fig.11

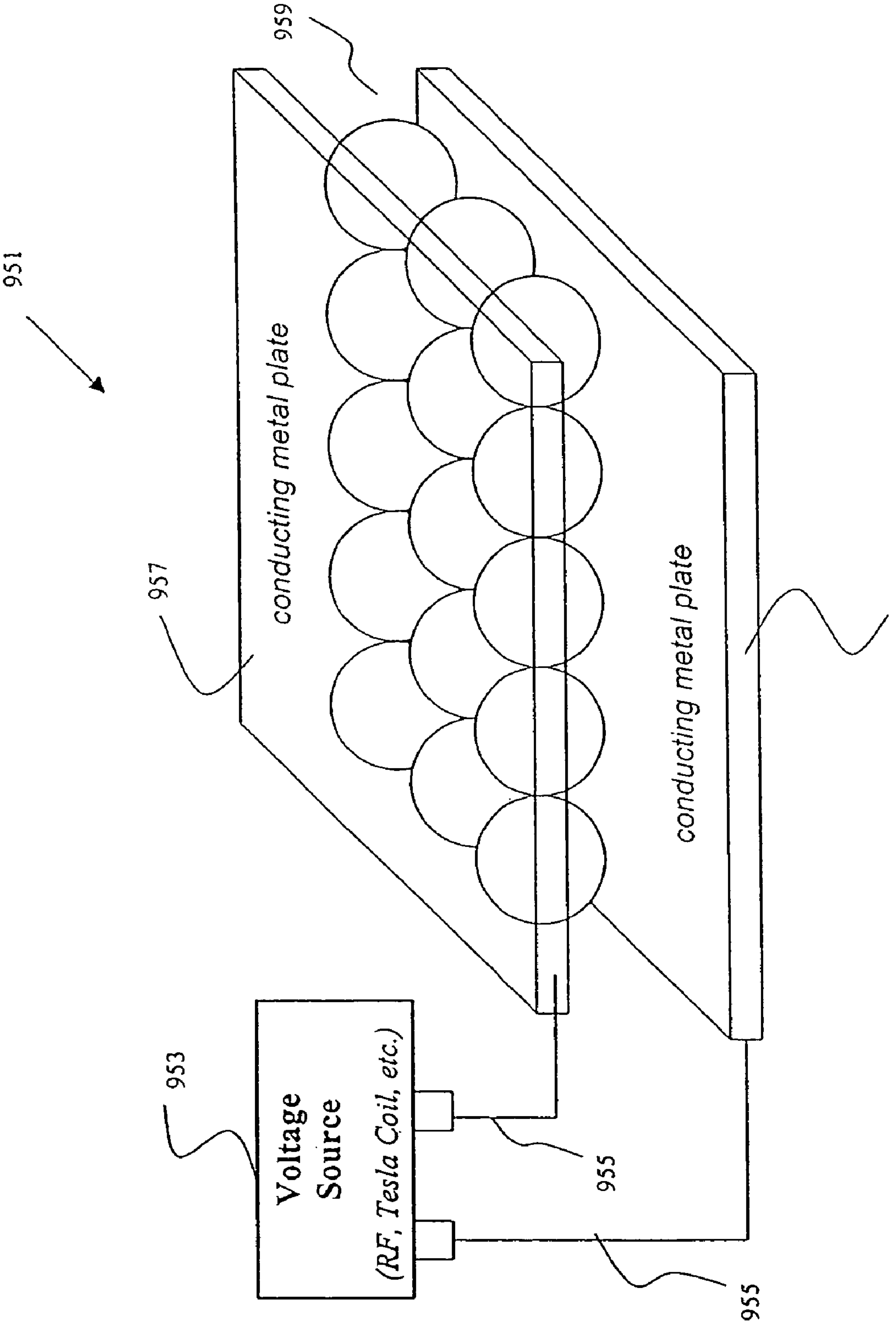

951
959
957
conducting metal plate
conducting metal plate
957
953
Voltage
Source
(RF, Tesla Coil, etc.)
955
955

Fig. 12

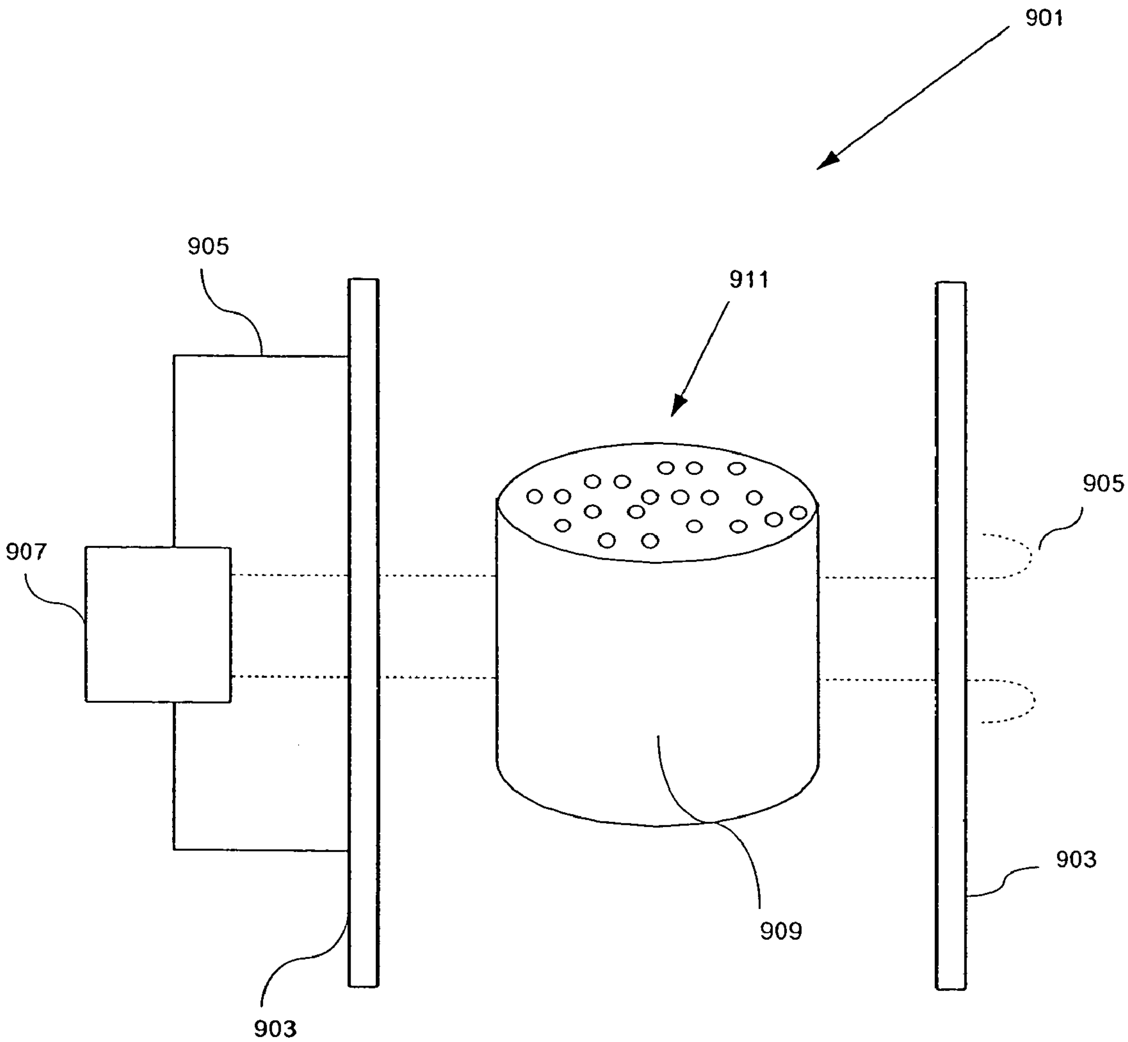



Fig. 13

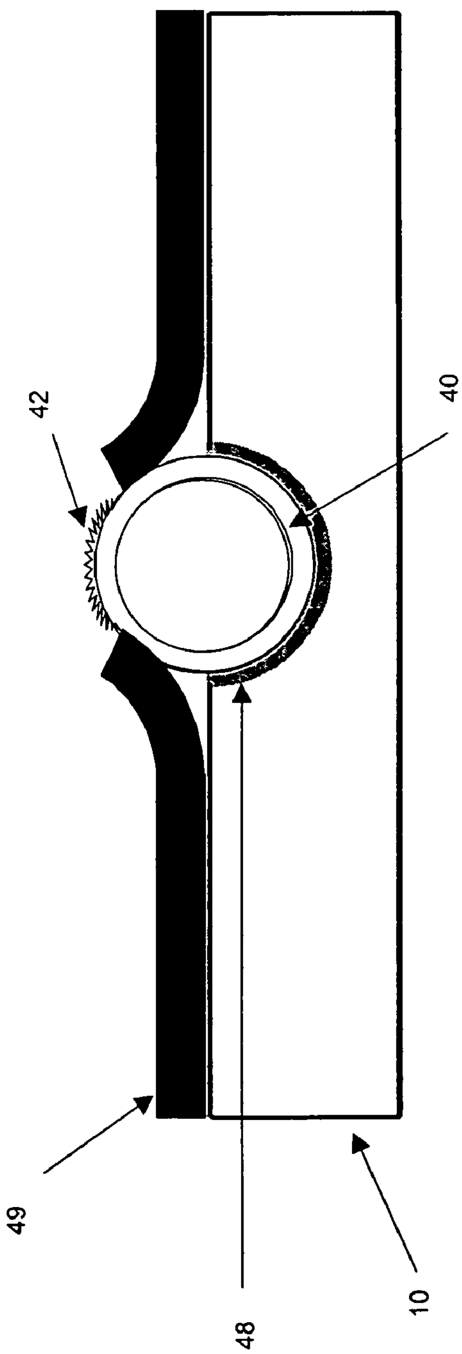



Figure 14a

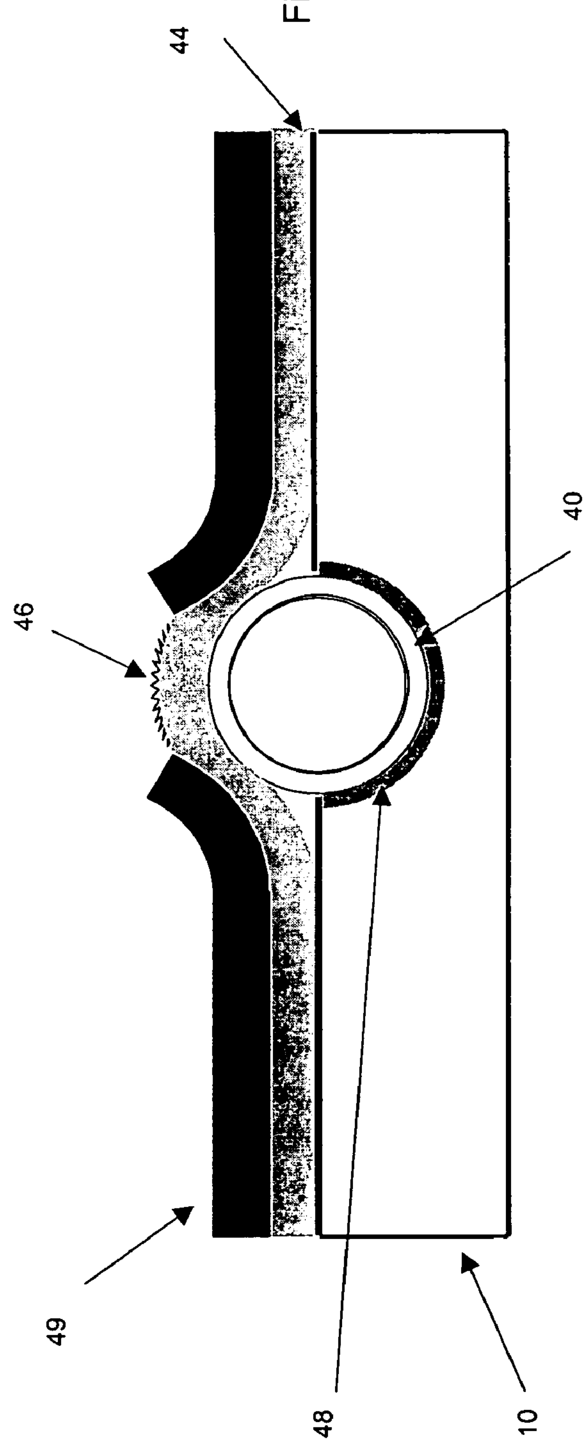



Figure 14b

# DESIGN, FABRICATION, TESTING, AND CONDITIONING OF MICRO-COMPONENTS FOR USE IN A LIGHT-EMITTING PANEL

## CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. patent application Ser. No. 10/214,768 filed Aug. 9, 2002, now U.S. Pat. No. 6,822,626, entitled "Design, Fabrication, Testing, and Conditioning of Micro-Components for Use in a Light-Emitting Panel" which is a continuation-in-part of U.S. patent application Ser. No. 09/697,358 entitled "A Micro-Component for Use in a Light-Emitting Panel," filed Oct. 27, 2000, now U.S. Pat. No. 6,762,566, and claims priority to that parent application's filing date. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties, and the filing dates thereof to which priority is also claimed: U.S. patent application Ser. No. 09/697,344 entitled "Method for Making a Light-Emitting Panel," filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889; U.S. patent application Ser. No. 09/697,498 entitled "A Method for Testing a Light-Emitting Panel and the Components Therein," filed Oct. 27, 2000, now U.S. Pat. No. 6,620,012; U.S. patent application Ser. No. 09/697,345 entitled "A Method and System for Energizing a Micro-Component in a Light-Emitting Panel," filed Oct. 27, 2000, now U.S. Pat. No. 6,570,335; U.S. patent application Ser. No. 09/697,346 entitled "A Socket for Use in a Light-Emitting Panel," filed Oct. 27, 2000, now U.S. Pat. No. 6,545,422; U.S. patent application Ser. No. 10/214,769 entitled "Use of Printing and Other Technology for Micro-Component Placement;" U.S. patent application Ser. No. 10/214,740 entitled "Liquid Manufacturing Processes for Panel Layer Fabrication;" U.S. patent application Ser. No. 10/214,716 entitled "Method for On-Line Testing of a Light-Emitting Panel;" and U.S. patent application Ser. No. 10/214,764 entitled "Method and Apparatus for Addressing Micro-Components in a Plasma Display Panel."

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a micro-component for use in a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this plasma-forming discharge occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the



cell where these charges produce an opposing voltage to the applied voltage and thereby eventually extinguish the discharge. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes may be located partially within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse a cross only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma-forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma-forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates, the pumping down to vacuum, the baking out under vacuum, and the introduction of the plasma-forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels without a write pulse being applied. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma-forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total physical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to pump down to vacuum, bake out under vacuum, introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma-forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing paint or other coatings, and for sterilization. With the addition of one or more phosphor coatings to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other electromagnetic wavelengths would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma-forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied a cross the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In one embodiment of the present invention, the micro-component is configured to emit ultra-violet (UV) light, which may be converted to visible light by at least partially coating each micro-component with phosphor. To obtain an improvement in the discharge characteristics, each micro-component may be at least partially coated with a secondary emission enhancement material.

In another embodiment, each micro-component is at least partially coated with a reflective material. An index matching material is disposed so as to be in contact with at least a portion of the reflective material. The combination of the index matching material and the reflective material permits a predetermined wavelength of light to be emitted from each micro-component at the point of contact between the index matching material and the reflective material.

Another object of the present invention is to provide a micro-component for use in a light-emitting panel. A shell at least partially filled with at least one plasma-forming gas provides the basic micro-component structure. The shell may be doped or ion implanted with a conductive material, a material that provides secondary emission enhancement, and/or a material that converts UV light to visible light. The micro-components will be made as a sphere, cylinder or any other shape. The size and shape will be determined in accordance with the desired resolution for the display panel to be assembled. Typical sizes are about hundreds of microns independent of shape.

Another preferred embodiment of the present invention is to provide a method of making a micro-component. In one embodiment, the method is part of a continuous process, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the plasma-forming gas or gas mixture.

In another embodiment, the micro-component is made by affixing a first substrate to a second substrate in the presence of at least one plasma-forming gas. In this method, either the first and/or the second substrate contains a plurality of cavities so that when the first substrate is affixed to the second substrate the plurality of cavities are filled with the plasma-forming gas or gas mixture. In a preferred embodiment, a first substrate is advanced through a first roller assembly, which includes a roller with a plurality of nodules and a roller with a plurality of depressions. Both the plurality of nodules and the plurality of depressions are in registration with each other so that when the first substrate passes through the first roller assembly, the first substrate has a plurality of cavities formed therein. A second substrate is advanced through a second roller assembly and then affixed to the first substrate in the presence of at least one gas so that when the two substrates are affixed the cavities are filled with the gas or gas mixture. In an alternate preferred embodiment, the second roller assembly includes a roller with a plurality of nodules and a roller with a plurality of depressions so that when the second substrate passes through the second roller assembly, the second substrate also has a plurality of cavities formed therein. In either of these embodiments, at least one electrode may be sandwiched between the first and second substrates prior to the substrates being affixed.

In another embodiment, at least one substrate is thermally treated in the presence of a least one plasma-forming gas so as to form shells filled with the plasma-forming gas or gas-mixture.

In a specific aspect, the micro-components, whether sphere, capillary or other shape are coated with a frequency converting coating. Phosphor is an example of such a coating. More specifically, the coating converts electromagnetic radiation generated in the plasma in the ultraviolet region of the spectrum, and converts it to the visible red, blue or green region of the spectrum.

Alternatives include putting a drop of the frequency converting material in a socket into which the micro-component is placed, or the micro-component itself can be doped with a material such as a rare earth that is a frequency converter. Examples of materials include barium fluoride or the like, yttrium aluminum garnet, or gadolinium gallium garnet. The plasma gases in the micro-component can include xenon chloride, argon chloride, etc., namely the rare gas halides.

In another aspect, the micro-components are tested as they are manufactured. The micro-components are optionally scanned for certain physical characteristics or defects, for example, in an optical field detecting shape such as sphericity and size as they drop through a tower. A micro-component displacement device can be used to remove those that are bad. At a subsequent layer, as they drop the micro-components are subjected to electron beam excitation, microwave or RF field, for example, to excite the gas. Another physical characteristic or defect is tested, such as if a certain luminous output is achieved, and if achieved, it is preliminarily accepted. Those for which a desired luminous output is not achieved are discarded, for example, through the use of a second micro-component displacement device.

In yet still another aspect, the micro-components are preconditioned by being excited for a predetermined period of time. Examples include taking the micro-components that passed the initial test, placing them in a container and exciting them, for example, for 5 to 10 hours. Alternatively, they can be placed between large parallel electrodes. After the batch run, they are dropped through a tower as they are excited, output detected and the ones that do not excite are knocked out of the stream.

In a further aspect of the invention, the micro-components are texturized using a technique such as sandblasting, etching, lithography or the like. The texturized portion allows light generated within the micro-component to exit the micro-component. Alternatively, the micro-components are optically contacted to one surface of an overlay layer, wherein the overlay has been texturized on the opposite surface at least those areas near wherein the other surface of the overlay optically contacts the micro-components.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** shows a socket with a micro-component disposed therein.

FIG. **2** depicts a portion of a light-emitting panel showing a plurality of micro-components disposed in sockets.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a hemicylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components.

FIG. **5** shows an apparatus used in an embodiment of the present invention as part of another process for forming micro-components.

FIG. **6** shows an variation of the apparatus shown in FIG. **5**, which is used as part of another process for forming micro-components.

FIG. **7** illustrates an example of selection of pixel size and micro-component (micro-sphere) size for different sized high definition television (HDTV) displays, which can be manufactured according to the micro-component method hereof.

FIG. **8** is a table showing numbers of pixels for various standard display resolutions.

FIG. **9** illustrates, according to an embodiment, one way in which an electrode may be disposed between two substrates as part of a process for forming micro-components.

FIG. **10** depicts the steps of another method for forming micro-components.

FIG. **11** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components similar to that of FIG. **4**, and including a mechanism for pretesting or pre-screening of micro-components prior to assembly in a panel.

FIG. **12** shows an apparatus used for batch conditioning of micro-components.

FIG. **13** shows an alternative embodiment of an apparatus used for batch conditioning of micro-components.

FIGS. **14***a* and **14***b* each depict a portion of a light-emitting panel showing a micro-component disposed in socket, further having a texturized portion and a black mask according to embodiments of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a micro-component capable of being used in the light-emitting panel and at least partially disposed in at least one socket.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3**A–**3**J, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. Further, rare gas halide mixtures such as xenon chloride, xenon fluoride and the like are also suitable plasma-forming gases. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed above. This description is not intended to be limiting. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, barium fluoride or similar materials such as yttrium aluminum garnet, gadolinium gallium garnet, silicates, borates, silicate/borate mixtures, phosphates, these and other compounds in a glassy state, alumino-silica glasses, alkali silicate glasses, any polymeric-based material, magnesium oxide, and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long a cross its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. In FIG. **2**, a two electrode configuration is shown including a first sustain electrode **520** and an address electrode **530**. In FIG. **1**, a three electrode configuration is shown, wherein a first sustain electrode **520**, an address electrode **530** and a second sustain electrode **540** are disposed within a plurality of material layers **60** that form the first substrate **10**. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr or higher pressure as appropriate. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as bandpass filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may also work. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside of the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used.

To obtain an improvement in discharge characteristics, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated on the inside surface with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

Alternatively to the previously discussed phosphor which can be used to coat the micro-component, or alternatively, placed into a socket in a display panel in which the micro-components are placed, the micro-component material can be doped with a rare earth that is a frequency converter. The micro-component material to host such dopants can include barium fluoride or similar materials such as yttrium aluminum garnet, or gadolinium gallium garnet. These types of frequency converting doped materials serve to convert plasma light at the UV wavelength to visible light of red, blue or green color. The gasses in the micro-component in such cases will include rare gas halide mixtures such as xenon chloride, xenon fluoride and the like. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed previously. This description is not intended to be limiting. In the case when such frequency converting materials are used, instead of using a phosphor coating, they can be integrated as a dopant in the shell of the micro-component. For example, yttrium aluminum garnet doped with cerium can serve to convert UV wavelengths from rare gas halides into green light.

Further to the embodiments described above, wherein the shell of the micro-component, made of a material such as barium fluoride or similar materials such as yttrium aluminum garnet, gadolinium gallium garnet, silicates, borates, silicate/borate mixtures, phosphates, these and other compounds in a glassy state, alumino-silica glasses, alkali silicate glasses, is doped with a rare earth, frequency converting species such as europium 2+ for blue, europium 3+ for red, cerium 3+ for violet (deep blue), or cerium 3+ plus terbium 3+ for green, an additional embodiment of the invention includes texturizing the surface of the shell in order to allow trapped, emitted light out of the shell. In certain embodiments of the present invention, the smooth, doped shell acts as a waveguide, wherein the visible photons emitted from the dopant ions in the micro-component become trapped in the shell of the micro-component, which is on the order of 2–4 microns in thickness, by internal reflection. In order to exit the shell, the trapped photons must achieve an appropriate exit angle with the surface. In this additional embodiment of the present invention, the photons are able to achieve the appropriate exit angle when the exiting surface of the shell is texturized. Referring to FIG. **14*a***, substrate **10** encompasses micro-component **40** which includes texturized area **42** on the exit surface. Alternatively, the exit surface itself is not actually texturized, but is optically contacted to an overlay layer **44** shown in FIG. **14*b*** that has a texturized surface area **46** nearby as described further below. An additional embodiment of the invention has a reflective element **48** under each micro-component to redirect those emitted photons that do escape from the micro-component shell layer back toward the front of the panel.

In a first particular embodiment, a portion of the surface of the shell of each micro-component is texturized through a texturizing process such as etching, lithography, sandblasting or the like. The texturing process may take place at various stages in the continuous process for forming micro-components. For example, referring to the process described below with regarding to FIG. **4** of the present application, the texturizing process could take place while the micro-component is in the refining region **660**. Further the micro-component may be texturized either before or after the doping process. Alternatively, referring to FIGS. **5**–**6** and **9**, the texturizing step could take place with respect to first substrate **200** in FIG. **5** and/or second substrate **210** in FIGS. **6** and **9**, prior to formation of the micro-components **250** and **270**, respectively or alternatively still, after formation of the micro-components **250** and **270**. Further, the micro-components may also be texturized after placement within the light emitting panels, i.e., after placement within their respect sockets. For example, referring to the processing steps described with regard to FIG. 12 of U.S. Pat. No. 6,612,889, which is incorporated herein by reference, the micro-components could be texturized after the "Micro-Component Placement Process" **850** and "Micro-Components in Sockets on Substrate with Electrodes" **440**, but before the "Substrate Application & Alignment Process" **870**. Also, referring to FIG. 10 of U.S. patent application Ser. No. 10/214,740, which is incorporated herein by reference, the micro-components could be texturized after step **210**, "Micro-component placement."

In this further embodiment, the surface of the doped micro-component is texturized using at least one process including etching, lithography, sandblasting or the like. The exact size of the texturized area varies with the size and spacing of the micro-components. For example, in a light-emitting panel wherein the micro-components are separated by hundreds of microns, e.g., 100 to 1000 microns, the diameter of the texturized portion of the micro-component is on the order of tens of microns in diameter, e.g., 20 to 300 microns. When the dopant ions in the micro-component material are stimulated by UV radiation from the plasma discharge within the micro-component, they emit visible radiation, some of which internally strikes the micro-component wall at an angle of incidence greater than the critical angle and therefore is totally reflected and initially trapped within the micro-component wall. Most of this trapped radiation is then emitted through the texturized portion of the micro-component and thus is concentrated. This concentrated luminosity contributes greatly to increased contrast ratio when viewing the light-emitting panel. In addition, contrast ratio is further increased with the use of a black mask **49** covering all but the texturized areas of the micro-components or texturized overlay as shown in FIGS. **14*a*** and ***b*** and described further below. The use of enhancement materials, such as the black mask, are described in the patents and patent applications incorporated by reference above.

In still a further embodiment of the present invention, the texturized area is included on an overlay, as opposed to physically altering the texture of the micro-components. Referring, for example, to the processing steps described with regard to FIG. 12 of U.S. Pat. No. 6,612,889, which is incorporated herein by reference, the texturized overlay could be part of the second substrate, wherein the second substrate is texturized at step **820** along with the "Circuit & Electrode Printing Process" in the continuous process for forming a light emitting panel. Alternatively, the texturizing step could be performed before or after step **820**. In addition to having a texturized area for trapped light release, the overlay is indexed matched to the micro-component material at the point of optical contact, so as to maximize the amount of trapped radiation transferred from the micro-component to the overlay. Similarly, referring to FIG. 10 of U.S. patent application Ser. No. 10/214,740, which is incorporated herein by reference, the formation of the texturized areas may be included after curing of the protective layer **224**, i.e., through the techniques described above such as etching, lithography, sandblasting or the like.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material, either in two or more localized areas to provide separate electrode-like paths or in a way to produce anisotropic conductivity in the shell (high perpendicular conductivity, low in-plane conductivity), provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel. In this manner, shorting is avoided and two or more separate electrode paths are maintained to allow exciting of the gas.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

Several methods are proposed, in various embodiments, for making a micro-component for use in a light-emitting panel. It has been contemplated that each of the coatings and dopants that may be added to a micro-component **40**, as disclosed herein, may also be included in steps in forming a micro-component, as discussed herein.

In one embodiment of the present invention, a continuous inline process for making a micro-component is described, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the gas or gas mixture. In a preferred embodiment, the process takes place in a drop tower. According to FIG. **4**, and as an example of one of many possible ways to make a micro-component as part of a continuous inline process, a droplet generator **600** including a pressure transducer port **605**, a liquid inlet port **610**, a piezoelectric transducer **615**, a transducer drive signal electrode **620**, and an orifice plate **625**, produces uniform water droplets of a predetermined size. The droplets pass through an encapsulation region **630** where each water droplet is encased in a gel outer membrane formed of an aqueous solution of glass forming oxides (or any other suitable material that may be used for a micro-component shell), which is then passed through a dehydration region **640** leaving a hollow dry gel shell. This dry gel shell then travels through a transition region **650** where it is heated into a glass shell (or other type of shell depending on what aqueous solution was chosen) and then finally through a refining region **660**. While it is possible to introduce a plasma-forming gas or gas mixture into the process during any one of the steps, it is preferred in an embodiment of the present invention to perform the whole process in the presence of the plasma-forming gas or gas mixture. Thus, when the shell leaves the refining region **660**, the plasma-forming gas or gas mixture is sealed inside the shell thereby forming a micro-component.

In an embodiment of the present invention, the above process is modified so that the shell can be doped with either a secondary emission enhancement material and/or a conductive material, although other dopants may also be used. While it is contemplated that the dopants may be added to the shell by ion implantation at later stages in the process, in a preferred embodiment, the dopant is added directly in the aqueous solution so that the shell is initial formed with the dopant already present in the shell.

The above process steps may be modified or additional process steps may be added to the above process for forming a micro-component to provide a means for adding at least one coating to the micro-component. For coatings that may be disposed on the inside of the shell including, but not limited to a secondary emission enhancement material and a conductive material, it is contemplated in an embodiment of the present invention that those coating materials are added to the initial droplet solution so that when the outer membrane is formed around the initial droplet and then passed through the dehydration region **640** the coating material is left on the inside of the hollow dry gel shell. For coatings that may be disposed on the outside of the shell including, but not limited to, coatings used to convert UV light to visible light, coatings used as reflective filters and coatings used as band-gap filters, it is contemplated that after the micro-component leaves the refining region **660**, the micro-component will travel through at least one coating region. The coatings may be applied by any number of processes known to those skilled in the art as a means of applying a coating to a surface.

A further modification of the drop tower of FIG. **4** is illustrated in FIG. **11** with a continuous testing region **801**. The continuous testing region **801** includes a first optical detector **821** which detects individual micro-components as they are formed. This optical detector can detect such things as sphericity and size in a continuous process, typically operating at about 10 kilohertz sampling rate. Signals representing the micro-component detected are passed through line **823** to a control module **825**. If a micro-component does not meet certain minimum standards, a signal is sent from control module **825** to mechanical actuator **827** which activates a micro-component displacement device or arm **829** which is activated to remove the failed micro-component from the stream. A second region of the continuing testing device **801** includes, optionally, electrodes **805** which are excited through leads **807** by power supply **809** to generate a field which excites the plasma gas within the manufactured micro-components. As the micro-components are exited, a luminous output is generated and a second optical detector **811** serves to detect the luminous output and send a signal representing the luminous output for each individual micro-component through line **813** to a second control unit **815**. Additionally, with respect to the optional texturizing step after step **660** described above, the continuing testing device **801** can be configured to test the luminous output, i.e., amount and concentration, from the texturized portion of the micro-component.

If no luminous output is detected or a luminous output of less than a predetermined threshold or concentration is detected, the control unit **815** sends a signal to actuator **817** which then actuates a second micro-component displacement device or arm **819** to remove the failed micro-component from the stream.

With respect to the photo-detectors, they are conventional, and can be of the type, for example, which detect UV light. Alternatively, if the micro-component has been coated prior to the end of the fabrication process, for example, with phosphor, the detector may be of the type which is sensitive to a red light output. It should be noted that although the micro-component displacement devices or arms **819** and **829** have been described as mechanical in nature, they may also be non-mechanical, such as an intermittent fluid stream such as a gas or liquid stream or a light pulse such as a high-intensity laser pulse.

In another embodiment of the present invention, two substrates are provided, wherein at least one of two substrates contain a plurality of cavities. The two substrates are affixed together in the presence of at least one plasma-forming gas so that when affixed, the cavities are filled with the gas or gas mixture. In an embodiment of the present invention at least one electrode is disposed between the two substrates. In another embodiment, the inside, the outside, or both the inside and the outside of the cavities are coated with at least one coating. It is contemplated that any coating that may be applied to a micro-component as disclosed herein may be used. As illustrated in FIG. **5**, one method of making a micro-component in accordance with this embodiment of the present invention is to take a first substrate **200** and a second substrate **210** and then pass the first substrate **200** and the second substrate **210** through a first roller assembly and a second roller assembly, respectively. The first roller assembly includes a first roller with nodules **224** and a first roller with depressions **228**. The first roller with nodules **224** is in register with the first roller with depressions **228** so that as the first substrate **200** passes between the first roller with nodules **224** and the first roller with depressions **228**, a plurality of cavities **240** are formed in the first substrate **200**. As may be appreciated, the cavities may be in the shape desired for micro-components manufactured therewith such as hemispheres, capillaries, cylinders, etc. The second roller assembly, according to a preferred embodiment, includes two second rollers, **232** and **234**. The first substrate **200**, with a plurality of cavities **240** formed therein, is brought together with the second substrate **210** in the presence of a plasma-forming gas or gas mixture and then affixed, thereby forming a plurality of micro-components **250** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **210** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller **234**.

The nodules on the first roller with nodules **224** may be disposed in any pattern, having even or non-even spacing between adjacent nodules. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the distance between adjacent nodules is approximately equal. The nodules may also be disposed in groups such that the distance between one group of nodules and another group of nodules is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each nodule in a group of nodules may be used to form a micro-component that is configured for red, green, and blue, respectively.

While it is preferred that the second roller assembly simply include two second rollers, **232** and **234**, in an embodiment of the present invention as illustrated in FIG. **6**, the second roller assembly may also include a second roller with nodules **236** and a second roller with depressions **238** that are in registration so that when the second substrate **210** passes between the second roller with nodules **236** and the second roller with depressions **238**, a plurality of cavities **260** are also formed in the second substrate **210**. The first substrate **200** and the second substrate **210** are then brought together in the presence of at least one gas so that the plurality of cavities **240** in the first substrate **200** and the plurality of cavities **260** in the second substrate **210** are in register. The two substrates are then affixed, thereby forming a plurality of micro-components **270** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **240** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller with depressions **238**.

In an embodiment of the present invention that is applicable to the two methods discussed above, and illustrated in FIG. **9**, at least one electrode **280** is disposed on or within the first substrate **200**, the second substrate **240** or both the first substrate and the second substrate. Depending on how the electrode or electrodes are disposed, the electrode or electrodes will provide the proper structure for either an AC or DC (FIG. **7**) light-emitting panel. That is to say, if the at least one electrode **280** is at least partially disposed in a cavity **240** or **260** then there will be a direct conductive path between the at least one electrode and the plasma-forming gas or gas mixture and the panel will be configured for D.C. If, on the other hand, the at least one electrode is disposed so as not to be in direct contact with the plasma-forming gas or gas mixture, the panel will be configured for A.C.

In another embodiment of the present invention, at least one substrate is thermally treated in the presence of at least one plasma-forming gas, to form a plurality of shells **50** filled with the plasma-forming gas or gas mixture. In a preferred embodiment of the present invention, as shown in FIG. **10**, the process for making a micro-component would entail starting with a material or material mixture **700**, introducing inclusions into the material **710**, thermally treating the material so that the inclusions start forming bubbles within the material **720** and those bubbles coalesce **730** forming a porous shell **740**, and cooling the shell. The process is performed in the presence of a plasma-forming gas so that when the shell cools the plasma-forming gas **45** is sealed inside the shell **50**. This process can also be used to create a micro-component with a shell doped with a conductive material and/or a secondary emission enhancement material by combining the appropriate dopant with the initial starting material or by introducing the appropriate dopant while the shell is still porous.

In a yet still further method of manufacture, the micro-components can be manufactured using any of the above-mentioned methods, but not in the presence of a plasma-forming gas, and either in a vacuum, air or other atmosphere such as an inert atmosphere. They can be fabricated with one or two openings, and the initial gas inside can be drawn out, for example, through injection of plasma-forming gas through one opening, forcing the gas therein out the other opening. The openings can then be sealed conventionally.

In yet another alternative method, a device having one or more micro-pipettes can create the micro-components much like conventional glass blowing. The gas used to effect the glass-blowing operation can be one of the aforementioned plasma-forming gasses.

In yet still another alternative, an optical fiber extrusion device can be used to manufacture the micro-components. Like an optical fiber, which is solid, the device can be used to extrude a capillary which is hollow on the inside. The capillary can then be cut, filled with plasma-forming gas and sealed.

With respect to the selection of materials and dimensions for the micro-components manufactured in the manner described herein, they are manufactured to meet requirements for various standard display resolutions. FIG. **7** illustrates an example of calculation of pixel size and micro-component size, in the case where the micro-components are spheres, for 42-inch and 60-inch high definition television display having a 16:9 aspect ratio. FIG. **8** is a table showing numbers of pixels for various standard display resolutions, and using the process for manufacturing in accordance with the invention herein, such standards can be easily met.

In a further aspect, once the micro-components are manufactured, it is desirable to condition them prior to assembly into a plasma display panel. By conditioning is meant exciting them for a time and at an excitation sufficient to cause those micro-components which are likely to fail a short time after assembly in a plasma display panel, to fail prior to assembly. In this manner the yield relative to non-defective micro-components which are eventually assembled into a plasma display panel is significantly increased. Examples of devices for achieving said conditioning are shown in FIGS. **11** and **12**. As shown in the conditioning device **951** of FIG. **11** the manufactured and pretested micro-components **959** can be assembled between two conducting metal plates **957** which are powered through leads **955** by a voltage source **953** which can take various forms as illustrated therein. The micro-components **959** are subjected to a field sufficient to excite the plasma gas contained therein, and preferably at a level higher than any excitation level achieved when assembled in a plasma display panel. This is done for a period of time sufficient such that any micro-components which are prone to fail, will fail during the conditioning phase, typically five to ten hours.

As may be appreciated, an alternative system is illustrated by FIG. **13** which shows a conditioning device **901** which further includes a container **909** for confining and containing micro-components **911**. The container **909** may be placed between parallel plates or electrodes **903** which are powered through leads **905** by a power source **907** such as a voltage source of the type previously discussed with reference to FIG. **11**. The advantage of such a system is that by having container **909**, the micro-components are easily contained. After the conditioning period, the individual micro-components can then be dropped through a system such as pretesting device **801** shown in FIG. **11** without the presence of manufacturing drop tower **600**, and tested previously described for the method during which the micro-components are assembled. In this manner, those micro-components which failed the conditioning are eliminated and only fully-functioning micro-components can then be assembled into a plasma display panel as heretofore described.

With respect to micro-components manufactured as discussed with reference to FIGS. **5**, **6**, and **9**, once assembled, they may be cut from the sheets on which they are formed. They can be pretested with a device such as shown in the lower half of FIG. **11** at **801** and **803**. They can then be pre-conditioned as previously described with reference to FIGS. **12** and **13**, and then retested with the device of the lower half of FIG. **11** at **801** and **803**.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A process for forming a light-emitting micro-component, comprising:

forming a shell of predetermined shape and encapsulating therein a plasma-forming gas to thereby form a micro-component; and

texturing a portion of the micro-component to form a texturized portion, wherein upon application of an electrical signal, the micro-component is caused to emit light through the texturized portion.

**2**. The process of claim **1**, wherein texturizing a portion of the micro-component is achieved by sandblasting the shell of the micro-component.

**3**. The process of claim **1**, wherein texturizing a portion of the micro-component is achieved by etching the shell of the micro-component.

**4**. The process of claim **1**, wherein texturizing a portion of the micro-component is achieved through lithography.

**5**. The process of claim **1**, wherein the texturized portion is approximately 10 to 100 microns in diameter, depending on the diameter of the micro-component.

**6**. The process of claim **1**, further comprising doping the shell of the micro-component with a rare earth material.

**7**. The process of claim **6**, wherein the rare earth material is selected from the group consisting of europium 2+ for blue, europium 3+ for red, cerium 3+ for violet, and cerium 3+ plus terbium 3+ for green.

**8**. The process of claim **1**, wherein the plasma-forming gas is a rare gas halide mixture.

* * * * *

US007420445B2

(12) **United States Patent**
**Wyeth et al.**

(10) **Patent No.:** **US 7,420,445 B2**
(45) **Date of Patent:** **Sep. 2, 2008**

(54) **PHASE CHANGE CONTROL DEVICES AND CIRCUITS FOR GUIDING ELECTROMAGNETIC WAVES EMPLOYING PHASE CHANGE CONTROL DEVICES**

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(73) Assignee: **Science Applications International Corporation**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **11/822,264**

(22) Filed: **Jul. 3, 2007**

(65) **Prior Publication Data**

US 2007/0290774 A1 Dec. 20, 2007

**Related U.S. Application Data**

(63) Continuation of application No. 11/376,341, filed on Mar. 16, 2006, now Pat. No. 7,256,668, which is a continuation of application No. 11/246,233, filed on Oct. 11, 2005, now Pat. No. 7,046,106, which is a continuation of application No. 10/980,601, filed on Nov. 4, 2004, now Pat. No. 6,956,451, which is a continuation of application No. 10/346,551, filed on Jan. 17, 2003, now Pat. No. 6,828,884, which is a continuation-in-part of application No. 09/851,619, filed on May 9, 2001, now Pat. No. 6,730,928.

(51) **Int. Cl.**
***H01P 1/10*** (2006.01)

(52) **U.S. Cl.** ...................................... **333/262**; 333/101

(58) **Field of Classification Search** ................. 333/101, 333/262; 257/3
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

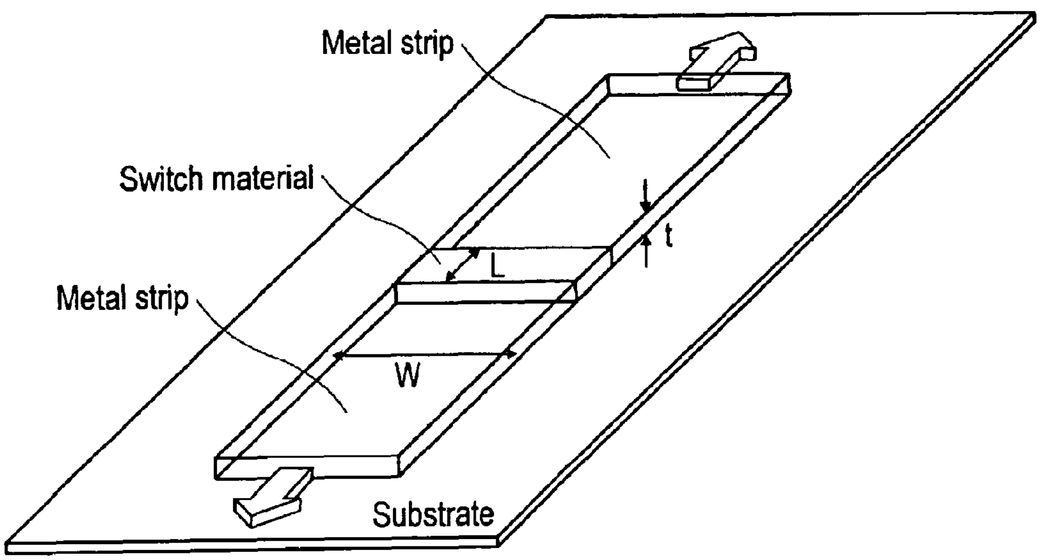
| | | | | |
|---|---|---|---|---|
| 3,530,441 | A | 9/1970 | Ovshinsky | 365/113 |
| 3,918,032 | A | 11/1975 | Nicolaides | 257/3 |
| 4,092,060 | A | 5/1978 | Nunoshita et al. | 385/7 |
| 4,545,111 | A | 10/1985 | Johnson | 438/6 |
| 4,782,340 | A | 11/1988 | Czubatyj et al. | 345/92 |
| 5,296,716 | A | 3/1994 | Ovshinsky et al. | 257/3 |
| 6,391,688 | B1 | 5/2002 | Gonzalez et al. | 438/128 |
| 6,730,928 | B2 | 5/2004 | Wyeth et al. | 257/3 |
| 6,828,884 | B2 | 12/2004 | Wyeth et al. | 333/262 |
| 6,903,362 | B2 | 6/2005 | Wyeth et al. | 257/3 |
| 6,956,451 | B2 | 10/2005 | Wyeth et al. | 333/262 |
| 7,046,106 | B2 | 5/2006 | Wyeth et al. | 333/262 |
| 2003/0072195 | A1 | 4/2003 | Mikolajick | 365/200 |

*Primary Examiner*—Dean O Takaoka
(74) *Attorney, Agent, or Firm*—King & Spalding LLP

(57) **ABSTRACT**

A circuit for guiding electromagnetic waves includes a substrate for supporting components of the circuit. The circuit includes a control device which includes a first conductive element on the substrate for connection to a first component of the circuit and a second conductive element on the substrate for connection to a second component. The control device is made up of a variable impedance switching material on the substrate which exhibits a bi-stable phase behavior. The compound has a variable impedance between a first impedance state value and a second impedance state value which can be varied by application of energy thereto to thereby affect the amplitude or phase delay of electromagnetic waves through the circuit.

**21 Claims, 11 Drawing Sheets**



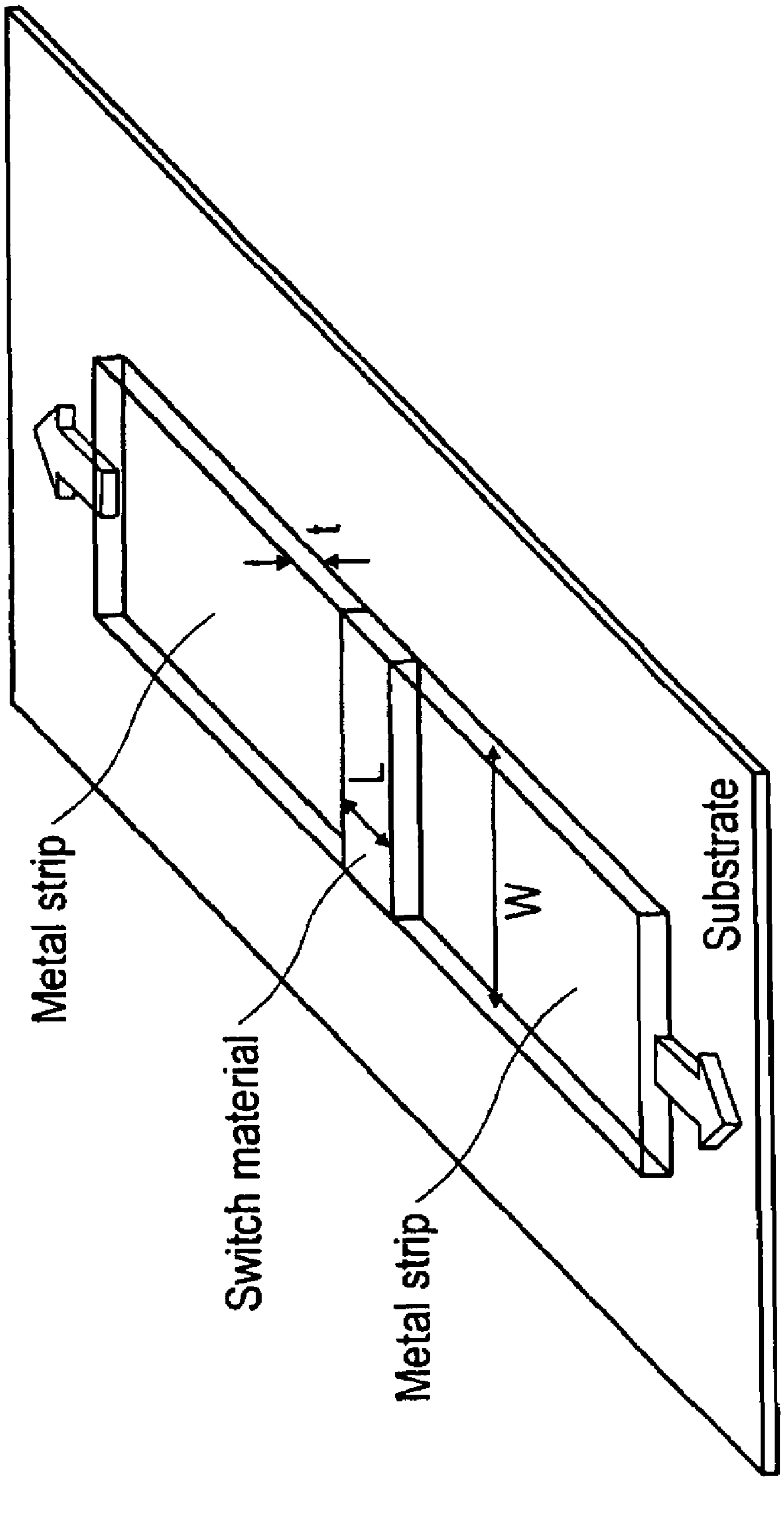
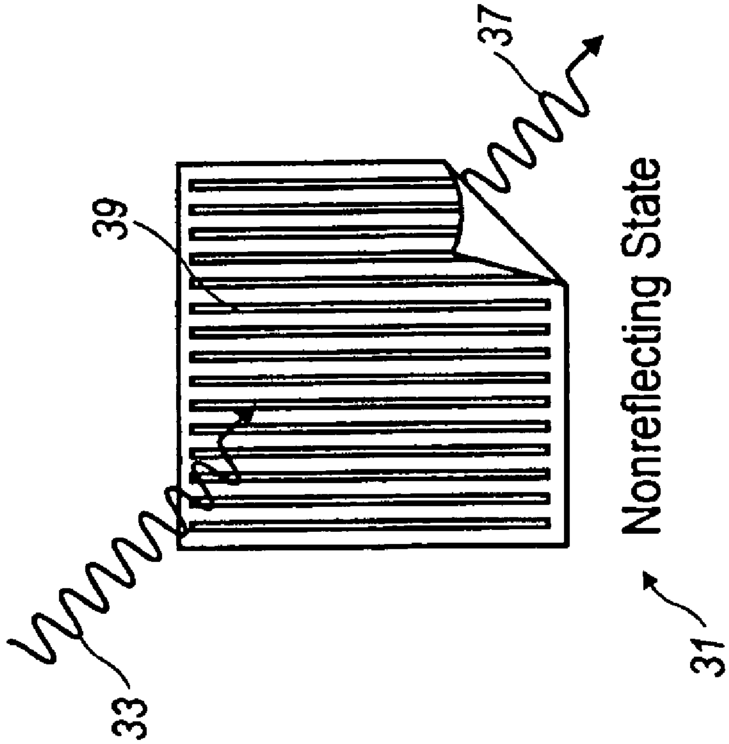
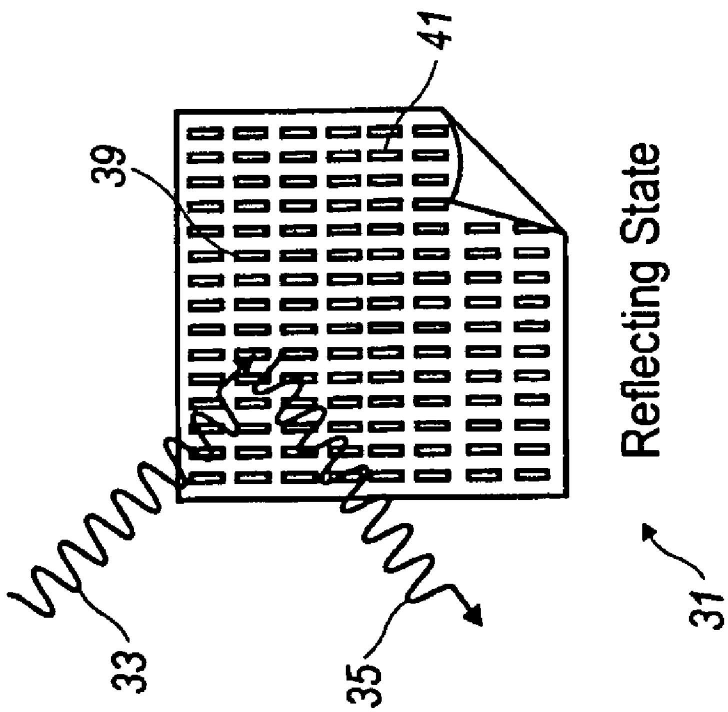



Fig. 1



37
39
Nonreflecting State
33
31


Fig. 3



41
39
Reflecting State
33
35
31


Fig. 2

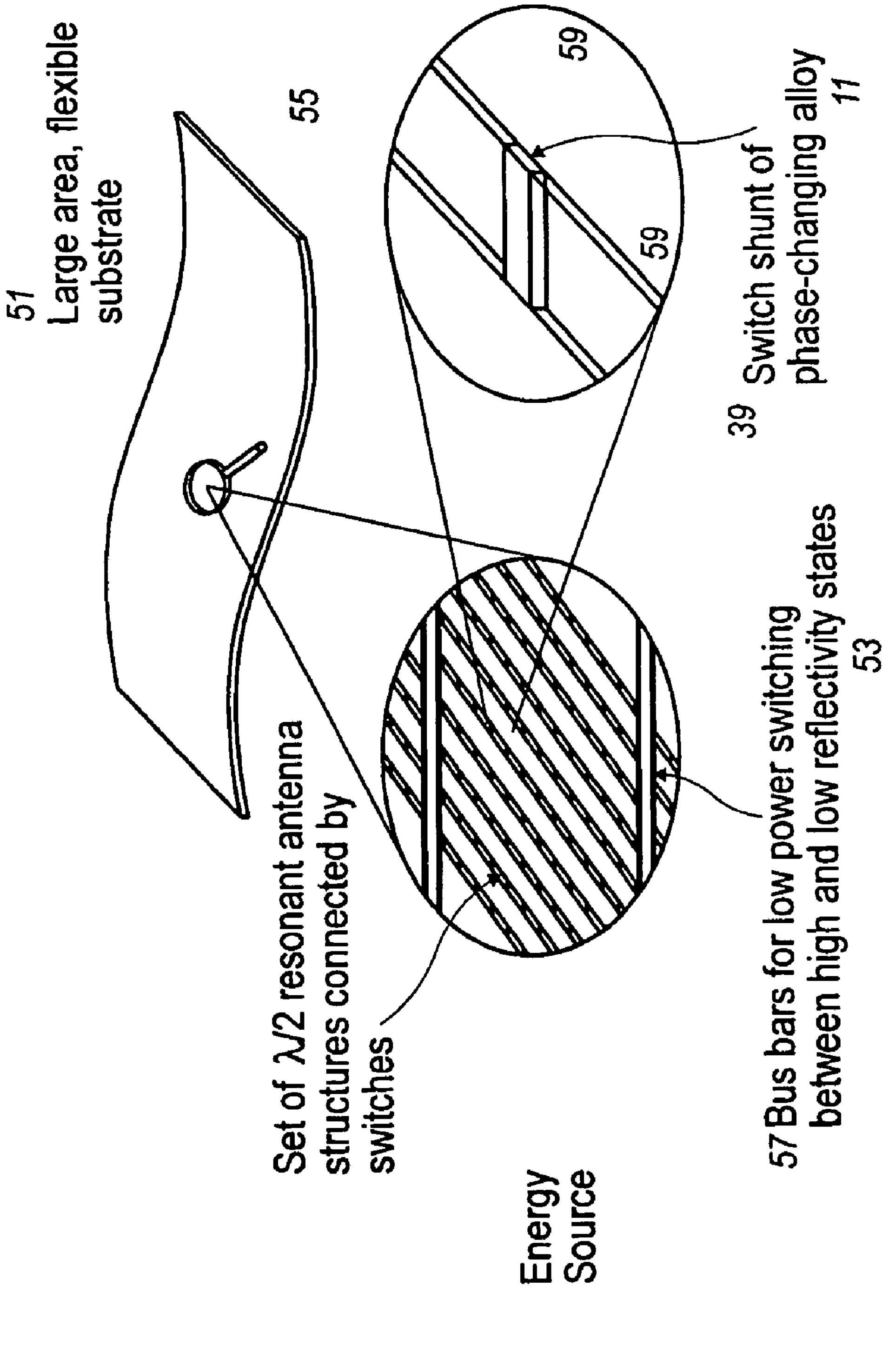

51
Large area, flexible substrate
55
Set of λ/2 resonant antenna structures connected by switches
Energy Source
59
59
Switch shunt of phase-changing alloy
39
11
57 Bus bars for low power switching between high and low reflectivity states
53

*Fig. 4*

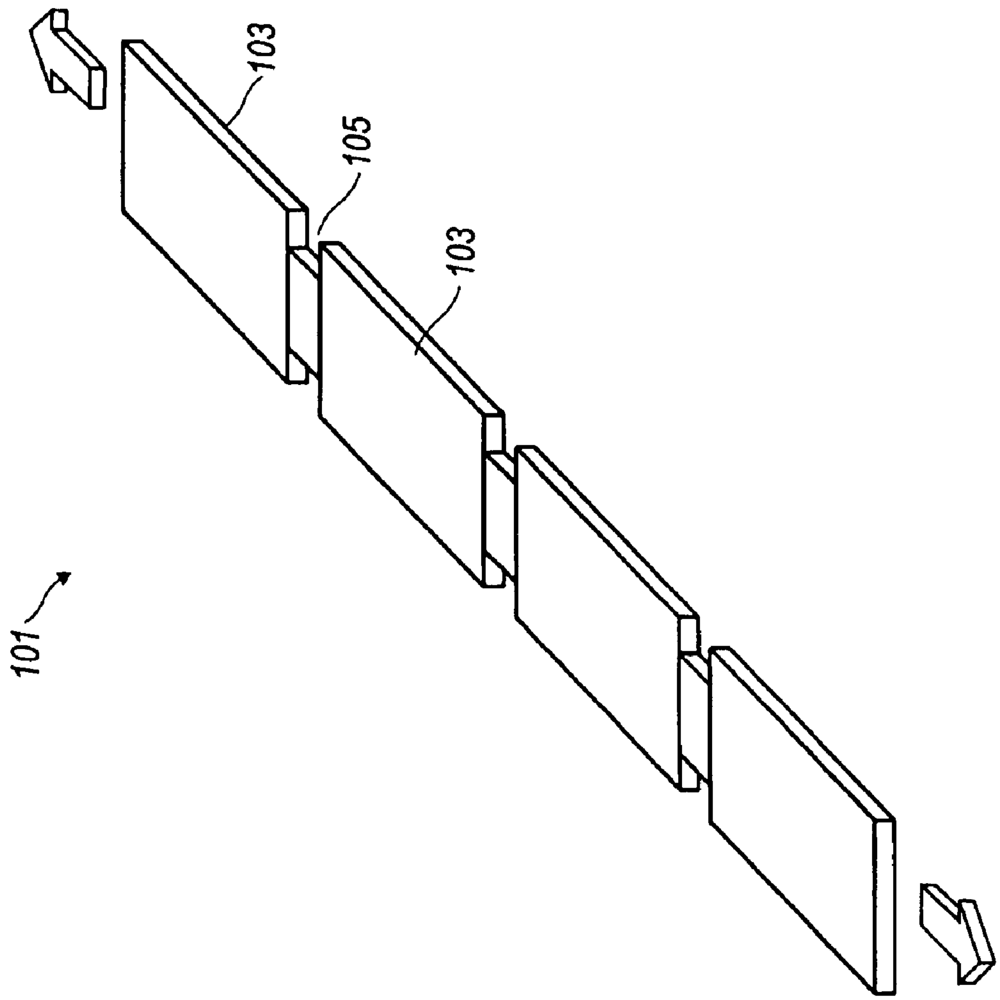
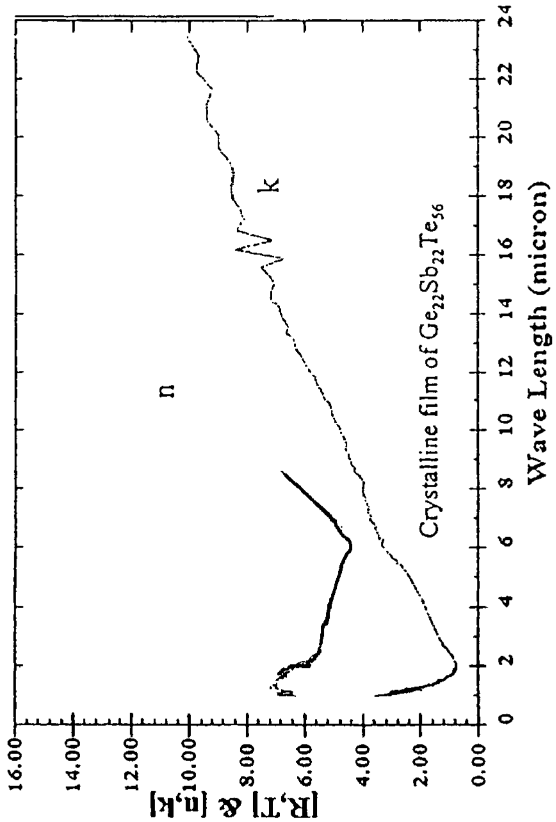



Fig. 5

Fig. 6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10.00
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0.00
n
k
Crystalline film of $Ge_{22}Sb_{22}Te_{56}$
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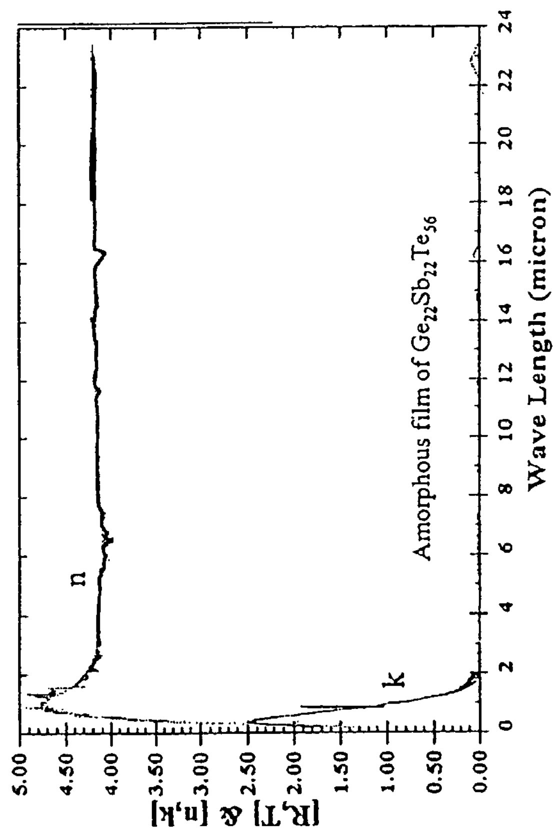
2
4
6
8
10
12
14
16
18
20
22
24
Wave Length (micron)

Fig. 7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n
k
Amorphous film of $Ge_{22}Sb_{22}Te_{56}$
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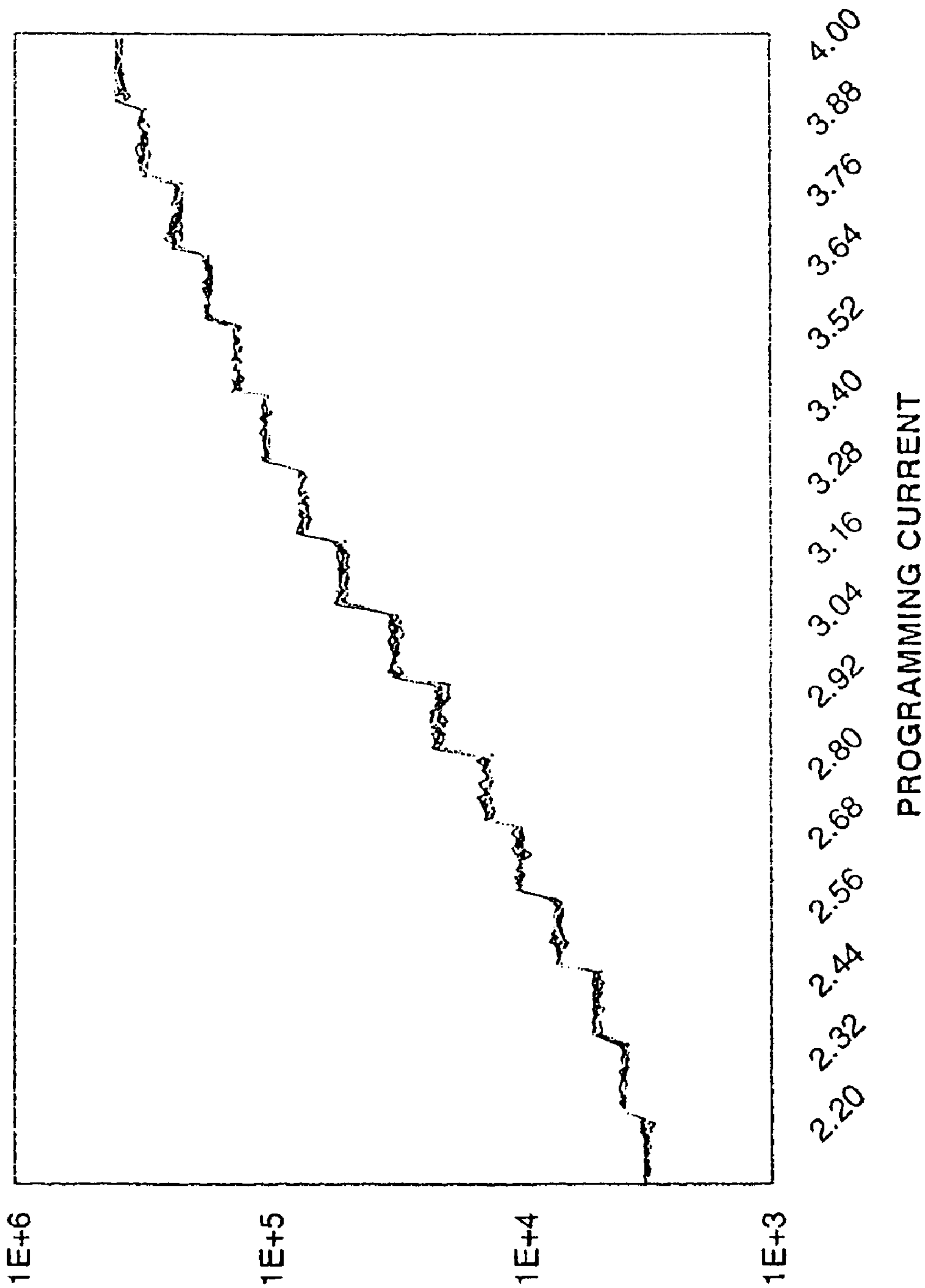
2
4
6
8
10
12
14
16
18
20
22
24
Wave Length (micron)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1E+3
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2.32
2.44
2.56
2.68
2.80
2.92
3.04
3.16
3.28
3.40
3.52
3.64
3.76
3.88
4.00
PROGRAMMING CURRENT

Fig. 8

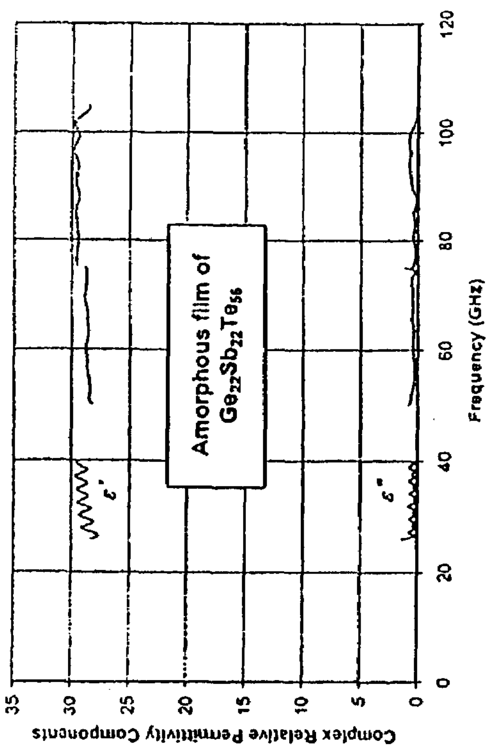


Fig. 9

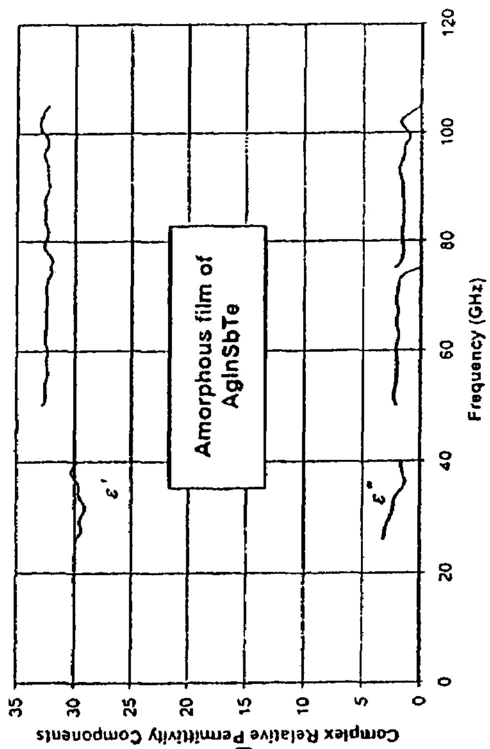


Fig. 10

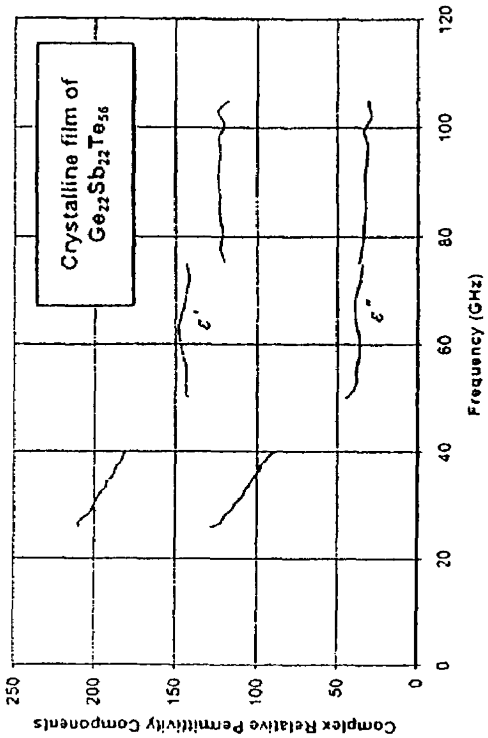


Fig. 11

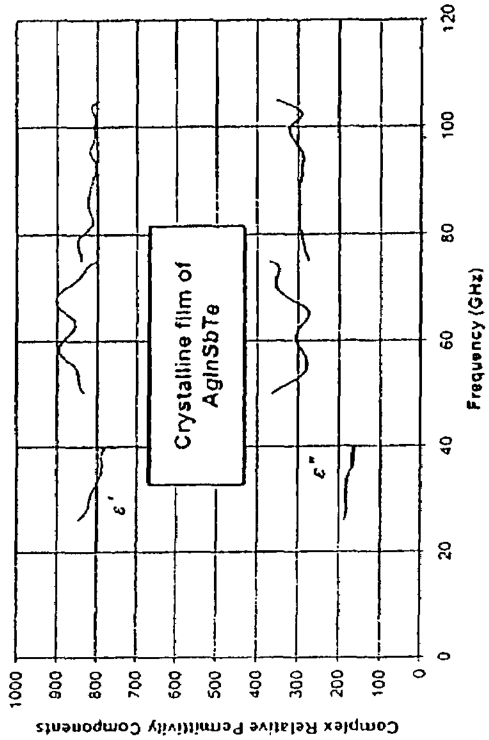


Fig. 12

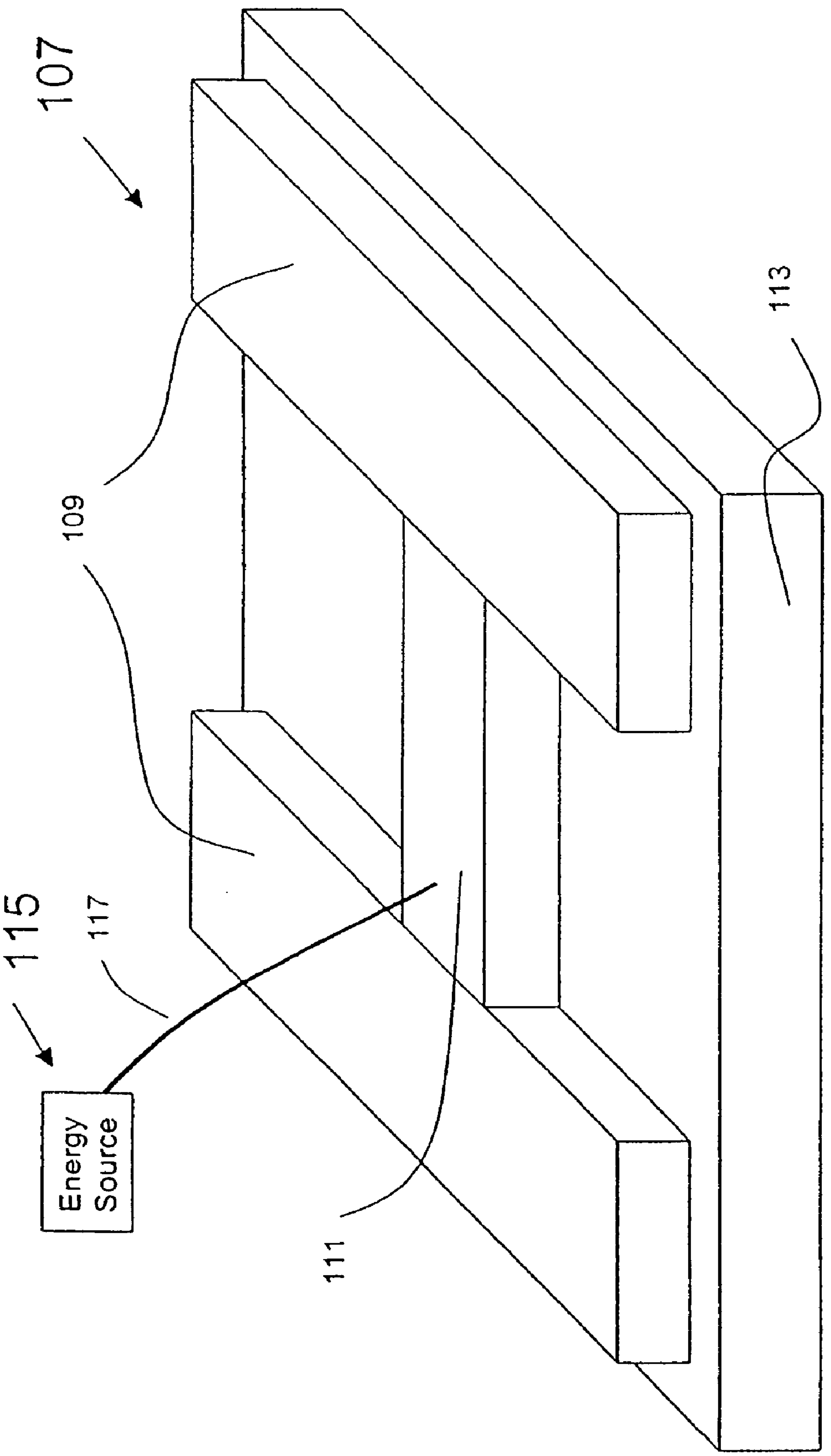


Fig. 13

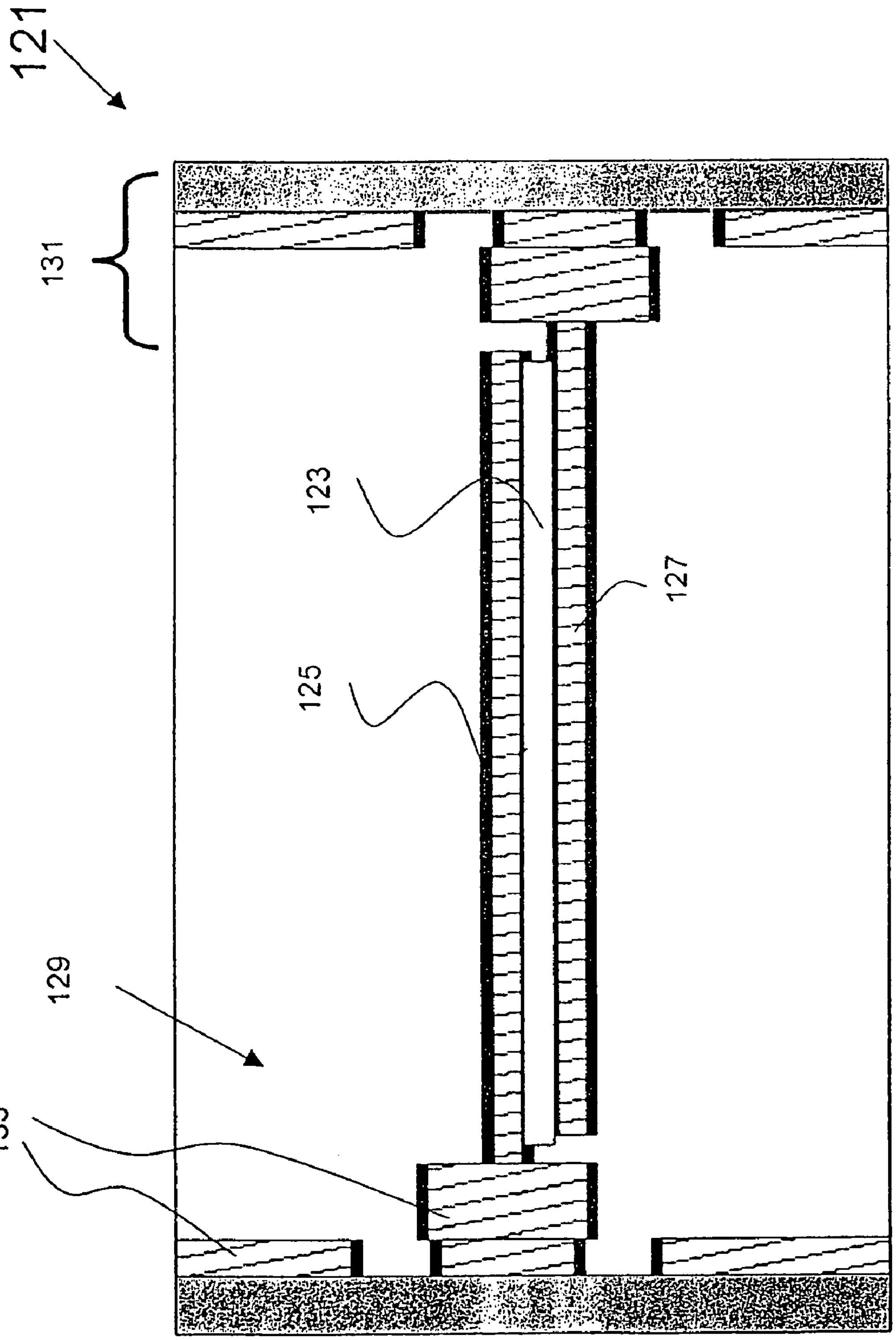


Fig. 14

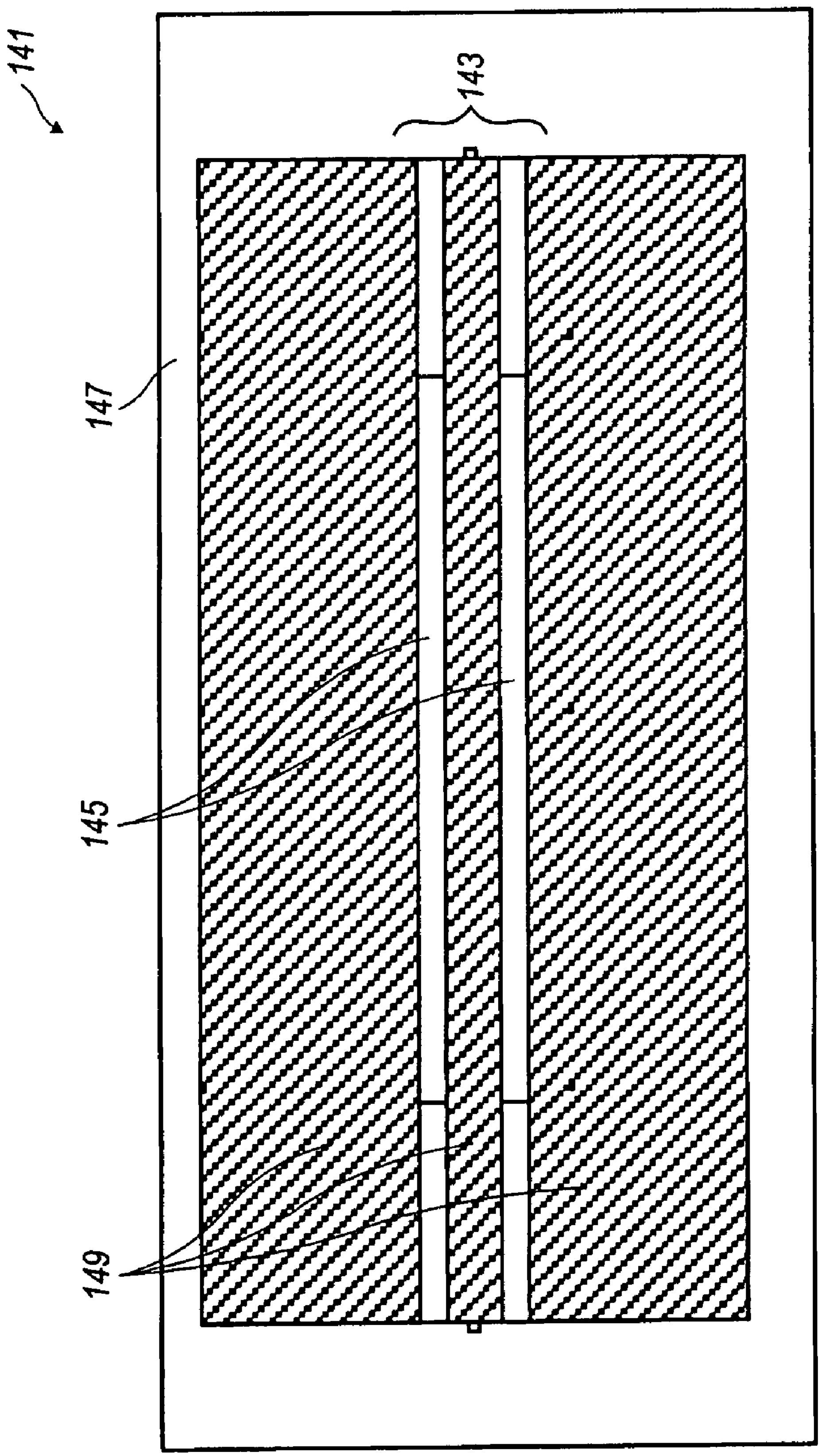


Fig. 15

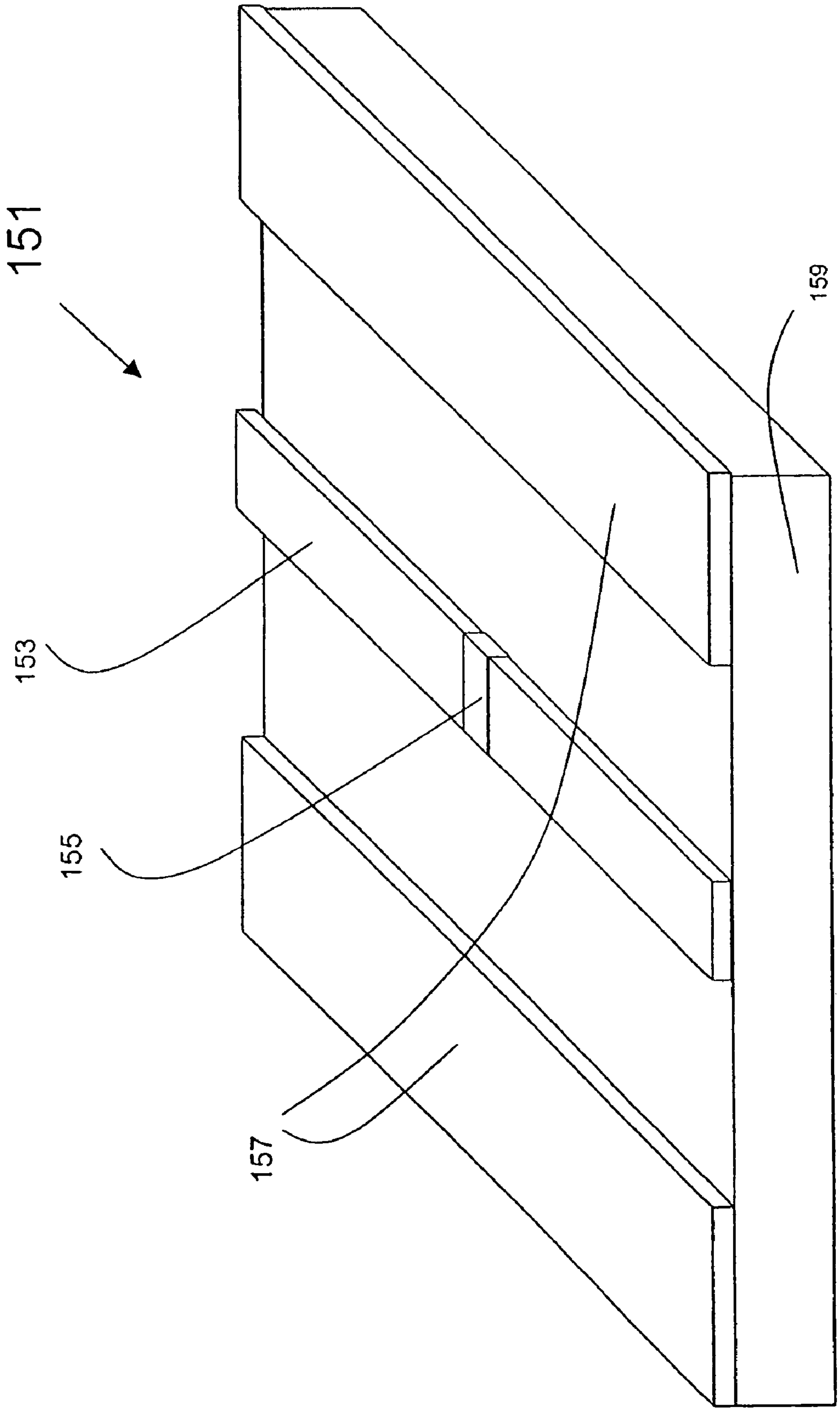


Fig. 16

# PHASE CHANGE CONTROL DEVICES AND CIRCUITS FOR GUIDING ELECTROMAGNETIC WAVES EMPLOYING PHASE CHANGE CONTROL DEVICES

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 11/376,341, entitled PHASE CHANGE CONTROL DEVICES AND CIRCUITS FOR GUIDING ELECTROMAGNETIC WAVES EMPLOYING PHASE CHANGE CONTROL DEVICES, which was filed on Mar. 16, 2006 now U.S. Pat. No. 7,256,668, which is continuation of application Ser. No. 11/246,233, which issued as U.S. Pat. No. 7,046,106, entitled PHASE CHANGE CONTROL DEVICES AND CIRCUITS FOR GUIDING ELECTROMAGNETIC WAVES EMPLOYING PHASE CHANGE CONTROL DEVICES, which was filed on Oct. 11, 2005 now U.S. Pat. No. 7,046,106, which is continuation of application Ser. No. 10/980,601, which issued as U.S. Pat. No. 6,956,451, entitled PHASE CHANGE CONTROL DEVICES AND CIRCUITS FOR GUIDING ELECTROMAGNETIC WAVES EMPLOYING PHASE CHANGE CONTROL DEVICES, which was filed on Nov. 4, 2004 and is incorporated herein by reference in its entirety, and claims priority to the filing date thereof, which is a continuation of application Ser. No. 10/346,551, which issued as U.S. Pat. No. 6,828,884, entitled PHASE CHANGE CONTROL DEVICES AND CIRCUITS FOR GUIDING ELECTROMAGNETIC WAVES EMPLOYING PHASE CHANGE CONTROL DEVICES, which was filed on Jan. 17, 2003 and is incorporated herein by reference in its entirety, and claims priority to the filing date thereof, which is a continuation in part of application Ser. No. 09/851,619, which issued as U.S. Pat. No. 6,730,928, entitled Phase Change Switches and Circuits Coupling to Electromagnetic Waves Containing Phase Change Switches, which was filed on May 9, 2001, and claims priority to the filing date thereof, the disclosure of which is expressly incorporated by reference herein.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to phase change switches and other control elements or devices, and more particularly, to phase change switches or control devices having a dynamic range of impedance, and circuits and components employing such switches or control devices. More specifically, the invention relates to such switches which can be employed in circuits such as on frequency selective surface arrays, for controlling current flow throughout the array, through the use of the switches. By controlling such current flow, the properties of the frequency selective surface array can be actively controlled. In addition, the invention also relates to implementation of such switches and other control devices in circuits, and the circuits themselves, that use conductive structures and dielectrics to guide electromagnetic (EM) waves.

2. Background of the Invention

Mechanical on/off switches have been used in circuits designed to interact with electromagnetic waves, and in particular, circuits designed to handle guided electromagnetic (EM) waves. Another set of such applications includes two-dimensional periodic arrays of patch or aperture elements known as frequency selective surfaces (FSS), the capabilities of which have been extended by addition of active devices, such as switches, and which are generally known as active grid arrays.

The mechanical process in these on/off switches involves the physical motion of a conductor (the “bridge”) between two positions, i.e., one where the bridge touches another conductor and completes the direct current (DC) conducting path of the circuit (“closed”) or moves close enough to it that the capacitive impedance is low enough to complete the path for alternating current (AC) flow, and the other where it has moved away from the contact (“open”) to break the DC conducting circuit path or to raise the capacitive impedance to block AC flow. Such mechanical switches have been made at micrometer size scale in so-called MEMS—Micro-Electro Mechanical Systems. MEMS switch technology to date has shown poor lifetimes and packaging costs.

A key goal in the use of MEMS switches with guided EM waves in the so-called radio frequency (RF) bands is to provide controllable phase delays in a circuit. This is done by using a set of switches to introduce combinations of fixed length phase delay branches into a circuit path. The degree of phase delay control is related to how many separate branches (and switches to control them) are added to the circuit. The switching in or out of a given fixed delay branch provides a step change in the net circuit phase delay. In this approach, if finer steps are desired to cover the same range of total phase delay, then more branches and switches are required.

Alternatively, transistor and transistor-like semiconductor switching devices have been used in circuits designed to interact with electromagnetic waves and in particular, in circuits and components thereof that guide EM waves. Such devices which include PIN diodes and field effect transistors (FETs) form the basis of a collection of solid-state circuits operating on guided EM waves of up to gigahertz (e.g., GHz, 1 GHz≈$10^9$ Hz) for use in microwave and communication systems. However, for the specific applications herein, the semiconductor switching devices typically have shortcomings in several areas, i.e., GHz and above. Such shortcomings may include high switching power required or high insertion losses.

In the field of semiconductor memory devices, it has been proposed to use a reversible structural phase change (from amorphous to crystalline phase) thin-film chalcogenide alloy material as a data storage mechanism and memory applications. A small volume of alloy in each memory cell acts as a fast programmable resistor, switching between high and low resistance states. The phase state of the alloy material is switched by application of a current pulse, and switching times are in the nanosecond range. The cell is bi-stable, i.e., it remains (with no application of signal or energy required) in the last state into which it was switched until the next current pulse of sufficient magnitude is applied.

## SUMMARY OF THE INVENTION

In accordance with one aspect of the invention there is provided a switch or control element or device for use in circuits and components that interact with electromagnetic radiation, and more specifically, in circuits or components that guide EM waves. The switch or control element or device includes a substrate for supporting components of the switch. A first conductive element is on the substrate for connection to a first component of the circuit or component (hereafter collectively “circuit”), and a second conductive element is also provided on the substrate for connection to a second component of the circuit. Such switches and circuits involve implementations to guide EM waves in circuits such as parallel wire transmission lines, coaxial cables, waveguides, coplanar waveguides, striplines and microstriplines. Use of such switch devices allows control of energy flow through the circuits with functional properties such as fast switching times, e.g, about 10 nanoseconds to about 1 microsecond; low insertion loss, e.g., about 1 dB or less; high isolation, e.g., about 20 dB or higher; long lifetime, e.g., at least about $10^{13}$ cycles; and low cost. Addressing of the control devices either electrically or optically allows flexibility in how the devices are used.

A circuit for guiding electromagnetic waves includes a substrate for supporting components of the circuit for guiding the electromagnetic waves and at least one control device. The control device includes at least one conductive element on the substrate for connection to at least one component of the circuit. A second conductive element is provided on the substrate for connection to at least one second component of the circuit and the control device is made up of a variable impedance switching material on the substrate. The switching material connects the at least one first conductive element to the at least one second conductive element. The switching material is made up of a compound which exhibits a bi-stable phase behavior, and is variably switchable to an impedance between the first impedance state value and up to a second impedance state value by application of energy thereto. As a result, the switching affects the amplitude and/or phase delay of electromagnetic waves through the circuit as a result of a change in the impedance value of the compound. Similarly, the path of the guided EM waves can also be affected and/or controlled.

In more specific aspects, the first and second impedance state values are such that at one value the control device is conductive, and at the other value the control device is less conductive or non-conductive. Preferably an energy source is connected to the control device for causing the change in impedance value. The energy source can be an electrical energy source with leads connected to the switch. Alternatively, the energy source could be a light source which is a laser positioned to direct a laser beam to the switch or control device to cause the change in impedance value. In a more specific aspect, fiber optics or an optical waveguide is associated with the laser and the switch to direct the laser light to the switch.

The circuit and components can be a circuit or component employing or made up as parallel wire transmission lines, coaxial cables, waveguides, coplanar waveguides, striplines, or microstriplines. The material making up the switch or control device is preferably a chalcogenide alloy, and more preferably at least one of $Ge_{22}Sb_{22}Te_{56}$, and AgInSbTe.

In a more preferred aspect, in some applications, the compounds for the control device are used in a range of stable intermediate stage set on a submicron scale or mixtures of amorphous and crystalline phases, but which exhibit (average) intermediate properties under larger scale measurement or functional conditions.

In an alternative aspect, the invention is directed to a control device for use in circuits which guide electromagnetic waves. The control device is made up as previously described herein.

## BRIEF DESCRIPTION OF THE DRAWINGS

Having thus briefly described the invention, the same will become better understood from the following detailed discussion, made with reference to the appended drawings wherein:

FIG. **1** is a schematic view of the control device between two conductive elements as described herein;

FIGS. **2** and **3** are schematic views of a frequency selective surface array shown, respectively, in a reflecting state and in a non-reflecting state, depending on the impedance value of control devices disposed throughout the array;

FIG. **4** shows three views of increasing magnification of an array, with conductive elements and control devices arranged therein, and with a further magnified view of a typical switch control device;

FIG. **5** is a schematic view of a circuit element similar to that of FIG. **1**, for use in a switching frequency selective surface array (as in FIGS. **2**, **3**, and **4**), where the entire element is made of switchable material but configured so that only the connecting elements change state upon application of electrical energy;

FIGS. **6** and **7** are graphs illustrating measured values of the complex index of refraction of an alloy used in the control device, in the infrared for the crystalline phase, and the amorphous phase;

FIG. **8** is a graph illustrating how the resistance of the phase change alloy can be continuously varied to provide reflectivity/transmissivity control in a circuit;

FIGS. **9-12** are graphs illustrating measurement result for the complex relative permittivity component magnitudes for $Ge_{22}Sb_{22}Te_{56}$ (GST-225 or GST) and AgInSbTe (AIST) phase change material over a frequency range of 26-105 GHz;

FIG. **13** is a top view of conductor layers and phase change material layer on a dielectric substrate of a guided wave device assembled as a coupled stripline;

FIG. **14** is a top view of conductor layers and phase change material layer on a dielectric substrate of a guided wave device arranged as a coplanar waveguide;

FIG. **15** is a perspective view of an alternative design for using phase change material to produce variable impedance switching action in a coplanar waveguide structure; and

FIG. **16** is a perspective view illustrating the use of phase change material to produce variable impedance switching action in a dual stripline arrangement, and further illustrating how a separate energy source might be coupled directly to the control device to effect switching thereof.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** schematically illustrates a switch **11** in accordance with one aspect of the invention. The control device includes a substrate **13** having a variable impedance switch material **15** deposited thereon to form a control device element, and connecting a first conductive element **17**, typically a metal strip, to a second conductive element **19**. In this embodiment, the conductive elements **17** and **19** can be, for example, two circuit paths of an array or circuit such as a frequency selective surface array. The entire array can sit on top of a dielectric substrate **13**, such as polyethylene.

The switch material **15** is typically a reversible phase change thin film material having a dynamic range of resistivity or impedance. An example of a typical switch material for use in accordance with the invention is a chalcogenide alloy, more specifically, $Ge_{22}Sb_{22}Te_{56}$. Although a specific alloy has been described, it will be readily apparent to those of ordinary skill in the art that other equivalent alloys providing the same functionality may be employed. Other such phase change alloys include the AgInSbTe (AIST), GeInSbTe (GIST), (GeSn)SbTe, GeSb(SeTe), and $Te_{51}Ge_{15}Sb_2S_2$ quaternary systems; the ternaries $Ge_2Sb_2Te_5$, InSbTe, GaSeTe, $SnSb_2Te_4$, and InSbGe; and the binaries GaSb, InSb, InSe, $Sb_2Te_3$, and GeTe. As already noted, several of these alloys are in commercial use in optical data storage disk products such as CD-RW, DVD-RW, PD, and DVD-RAM. However, there has been no use or suggestion of use of such an alloy as a control element in applications such as described herein. Typically, the alloy is deposited by evaporation or sputtering in a layer that is typically 20-30 nm thick to a tolerance of ±1 nm or less as part of a large volume, conventional, and well known to those of ordinary skill in the art, manufacturing process.

In this regard, with reference to the specific alloy discussed, FIGS. **6** and **7** illustrate measured values of the complex index of refraction of $Ge_{22}Sb_{22}Te_{56}$ over a spectral wavelength range that includes 8-12 μm. At the mid-band wavelength of 10 μm, the real index, n, changes by a factor of 2 between the two phases, but the so-called extinction coefficient, k, goes from approximately 4.8 in the crystalline phase to near zero in the amorphous phase.

Accordingly, the following table shows calculations using this data to find the changes in resistivity (ρ) and dielectric constant (∈) of the material.

Optical and Electrical Properties of the alloy $Ge_{22}Sb_{22}Te_{56}$ at IR vacuum wavelength of 10 μm.

| | Phase | |
|---|---|---|
| | Crystalline | Amorphous |
| n | | 4.2 |
| k | 4.8 | 0.01 |
| f (frequency in Hz) | $3 \times 10^{13}$ | $3 \times 10^{13}$ |
| $\rho \propto (nkf)^{-1}$ (ohm-cm) | $7.6 \times 10^{-4}$ | 0.71 |
| $\epsilon = n^2 - k^2$ | 44.2 | 17.6 |

As the table shows, the change in k correlates with a change in resistivity of almost three orders of magnitude.

In order to determine the thermal IR (infrared) performance, the shunt is modeled as a capacitor and a resistor in parallel. The following table shows the calculated values for the capacitive and resistive impedance components with switch dimensions in the expected fabrication range, using the expressions shown in the table.

state, thereby interrupting the conductive paths such that electromagnetic radiation **33** impinging on the array then becomes reflected radiation **35**. Conversely, FIG. **3** shows the array with the control devices at a low impedance such that the conductors **39** are continuous, and the impinging radiation **33** passes through the array **31** as transmitted radiation **37**.

FIG. **4** illustrates in greater detail a typical circuit **51**, which as illustrated in the intermediate magnification **53**, includes a plurality of conductors **39** having the switches shown as dots interconnected therebetween. In order to vary the impedance of the switches, an energy source **57** may be connected to the individual conductors to provide current flow to the control devices **11** to thereby change the impedance of the control devices **11** by the application of energy, in the form of electricity. As further shown in the third magnification **55**, while the conductors **39** themselves can be directly connected to an energy source, it is also possible to selectively establish leads **59** to the switch material **15** to apply energy to the switch material directly and not through the conductors **39** to cause the impedance to vary.

FIG. **5** shows in detail an additional embodiment **101** of the invention in which conductive elements **103** and the connecting control device **105** are entirely made of the same phase change material to form the control device element as compared to the embodiment of FIG. **1**. In this embodiment, the control device **105** is purposely made less wide to form a switch element which is narrower than the conductive elements **103** that connect to it on either side, but having a thickness equal to the conductive elements **103**. In this case, the cross section of the control device element is less than the cross section of the conductive elements **103**, causing the electrical resistance per unit length to be greater in the control device element than in the conducting elements. When electrical current is passed through a circuit made up of a series of these constricted switch connections, i.e., control devices **105**, the phase change material in the control devices **105** will dissipate more electrical energy per unit length than the conducting elements because of the higher resistance per unit length. This higher dissipation will cause the control devices **105** to experience a greater temperature rise than the conductive elements **103**. Therefore a correctly sized electrical current pulse will cause the phase change material in the control devices **105** to change state while the phase change material in the conductive elements **103** remains in the low impedance state. As is the case with the earlier described embodiment as shown in FIG. **4**, the leads **59** (not shown) can also be established to connect to the control devices **105** to apply energy directly to the control device **105**, and not through the conductive elements **103**.

Resistance (R) and capacitive reactance ($X_C$) components of the switch impedance in the crystalline and amorphous states for several representative values of the switch dimensions shown in FIG. 1. The capacitive reactance values are calculated using $\omega = 1.9 \times 10^{14}$ Hz, which corresponds to f = 30 THz or λ = 10 μm.

| | | | Crystalline | | Amorphous | |
|---|---|---|---|---|---|---|
| L (μm) | W (μm) | t (μm) | $X_C = (\omega C)^{-1}$ with $C = \epsilon Wt/L$ (ohms) | $R = \rho L/Wt$ (ohms) | $X_C = (\omega C)^{-1}$ with $C = \epsilon Wt/L$ (ohms) | $R = \rho L/Wt$ (ohms) |
| 1.0 | 1.0 | 0.01 | 1.36K | 1K | 3.4K | 1 M |
| 1.0 | 1.0 | 0.1 | 136 | 100 | 340 | 100K |
| 1.0 | 1.0 | 0.2 | 68 | 50 | 170 | 50K |
| 1.0 | 0.5 | 0.1 | 271 | 200 | 680 | 200K |

As further shown in FIG. **8**, the resistance of the specific alloy discussed herein can therefore be continuously varied to provide reflectivity control.

FIGS. **2** and **3** thus show the effect on an array of the use of control devices **11**. This is shown, for example, in a frequency selective surface array **31**. In the case of FIG. **2**, the array includes a plurality of conductors **39** having control devices **41** as described herein interconnected therebetween. In the case of FIG. **2**, the control devices are in a high impedance

While in a specific embodiment the impedance of the phase change material of control devices is varied by application of electrical current to change the state of the phase change material, it will be appreciated by those of ordinary skill in the art that given the nature of the material, other energy sources can be employed. For example, selectively targeted laser beams may be directed at the control devices to change the overall circuit current flow configuration, as well as other alternative means of providing energy to change the state and thus vary the impedance can be used. The laser beam can be directed through free space or can be directed through fiber optics or optical waveguide directly onto the control device as, for example, is schematically illustrated in FIG. **16** for a different embodiment application.

As already discussed, in its various aspects the invention uses the changing properties of a specific type of metallic alloy. The alloys, as already noted, among others can include the compounds GST-225, GST, or AIST. The amount of energy needed to cause transition in alloy volumes on the order of 1 $\mu m^3$ is in the range of about 1 to about 3 nanojoules for known materials depending on the thermal dissipation environment of the alloy volume. The energy can be supplied to the material, as already noted, in various ways including exposure to pulse, focused laser beams or application of a pulse of electrical current. The two phases, crystalline and amorphous, have different electromagnetic properties across a significant part of the electromagnetic spectrum.

FIGS. **9-12** show the measured magnitude of the real and imaginary components ($\in'$ and $\in''$ respectively) of the complex (relative, i.e., normalized to $\epsilon_0$) dielectric constant of the alloy GST over a range of RF electromagnetic frequency from about 26 GHz up to about 105 GHz for both phases, and show similar data for the alloy AIST.

As the figures show, at a frequency of 50 GHz, for example, the real dielectric constant, $\in'$, changes by a factor of 5 between the two GST phases, and by a factor of approximately 25 between the two IST phases. However, the imaginary dielectric constant magnitude, $\in''$, which is related to the conductivity of the material goes from approximately 45 (at 50 GHz) in the GST crystalline phase to less than one in the GST amorphous phase. The corresponding change for $\in''$ of AIST at 50 GHz is from about 350 to about 2.5.

FIG. **13** shows a schematic depiction of a partial embodiment of the invention in which the phase change material is placed between two metallic conductors **109** as a part of a structure **107**, for example, an electromagnetic (EM) wave guiding structure. In this embodiment, the structure **107** is a dual stripline structure which guides EM waves in a manner well known to those of ordinary skill in this art. Based on the known properties of the phase change material, the change in the lumped impedance of the material can be estimated as the material changes from crystalline to amorphous phase. For the GST material at 50 GHz, the resistive (real) impedance, which scales inversely with $\in''$, will increase by a factor of over 50 as the material changes from crystalline to amorphous, while the capacitive (imaginary) impedance, which scales inversely with $\in'$, will increase by a factor of approximately eight (8) at the same time. Similarly, for the AIST material at 50 GHz, the resistive (real) impedance will increase by a factor of approximately 140 as the material changes from crystalline to amorphous, while the capacitive (imaginary) impedance will increase by a factor of about 25 at the same time. Without predicting exact effects in a specific embodiment, it will be readily apparent to those of ordinary skill in the art that this level of change in lumped impedance components is sufficiently large to design devices to produce significant control effects in wave guiding structures. In the case of the dual stripline structure of FIG. **13**, the components are arranged on a dielectric substrate **113** to guide the electromagnetic waves in desired paths.



In a more specific embodiment as schematically illustrated in FIG. **13**, an energy source **115** can be coupled through a direct connection **117** to the control device **111** to effect the change in impedance. The energy source can be an electrical source **115** coupled through a lead or leads **117** to the switch material **111**, or alternatively, can be a laser coupled through a fiber optic fiber to the switch material. As already previously noted, the laser can alternatively also be free standing and the laser beam directed in free space to the control device or switch material to provide the necessary energy to change the state thereof.

FIG. **14** illustrates yet still another embodiment of an implementation of the invention described herein in which the guided wave device is a coupled stripline **121**. The phase change material **123** is arranged between conductors **125** and **127** of the coupled stripline **121** structure which are respectively connected at each end through conductor layers **133** making up a part of a coplanar waveguide termination **131**.

In a yet still further embodiment, FIG. **15** illustrates an implementation of the control device in a guided wave device made up as a coplanar waveguide **141**. The coplanar components **143** are arranged adjacent to each other and include the phase change material **145** arranged between conductor layer **149** on a dielectric substrate **147**.

In a final embodiment described herein as shown in FIG. **16**, the guided wave device is a coplanar waveguide structure **151** which includes a metal center conductor **153** with the phase change material or control device **155** arranged as an insert. The device **151** also includes parallel metal ground planes **157** arranged on a dielectric substrate **159**.

As may be appreciated from the table in FIG. **8**, in these types of guided wave devices such as shown in FIGS. **13-16**, the variable impedance carries with it a variation of the phase delay in the guided wave, as will be readily apparent to those of ordinary skill. Thus, the guided wave devices can be employed as variable phase delay devices.

Having thus described the invention in detail, the same will become better understood from the appended claims in which it is set forth in a non-limiting manner.

The invention claimed is:

**1**. A circuit for guiding electromagnetic waves, comprising:

a substrate for supporting components of the circuit for guiding electromagnetic waves;

a co-planar waveguide; and

at least one control device comprising:

(a) at least one first conductive element on the substrate for connection to at least one first component of the circuit,

(b) at least one second conductive element on the substrate for connection to at least one second component of the circuit, and

(c) a control element made up of a variable impedance switching material on the substrate, and connecting the at least one first conductive element to the at least one second conductive element;

wherein the switching material is comprised of compound which exhibits a bi-stable phase behavior, and having a variable impedance between a first impedance state value and a second impedance state value by application of energy thereto, thereby affecting at least one amplitude and phase delay of electromagnetic waves flowing through the circuit, as a result of change in the impedance value of the compound; and wherein the co-planar waveguide further comprising components that are arranged adjacent to each other.

2. The circuit of claim 1, further wherein the components include the switching material arranged between a conductor layer on a dielectric substrate.

3. A circuit for guiding electromagnetic waves, comprising:

a substrate for supporting components of the circuit for guiding electromagnetic waves;

a co-planar waveguide; and

at least one control device comprising:

(a) at least one first conductive element on the substrate for connection to at least one first component of the circuit,

(b) at least one second conductive element on the substrate for connection to at least one second component of the circuit, and

(c) a control element made up of a variable impedance switching material on the substrate, and connecting the at least one first conductive element to the at least one second conductive element;

wherein the switching material is comprised of compound which exhibits a bi-stable phase behavior, and having a variable impedance between a first impedance state value and a second impedance state value by application of energy thereto, thereby affecting at least one amplitude and phase delay of electromagnetic waves flowing through the circuit, as a result of change in the impedance value of the compound; and

wherein the co-planar waveguide structure includes a metal center conductor with the control device arranged as an insert.

4. The circuit of claim 3, wherein the first and second impedance state values are such that at one value the control device is conductive, and at the other value the switch is from less conductive to being non-conductive.

5. The circuit of claim 3, further comprising an energy source connected to the control device for causing the change in impedance values.

6. The circuit of claim 3, further comprising separate leads connected to the control device for connection to an energy source.

7. The circuit of claim 6, wherein the energy source comprises a light source.

8. The circuit of claim 7, wherein the light source is a laser positioned for directing a laser beam to the control device to cause the change in impedance values.

9. The circuit of claim 8, further comprising at least one of fiber optics and optical waveguides associated with the laser and the control device to direct laser light from the laser to the switch.

10. A control device for use in circuits which guide electromagnetic waves where the circuit is a coplanar waveguide, the control device comprising:

a substrate for supporting components of the control device;

at least one first conductive element on the substrate for connection to a first component of a circuit which guides electromagnetic waves;

at least one second conductive element on the substrate for connection to a second component of the circuit; and

a control element made up of a variable impedance switching material on the substrate, and connectable to the at least one first conductive element and to the at least one second conductive element;

wherein the switching material comprised of a compound which exhibits a bi-stable phase behavior, and having a variable impedance state value by application of energy thereto, to thereby affect at least one of amplitude and phase delay of electromagnetic waves flowing through a circuit employing the control device when connected thereto, as a result of a change in the impedance value of the compound; and

wherein the switching material is a thin film material.



11. The control device of claim 10, wherein the switching material is a reversible phase change material having a variable impedance over a specified range which is dependent on the amount of energy applied to the material.

12. The control device of claim 10, wherein the first and second conducting elements are the same material as the switching material.

13. The control device of claim 10, wherein the control device is shaped to switch its phase state to the second impedance state in response to an application of energy to the switch, and remains in the second impedance state without continuing the application of energy.

14. A control device for use in circuits which guide electromagnetic waves where the circuit is a coplanar waveguide, the control device comprising:

a substrate for supporting components of the control device;

at least one first conductive element on the substrate for connection to a first component of a circuit which guides electromagnetic waves;

at least one second conductive element on the substrate for connection to a second component of the circuit; and

a control element made up of a variable impedance switching material on the substrate, and connectable to the at least one first conductive element and to the at least one second conductive element;

wherein the switching material comprised of a compound which exhibits a bi-stable phase behavior, and having a variable impedance state value by application of energy thereto, to thereby affect at least one of amplitude and phase delay of electromagnetic waves flowing through a circuit employing the control device when connected thereto, as a result of a change in the impedance value of the compound; and

wherein the alloy comprises $Ge_{22}Sb_{22}Te_{56}$ or AgInSbTe.

15. The control device of claim 14, further comprising an energy source connected thereto for causing the change in impedance values.

16. The control device of claim 14, further comprising separate leads connected to the switch for connection to an energy source.

17. The control device of claim 16, wherein the energy source comprises a light source.

18. The control device of claim 17, wherein the light source is a laser positioned for directing a laser beam thereto to cause the change in impedance values.

19. The control device of claim 18, further comprising at least one of fiber optics and optical waveguides associated with the laser and the switch to direct laser light from the laser thereto.

20. The control device of claim 14, wherein the switching material comprises chalcogenide alloy.

21. The control device of claim 14, wherein the first and second impedance state values are such that at one value the control device is conductive and at the other value the switch is from less conductive to being non-conductive.

* * * * *

US007789725B1

(12) United States Patent
George et al.

(10) Patent No.: US 7,789,725 B1
(45) Date of Patent: Sep. 7, 2010

(54) **MANUFACTURE OF LIGHT-EMITTING PANELS PROVIDED WITH TEXTURIZED MICRO-COMPONENTS**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 451 days.

(21) Appl. No.: **11/976,037**

(22) Filed: **Oct. 19, 2007**

**Related U.S. Application Data**

(60) Division of application No. 10/756,266, filed on Jan. 14, 2004, now Pat. No. 7,288,014, which is a continuation-in-part of application No. 10/214,768, filed on Aug. 9, 2002, now Pat. No. 6,822,626, which is a continuation-in-part of application No. 09/697,358, filed on Oct. 27, 2000, now Pat. No. 6,762,566.

(51) **Int. Cl.**
***H01J 9/00*** (2006.01)

(52) **U.S. Cl.** .......................................... **445/25**; 445/24

(58) **Field of Classification Search** ......... 313/582–587; 445/24, 25
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,923,148 A 8/1933 Hotchner ......................... 49/7
1,961,735 A 6/1934 Braum ......................... 40/130
2,036,616 A 4/1936 Asch ......................... 176/14
2,095,291 A 10/1937 Schneider ..................... 40/130
2,644,113 A 6/1953 Etzkorn ...................... 315/228
2,984,534 A 5/1961 Kallweit et al. ................ 316/8
3,453,478 A 7/1969 Shoulders et al. ........... 313/309
3,559,190 A 1/1971 Blitzer ........................ 340/173
3,646,384 A 2/1972 Lay ......................... 313/109.5
3,684,468 A 8/1972 Bode et al. ....................... 65/4
3,704,052 A 11/1972 Coleman ..................... 316/17
3,755,027 A 8/1973 Gilsing ........................ 156/67
3,755,704 A 8/1973 Spindt et al. ................ 313/309
3,848,248 A 11/1974 MacIntyre, Jr. ......... 340/324 M
3,935,494 A 1/1976 Dick et al. .................. 313/587
3,969,651 A 7/1976 Greeson, Jr. .......... 315/169 TV
3,990,068 A 11/1976 Mayer et al. ............ 340/324 M
3,998,618 A 12/1976 Kreick et al. ................. 65/105
4,027,246 A 5/1977 Caccoma et al. ......... 235/151.1
4,035,690 A 7/1977 Roeber ................. 315/169 TV

(Continued)

FOREIGN PATENT DOCUMENTS

FR 2 333 341 6/1977

(Continued)

OTHER PUBLICATIONS

Supplementary European Search Report for Application No. EP 01 27 4105, dated May 16, 2008 (mailing date).

(Continued)

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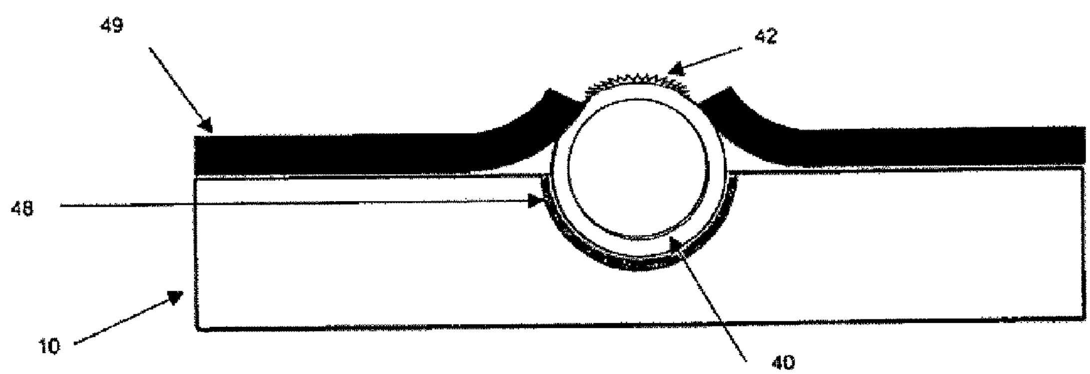
(57) **ABSTRACT**

A method of forming micro-components is disclosed. The method includes pretesting and conditioning of the micro-components. The micro-components that fail testing or conditioning are discarded, and those remaining are assembled into a panel.

**7 Claims, 15 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 4,257,798 | A | 3/1981 | Hendricks et al. | 65/21.4 |
| 4,303,433 | A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | 1/1984 | Aboelfotoh | 340/701 |
| 4,459,145 | A | 7/1984 | Elsholz | 54/21.3 |
| 4,534,743 | A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,692,662 | A | 9/1987 | Wada et al. | 313/493 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,890,383 | A | 1/1990 | Lumbard et al. | 438/27 |
| 4,912,364 | A | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,194,027 | A | 3/1993 | Kruskopf et al. | 445/24 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,482,486 | A | 1/1996 | Vaudaine et al. | 445/3 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,872,355 | A | 2/1999 | Hueschen | 250/208.1 |
| 5,889,568 | A | 3/1999 | Seraphim et al. | 349/73 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,949,513 | A | 9/1999 | Ma et al. | 349/187 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,008,582 | A | 12/1999 | Asano et al. | 313/582 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 384/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,111,424 | A | 8/2000 | Bosacchi | 324/770 |
| 6,120,975 | A | 9/2000 | Tokai et al. | 430/321 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 6,527,964 | B1 | 3/2003 | Smith et al. | 216/19 |
| 6,545,422 | B1 | 4/2003 | George et al. | 315/169.3 |
| 6,570,335 | B1 | 5/2003 | George et al. | 316/169.3 |

| | | | | |
|---|---|---|---|---|
| 6,577,062 | B2 | 6/2003 | Itokawa et al. | 313/582 |
| 6,612,889 | B1 | 9/2003 | Green et al. | 445/24 |
| 6,620,012 | B1 | 9/2003 | Johnson et al. | 445/3 |
| 6,646,388 | B2 | 11/2003 | George et al. | 315/169.3 |
| 6,762,566 | B1 | 7/2004 | George et al. | 315/169.3 |
| 6,764,367 | B2 | 7/2004 | Green et al. | 445/24 |
| 6,791,264 | B2 | 9/2004 | Green et al. | 313/582 |
| 6,796,867 | B2 | 9/2004 | George et al. | 445/24 |
| 6,801,001 | B2 | 10/2004 | Drobot et al. | 315/169.3 |
| 6,822,626 | B2 | 11/2004 | George et al. | 345/60 |
| 6,864,631 | B1 | 3/2005 | Wedding | 313/587 |
| 6,902,456 | B2 | 6/2005 | George et al. | 445/24 |
| 6,935,913 | B2 | 8/2005 | Wyeth et al. | 445/3 |
| 6,975,068 | B2 | 12/2005 | Green et al. | 313/582 |
| 7,005,793 | B2 | 2/2006 | George et al. | 313/484 |
| 7,025,648 | B2 | 4/2006 | Green et al. | 445/24 |
| 7,122,961 | B1 | 10/2006 | Wedding | 313/582 |
| 7,125,305 | B2 | 10/2006 | Green et al. | 445/24 |
| 7,137,857 | B2 | 11/2006 | George et al. | 445/24 |
| 7,140,941 | B2 | 11/2006 | Green et al. | 445/24 |
| 7,157,854 | B1 | 1/2007 | Wedding | 313/582 |
| 7,176,628 | B1 | 2/2007 | Wedding | 313/582 |
| 7,247,989 | B1 | 7/2007 | Wedding | 313/587 |
| 2001/0008825 | A1 | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0024084 | A1 | 9/2001 | Kajiwara | 313/486 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |
| 2002/0070678 | A1 | 6/2002 | Kim et al. | 315/169.4 |
| 2002/0195936 | A1 | 12/2002 | Kato et al. | 313/582 |
| 2003/0073372 | A1 | 4/2003 | Nakatake et al. | 445/25 |
| 2003/0090213 | A1 | 5/2003 | George et al. | 315/169.3 |
| 2003/0094891 | A1 | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1 | 9/2003 | Green et al. | 313/582 |
| 2003/0207643 | A1 | 11/2003 | Wyeth et al. | 445/3 |
| 2003/0207644 | A1 | 11/2003 | Green et al. | 445/24 |
| 2003/0207645 | A1 | 11/2003 | George et al. | 445/24 |
| 2003/0214243 | A1 | 11/2003 | Drobot et al. | 315/169.3 |
| 2004/0004445 | A1 | 1/2004 | George et al. | 315/169.3 |
| 2004/0051450 | A1 | 3/2004 | George et al. | 313/512 |
| 2004/0063373 | A1 | 4/2004 | Johnson et al. | 445/24 |
| 2004/0106349 | A1 | 6/2004 | Green et al. | 445/24 |
| 2004/0166762 | A1 | 8/2004 | Green et al. | 445/24 |
| 2004/0175854 | A1 | 9/2004 | George et al. | 438/30 |
| 2005/0095944 | A1 | 5/2005 | George et al. | 445/3 |
| 2005/0206317 | A1 | 9/2005 | George et al. | 313/582 |
| 2006/0097620 | A1 | 5/2006 | George et al. | 313/484 |
| 2006/0205311 | A1 | 9/2006 | Green et al. | 445/24 |
| 2007/0015431 | A1 | 1/2007 | Green et al. | 445/24 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| JP | 4-287397 | 10/1992 |
| JP | 10-3869 | 1/1998 |
| JP | 11-162358 | 6/1999 |
| JP | 2000251848 | 9/2000 |
| WO | WO 00/36465 | 6/2000 |
| WO | WO 02/35510 | 5/2002 |

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

Sheats, James, "Introduction to Organic Light-Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll-to-Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www-star.stanford.edu/~vlf/plasma_display/index.htm.

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21-25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," *Journal of Microelectromechanical Systems*, vol. 10, No. 1, Mar. 2001, pp. 17-17-24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.
"Runco PlasmaWall PL-42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.
"Runco PlasmaWall PL-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.
"Runco PlasmaWall™ PL-61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.
Alien Technology Corporation's Technology Overview; copyright © 2000, Alien Technology™; http://www.alientechnology.com/d/technology/overview.html.
Anonymous, *Alien Technology Corporation White Paper—Fluidic Self Assembly*, Alien Technology Corp., Oct. 1999, pp. 1-7.
Shin, Y. K., Lee, J. K., Shon, C. H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 14-15.
Raulf, S., Kushner, M. J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10-11.
Kurihara, M., Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372-1378.
Peterson, "Rethinking Ink" [online], Science News, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.
"Transparent Conductive Coatings," Copyright 1998, 4 pp.
Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep. 1997, pp. 1241-.
Jacobson, et al., "The Last Book" [online], IBM Systems Journal, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.researchibm.com/journal/sj/363/Jacobson.html.
Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.
"Flat Panel Displays in Perspective," 44 pp., Sep. 1995.
Franjione, et al., "The Art and Science of Microencapsulation" [online] Technology Today, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

Fig. 1

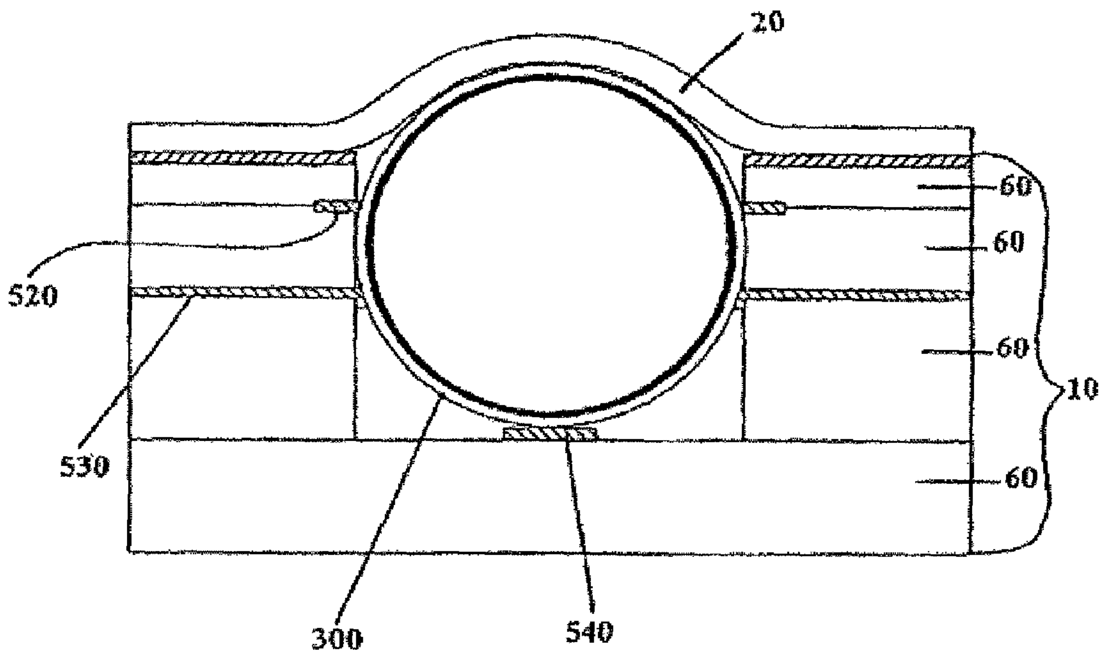
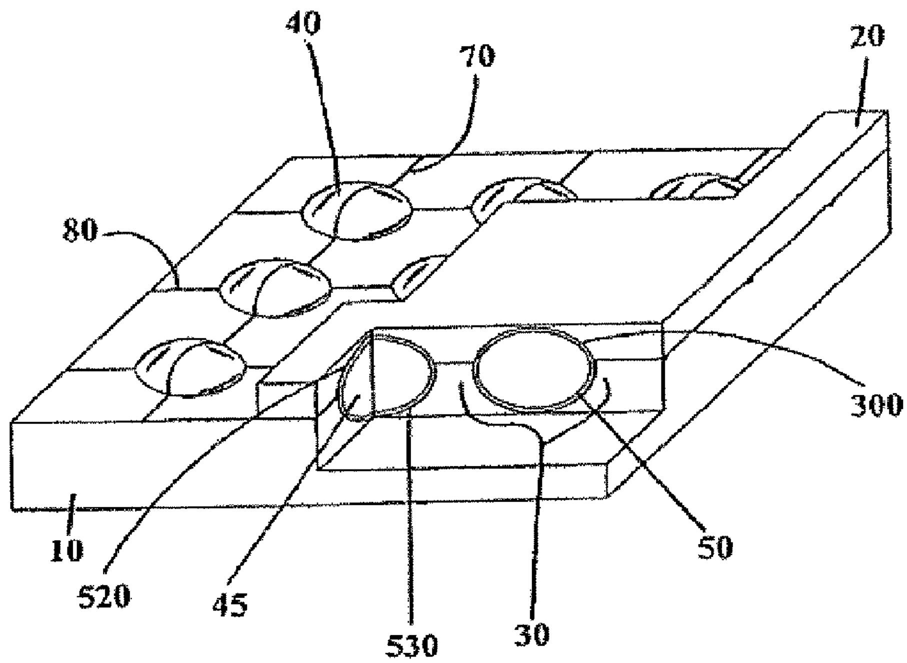


Fig. 2



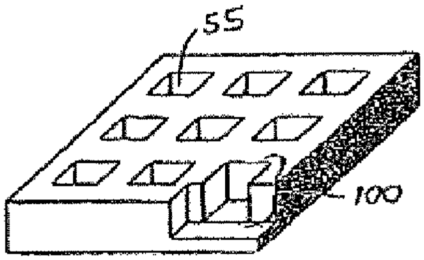



Fig. 3A

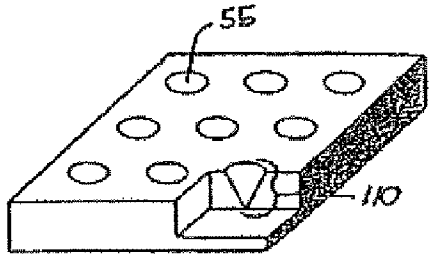



Fig. 3B

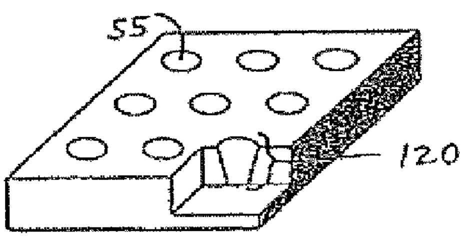



Fig. 3C

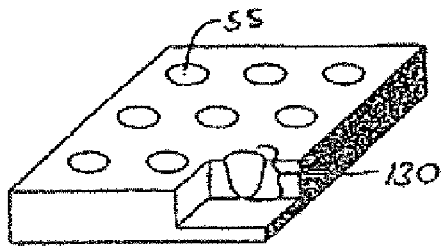



Fig 3D

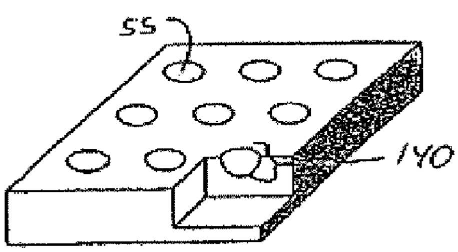



Fig 3E

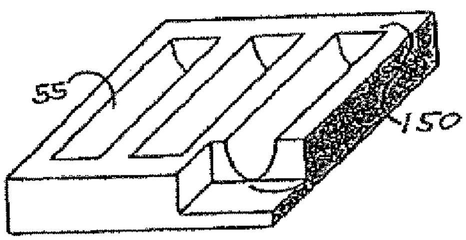



Fig. 3F

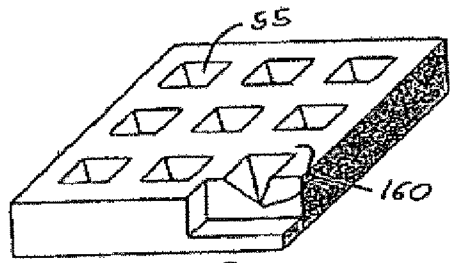



Fig. 3G

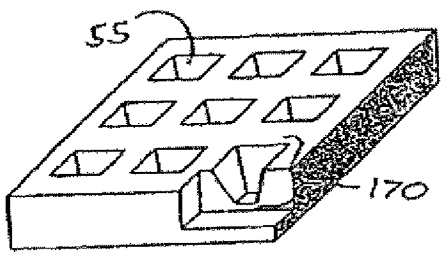



Fig. 3H

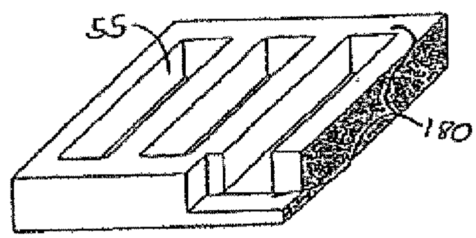



Fig. 3I

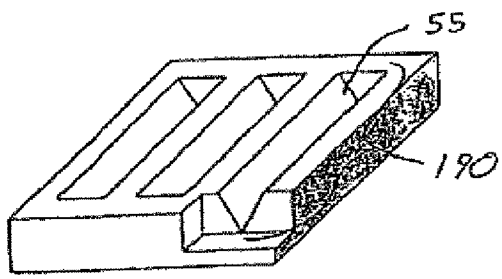



Fig. 3J

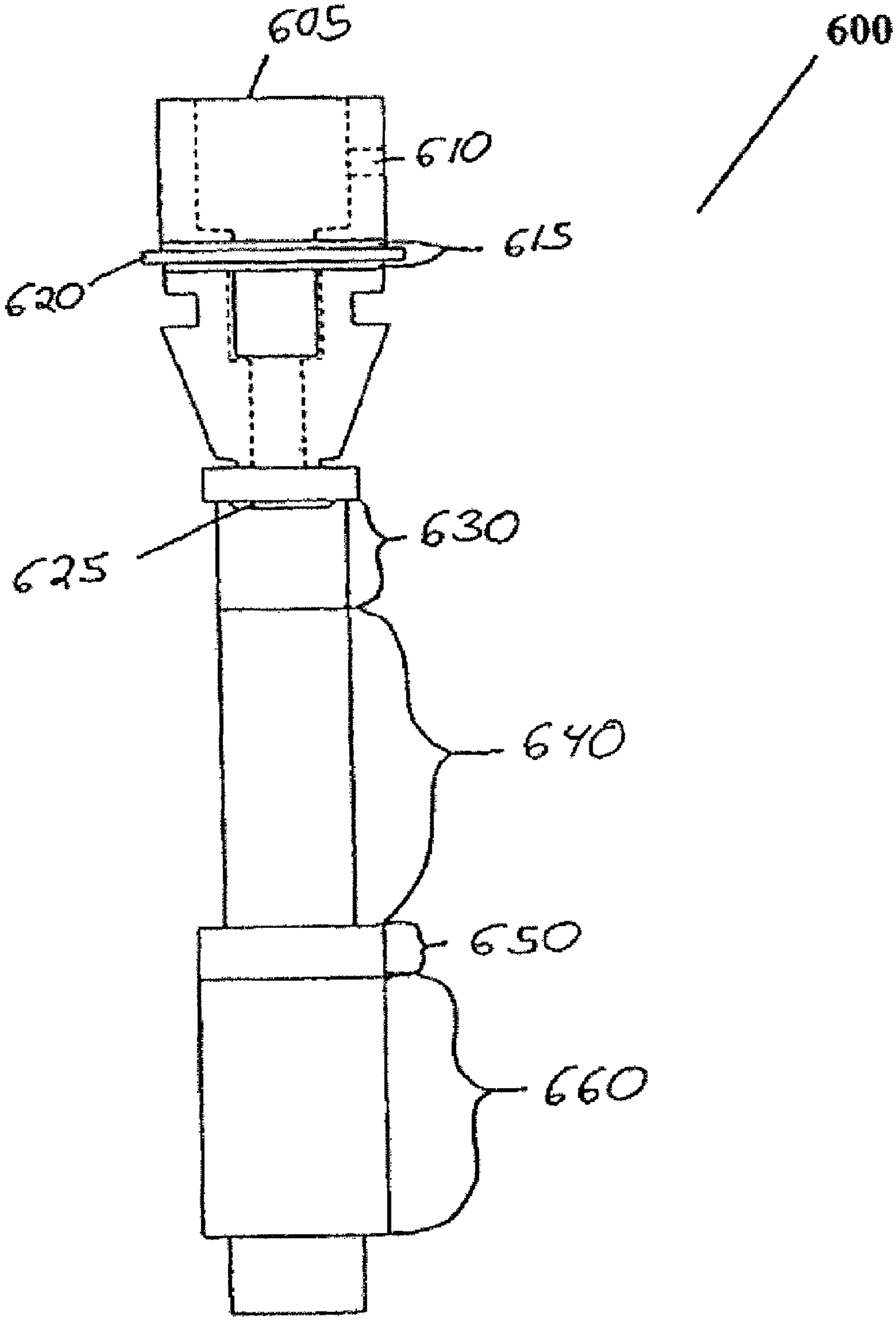



Fig. 4

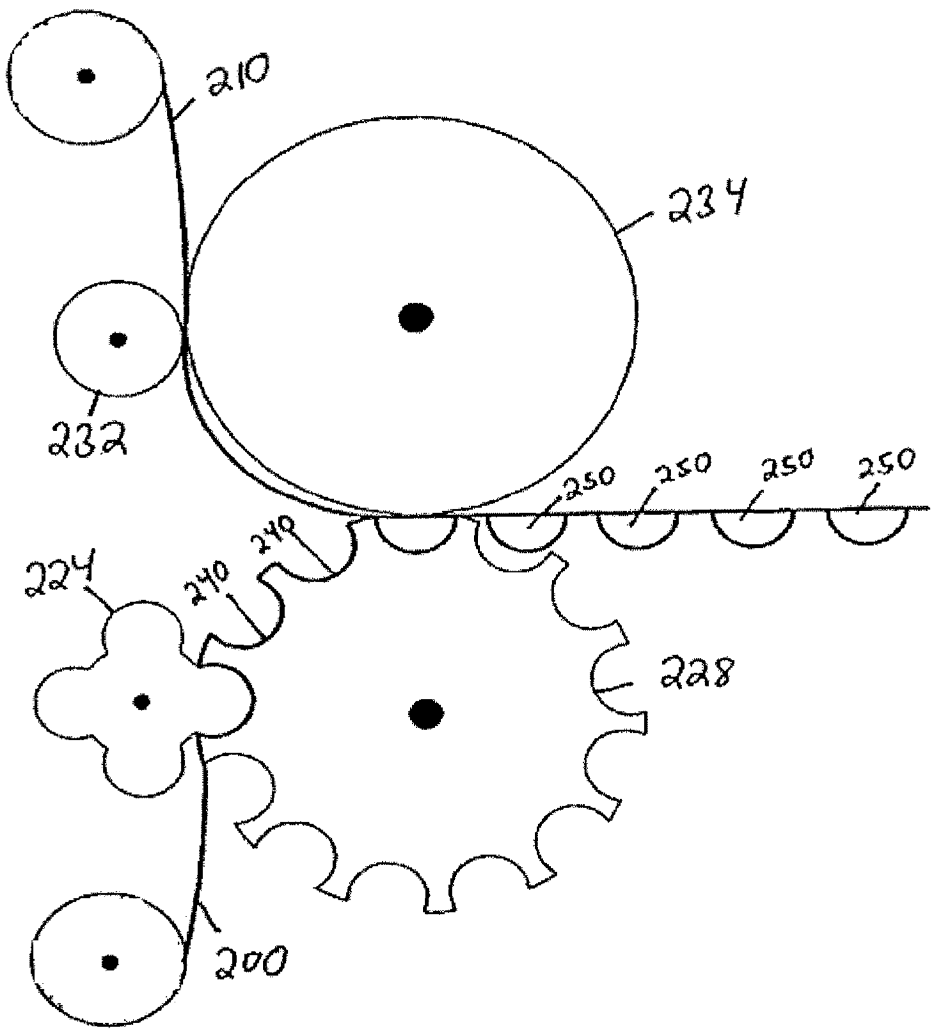
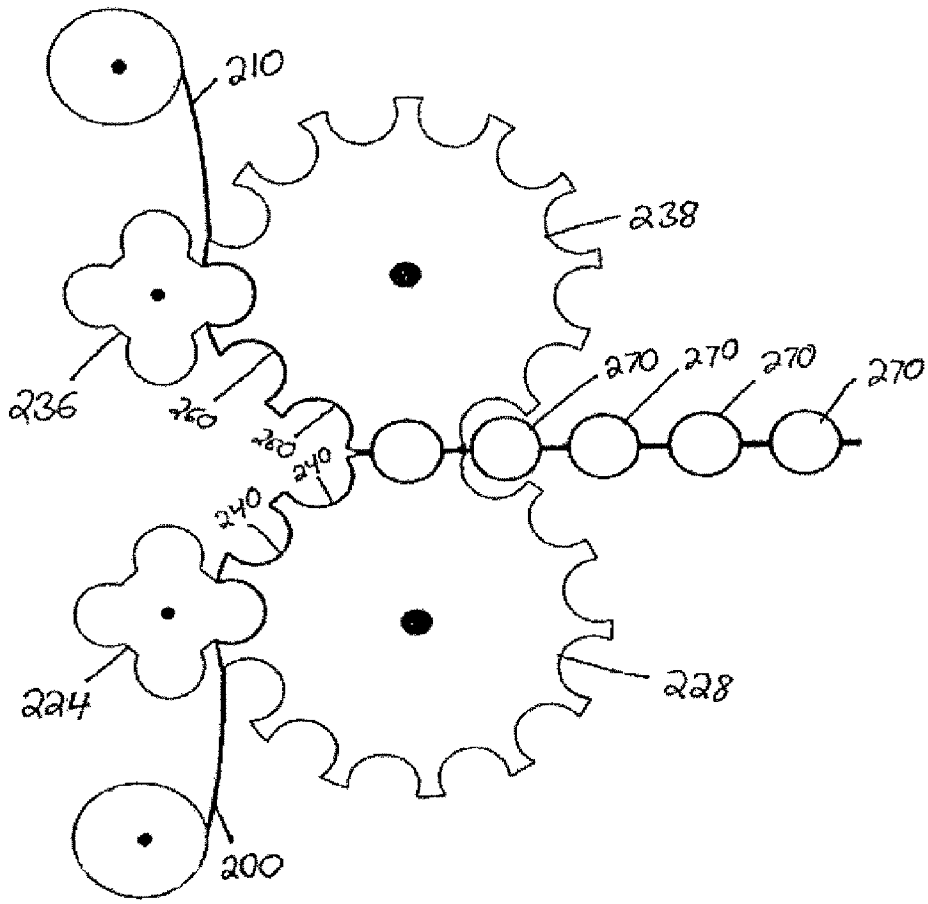
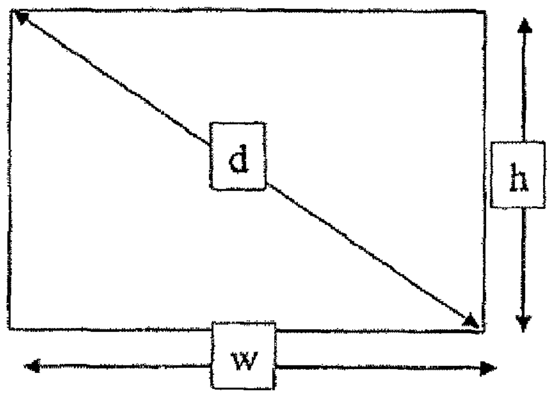



Fig. 5

Fig. 6



Example of Calculation of Pixel Size and Micro-component Size for 42-inch & 60-inch HDTV Displays (16:9 aspect ratio)




- Pixel Size
  - 1024 x 1024 pixels
  - 42" pixel dimensions=508 x 908 μm
  - 60" pixel dimensions=1292 x 729 μm
- Microsphere Size
  - 3 microspheres/pixel
  - 42" - 175 μm
  - 60" - 250 μm

Display Size
- w=d*0.87
- h=d*0.49
- 42" diagonal 16 x 9 = 20.6 x 36.6 in
- 60" diagonal 16 x 9 = 52.2 x 29.4 in

Fig. 7

Table showing number of pixels, etc. for various standard display resolutions

| Acronym | Pixels HxV | Aspect | Mpixels |
|---|---|---|---|
| CIF | 352x288 | 4:3 | 0.1 |
| VGA | 640x480 | 4:3 | 0.3 |
| SVGA | 800x600 | 4:3 | 0.5 |
| XGA | 1024x768 | 4:3 | 0.8 |
| HDTV (720p) | 1280x720 | 16:9 | 0.9 |
| SXGA | 1280x1024 | 5:4 | 1.3 |
| SXGA+ | 1400x1050 | 3:4 | 1.5 |
| UXGA | 1600x1200 | 4:3 | 1.9 |
| HDTV (1080i,p) | 1920x1080 | 16:9 | 2.1 |
| WUXGA | 1920x1200 | 16:10 | 2.3 |
| QXGA | 2048x1536 | 4:3 | 3.1 |
| VXGA | 2048x2048 | 1:1 | 4.2 |
| GXGA/QSXGA | 2560x2048 | 5:4 | 5.2 |
| Photo CD (16Base) | 3072x2048 | 3:2 | 6.3 |
| Photo CD (64Base) | 6144x4096 | 3:2 | 25.0 |

Fig. 8

Fig. 9

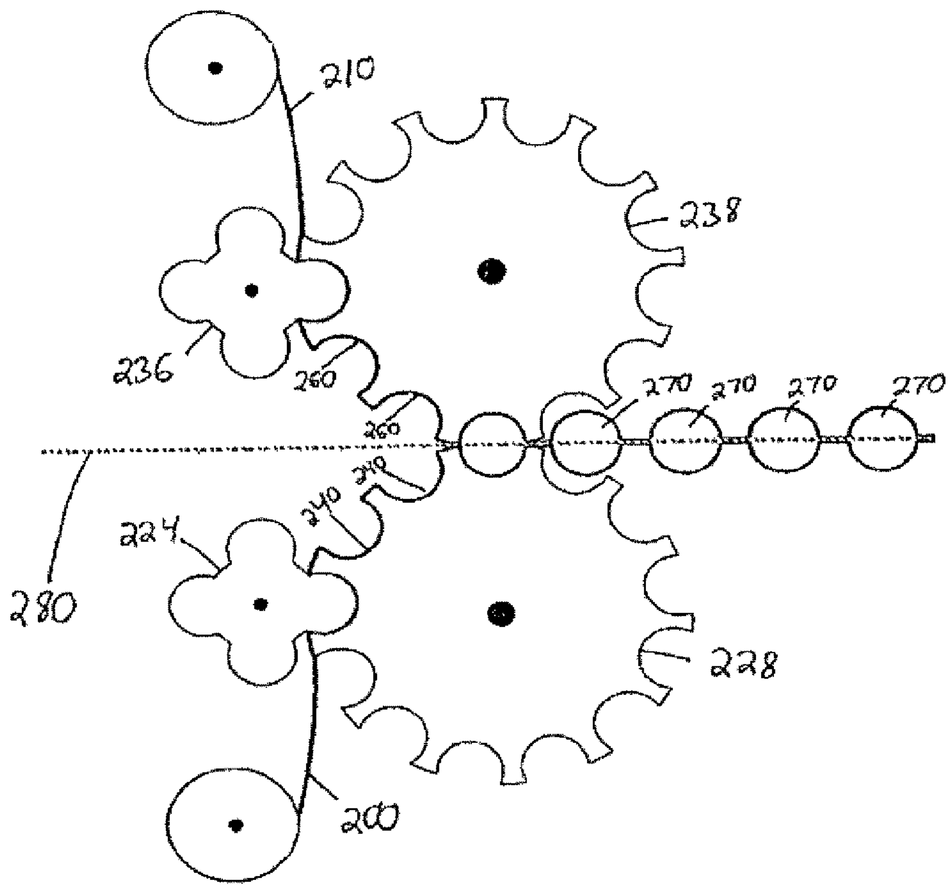
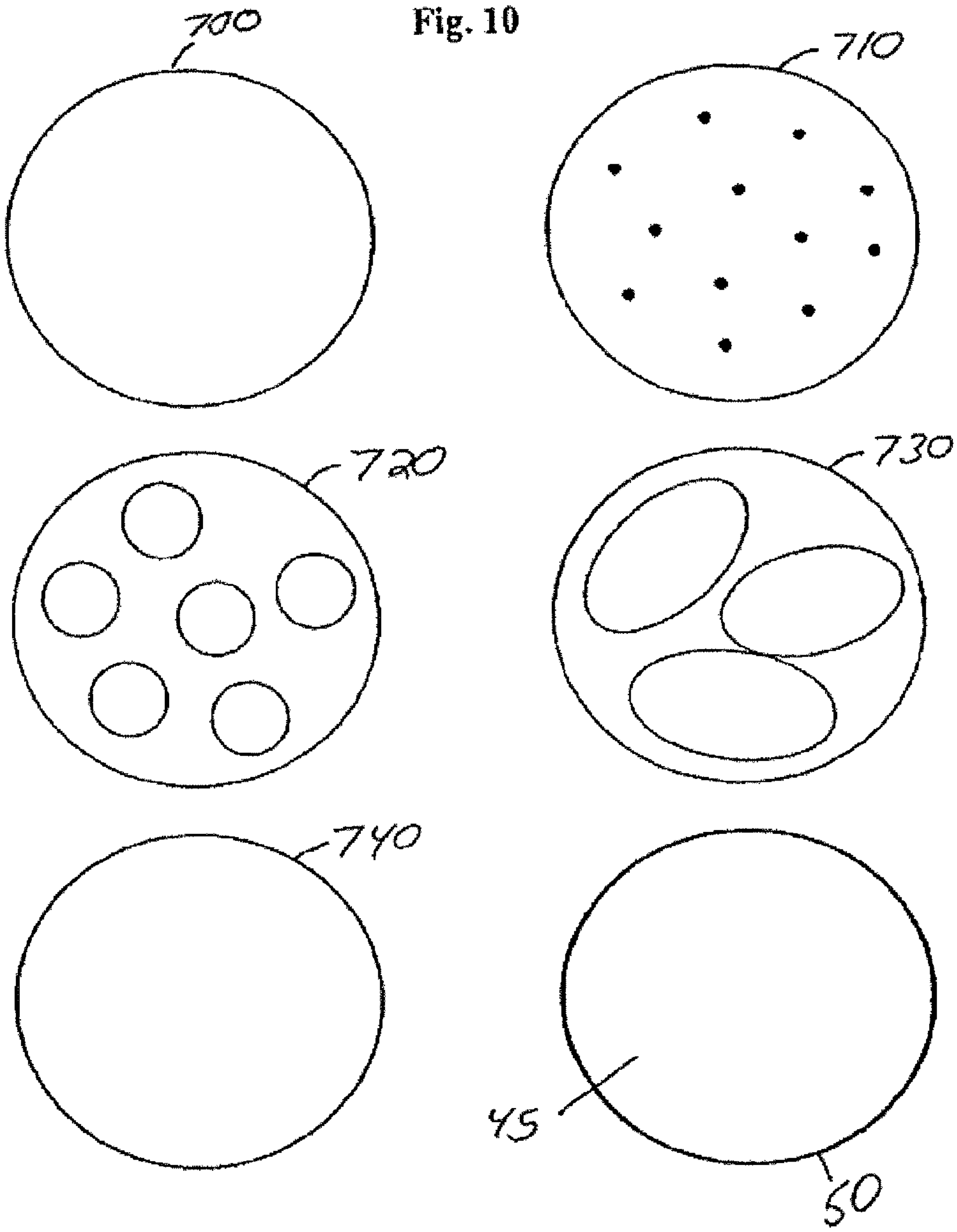
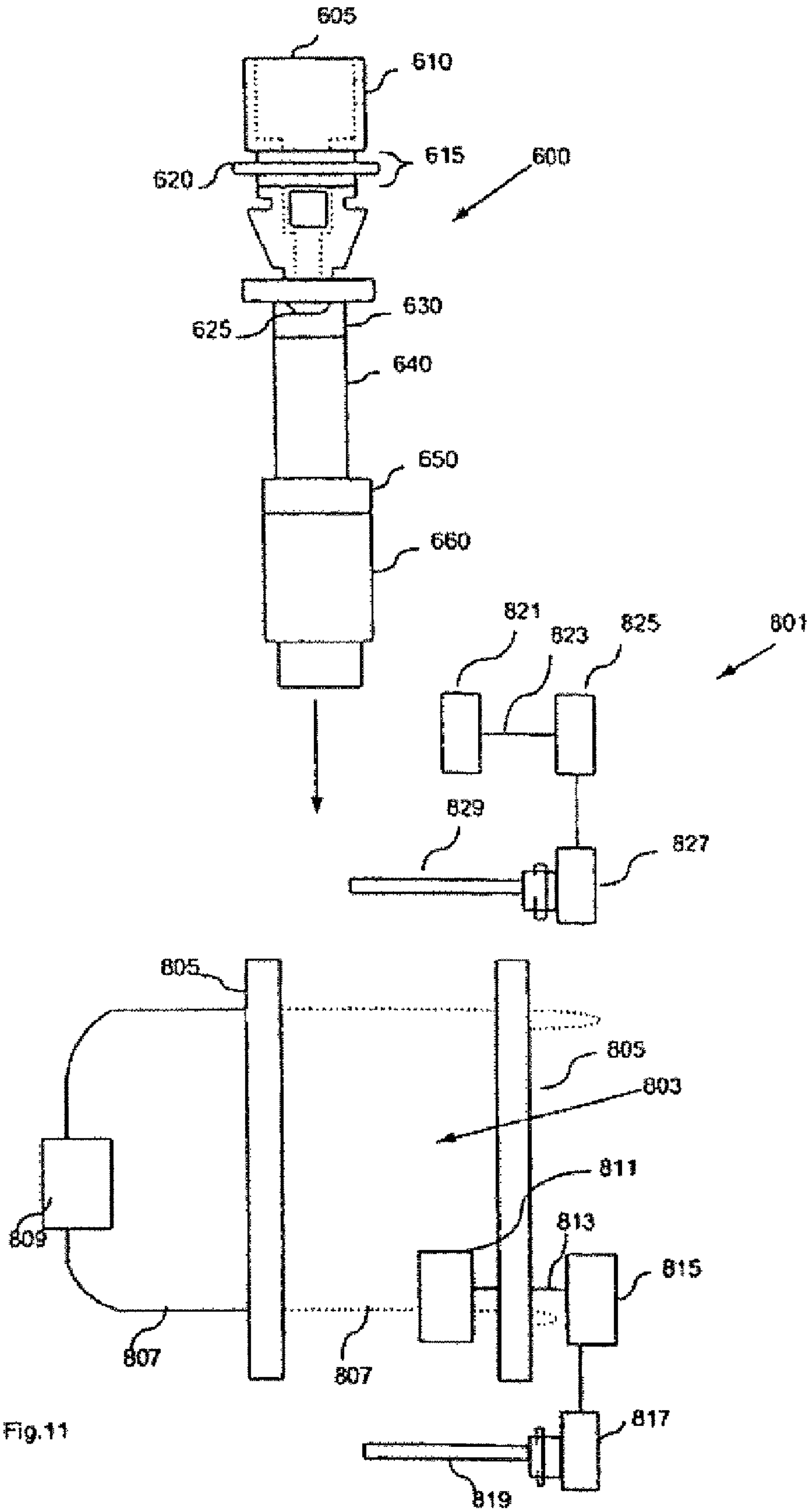


Fig. 10




605
610
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650
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817
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Fig.11

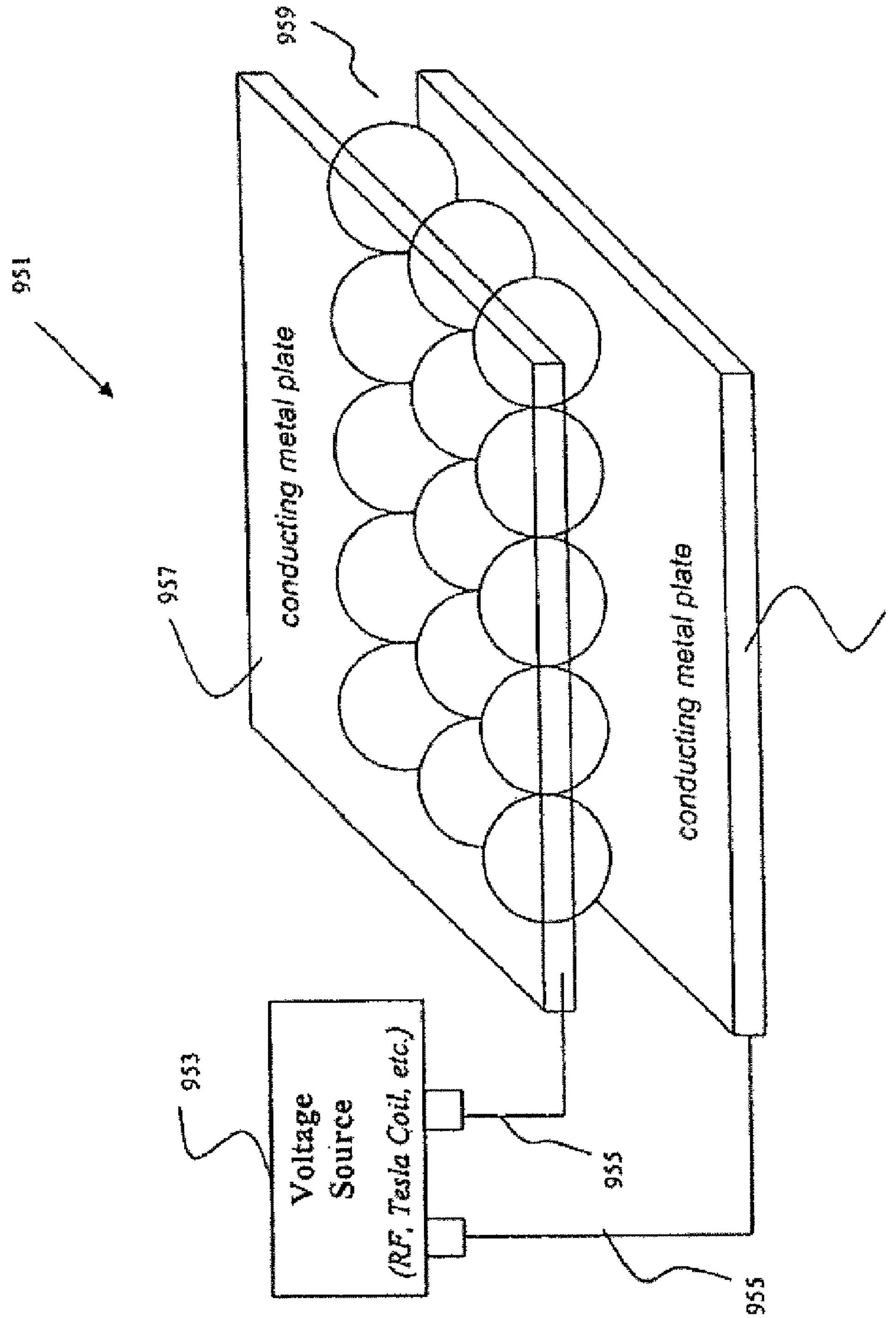
951
959
957
conducting metal plate
conducting metal plate
957
953
Voltage Source
(RF, Tesla Coil, etc.)
955
955

Fig. 12

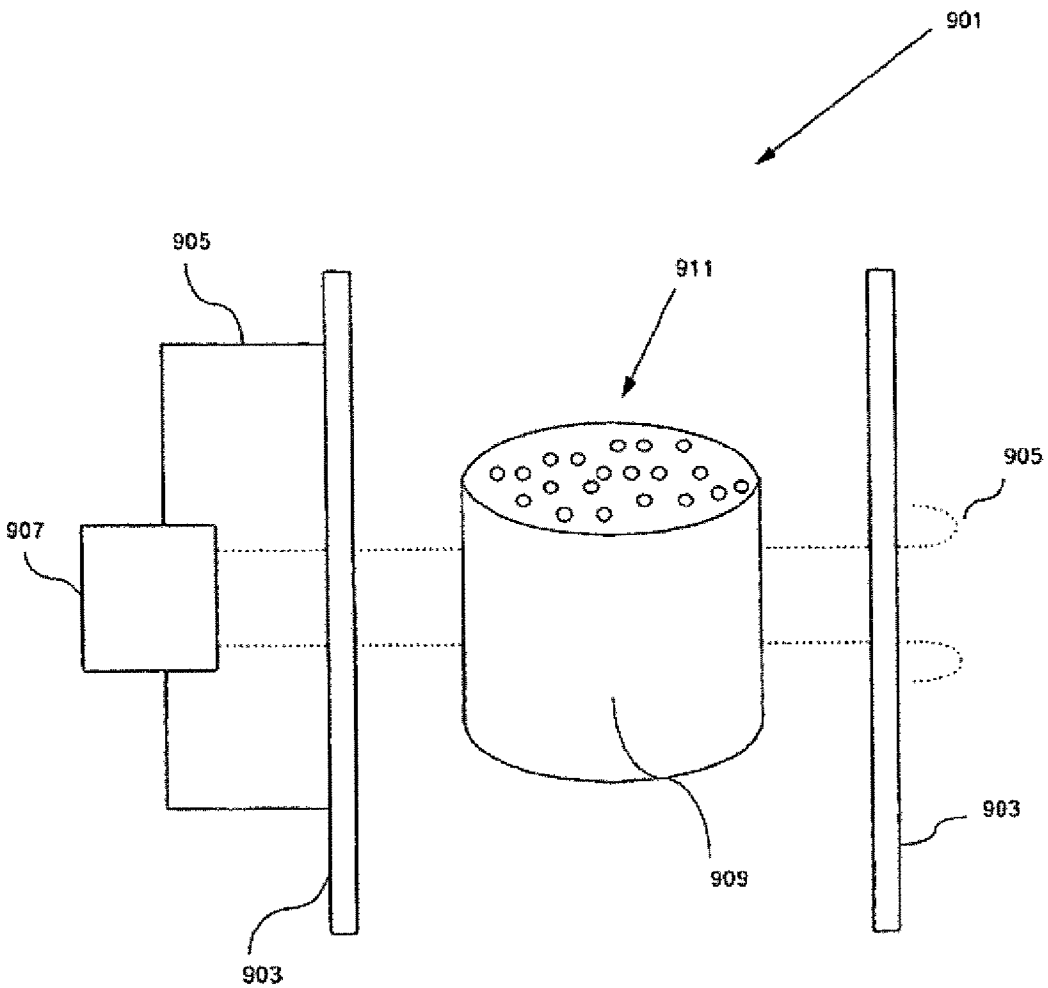


Fig. 13

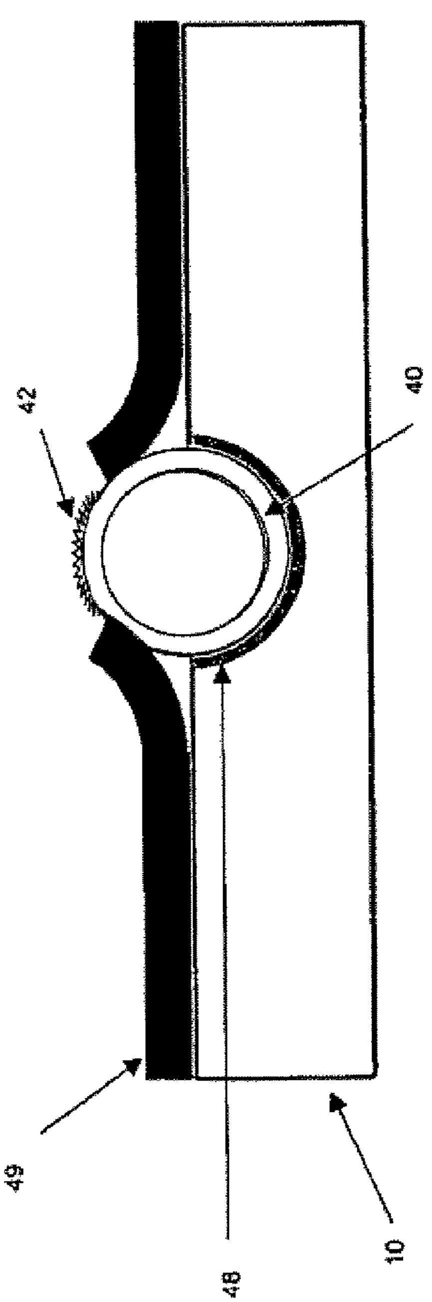


Figure 14a

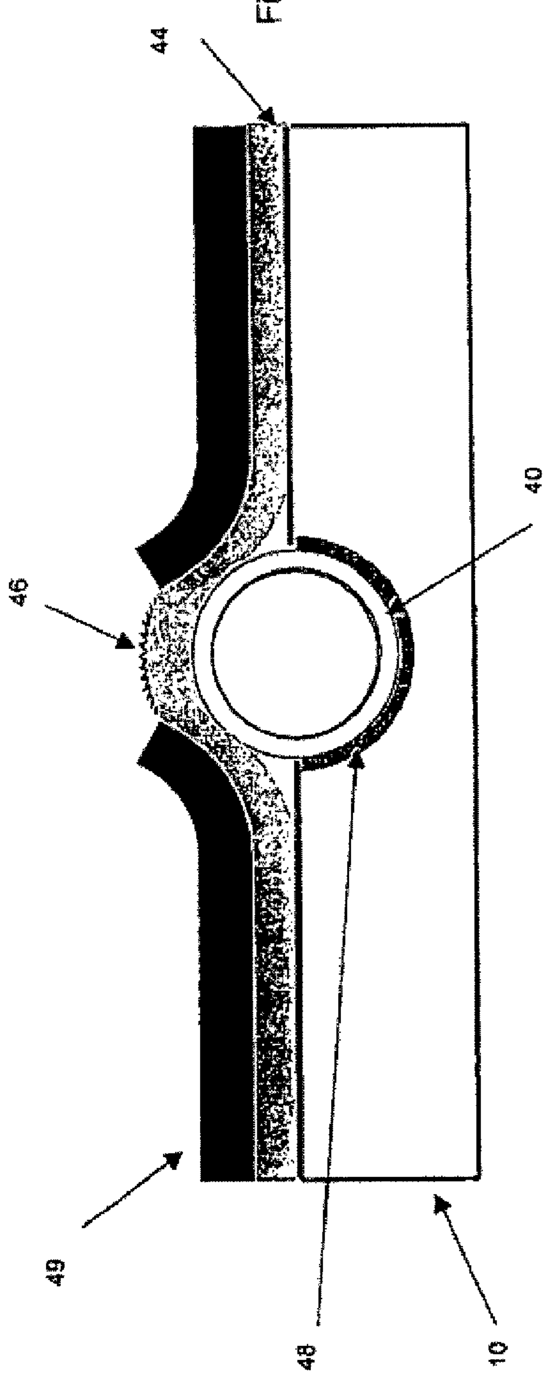


Figure 14b

# MANUFACTURE OF LIGHT-EMITTING PANELS PROVIDED WITH TEXTURIZED MICRO-COMPONENTS

## CROSS-REFERENCE TO RELATED APPLICATIONS

This is a divisional of U.S. patent application Ser. No. 10/756,266 entitled "Design, Fabrication, Testing, and Conditioning of Micro-Components for use in a Light-Emitting Panel," filed Jan. 14, 2004 now U.S. Pat. No. 7,288,014, which is a continuation-in-part of U.S. Pat. No. 6,822,626, application Ser. No. 10/214,768 entitled "Design, Fabrication, Testing, and Conditioning of Micro-Components for use in a Light-Emitting Panel," filed Aug. 9, 2002, which is a continuation-in-part of U.S. Pat. No. 6,762,566, application Ser. No. 09/697,358 entitled "A Micro-Component for Use in a Light-Emitting Panel," filed Oct. 27, 2000, and claims priority to that parent application's filing date. Also referenced hereby are the following patents which are incorporated herein by reference in their entireties, and the filing dates thereof to which priority is also claimed: U.S. patent application Ser. No. 09/697,344 entitled "A Light-Emitting Panel and a Method for Making," filed Oct. 27, 2000 now U.S. Pat. No. 6,612,889; U.S. patent application Ser. No. 09/697,498 entitled "A Method for Testing a Light-Emitting Panel and the Components Therein," filed Oct. 27, 2000 now U.S. Pat. No. 6,620,012; U.S. patent application Ser. No. 09/697,345 entitled "A Method and System for Energizing a Micro-Component in a Light-Emitting Panel," filed Oct. 27, 2000 now U.S. Pat. No. 6,570,335; U.S. patent application Ser. No. 09/697,346 entitled "A Socket for Use in a Light-Emitting Panel," filed Oct. 27, 2000 now U.S. Pat. No. 6,545,422; U.S. patent application Ser. No. 10/214,769 entitled "Use of Printing and Other Technology for Micro-Component Placement," now U.S. Pat. No. 6,796,867; U.S. patent application Ser. No. 10/214,740 entitled "Liquid Manufacturing Processes for Panel Layer Fabrication," now U.S. Pat. No. 6,764,367; U.S. patent application Ser. No. 10/214,716 entitled "Method for On-Line Testing of a Light-Emitting Panel" now U.S. Pat. No. 6,935,913; and U.S. patent application Ser. No. 10/214,764 entitled "Method and Apparatus for Addressing Micro-Components in a Plasma Display Panel," now U.S. Pat. No. 6,801,001.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a micro-component for use in a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this plasma-forming discharge occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby eventually extinguish the discharge. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes may be located partially within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold:

to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma-forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma-forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates, the pumping down to vacuum, the baking out under vacuum, and the introduction of the plasma-forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels without a write pulse being applied. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma-forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total physical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to pump down to vacuum, bake out under vacuum, introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma-forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one basic form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing paint or other coatings, and for sterilization. With the addition of one or more phosphor coatings to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other electromagnetic wavelengths would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel.

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma-forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to a general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a large enough voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In one embodiment of the present invention, the micro-component is configured to emit ultra-violet (UV) light, which may be converted to visible light by at least partially coating each micro-component with phosphor. To obtain an improvement in the discharge characteristics, each micro-component may be at least partially coated with a secondary emission enhancement material.

In another embodiment, each micro-component is at least partially coated with a reflective material. An index matching material is disposed so as to be in contact with at least a portion of the reflective material. The combination of the index matching material and the reflective material permits a predetermined wavelength of light to be emitted from each micro-component at the point of contact between the index matching material and the reflective material.

Another object of the present invention is to provide a micro-component for use in a light-emitting panel. A shell at least partially filled with at least one plasma-forming gas provides the basic micro-component structure. The shell may be doped or ion implanted with a conductive material, a material that provides secondary emission enhancement, and/or a material that converts UV light to visible light. The micro-components will be made as a sphere, cylinder or any other shape. The size and shape will be determined in accordance with the desired resolution for the display panel to be assembled. Typical sizes are about hundreds of microns independent of shape.

Another preferred embodiment of the present invention is to provide a method of making a micro-component. In one embodiment, the method is part of a continuous process, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the plasma-forming gas or gas mixture.

In another embodiment, the micro-component is made by affixing a first substrate to a second substrate in the presence of at least one plasma-forming gas. In this method, either the first and/or the second substrate contains a plurality of cavities so that when the first substrate is affixed to the second substrate the plurality of cavities are filled with the plasma-forming gas or gas mixture. In a preferred embodiment, a first substrate is advanced through a first roller assembly, which includes a roller with a plurality of nodules and a roller with a plurality of depressions. Both the plurality of nodules and the plurality of depressions are in registration with each other so that when the first substrate passes through the first roller assembly, the first substrate has a plurality of cavities formed therein. A second substrate is advanced through a second roller assembly and then affixed to the first substrate in the presence of at least one gas so that when the two substrates are affixed the cavities are filled with the gas or gas mixture. In an alternate preferred embodiment, the second roller assembly includes a roller with a plurality of nodules and a roller with a plurality of depressions so that when the second substrate passes through the second roller assembly, the second substrate also has a plurality of cavities formed therein. In either of these embodiments, at least one electrode may be sandwiched between the first and second substrates prior to the substrates being affixed.

In another embodiment, at least one substrate is thermally treated in the presence of a least one plasma-forming gas so as to form shells filled with the plasma-forming gas or gas-mixture.

In a specific aspect, the micro-components, whether sphere, capillary or other shape are coated with a frequency converting coating. Phosphor is an example of such a coating. More specifically, the coating converts electromagnetic radiation generated in the plasma in the ultraviolet region of the spectrum, and converts it to the visible red, blue or green region of the spectrum.

Alternatives include putting a drop of the frequency converting material in a socket into which the micro-component is placed, or the micro-component itself can be doped with a material such as a rare earth that is a frequency converter. Examples of materials include barium fluoride or the like, yttrium aluminum garnet, or gadolinium gallium garnet. The plasma gases in the micro-component can include xenon chloride, argon chloride, etc., namely the rare gas halides.

In another aspect, the micro-components are tested as they are manufactured. The micro-components are optionally scanned for certain physical characteristics or defects, for example, in an optical field detecting shape such as sphericity and size as they drop through a tower. A micro-component displacement device can be used to remove those that are bad. At a subsequent layer, as they drop the micro-components are subjected to electron beam excitation, microwave or RF field, for example, to excite the gas. Another physical characteristic or defect is tested, such as if a certain luminous output is achieved, and if achieved, it is preliminarily accepted. Those for which a desired luminous output is not achieved are discarded, for example, through the use of a second micro-component displacement device.

In yet still another aspect, the micro-components are preconditioned by being excited for a predetermined period of time. Examples include taking the micro-components that passed the initial test, placing them in a container and exciting them, for example, for 5 to 10 hours. Alternatively, they can be placed between large parallel electrodes. After the batch run, they are dropped through a tower as they are excited, output detected and the ones that do not excite are knocked out of the stream.

In a further aspect of the invention, the micro-components are texturized using a technique such as sandblasting, etching, lithography or the like. The texturized portion allows light generated within the micro-component to exit the micro-component. Alternatively, the micro-components are optically contacted to one surface of an overlay layer, wherein the overlay has been texturized on the opposite surface at least those areas near wherein the other surface of the overlay optically contacts the micro-components.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** shows a socket with a micro-component disposed therein.

FIG. **2** depicts a portion of a light-emitting panel showing a plurality of micro-components disposed in sockets.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a hemi-cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components.

FIG. **5** shows an apparatus used in an embodiment of the present invention as part of another process for forming micro-components.

FIG. **6** shows an variation of the apparatus shown in FIG. **5**, which is used as part of another process for forming micro-components.

FIG. **7** illustrates an example of selection of pixel size and micro-component (micro-sphere) size for different sized high definition television (HDTV) displays, which can be manufactured according to the micro-component method hereof.

FIG. **8** is a table showing numbers of pixels for various standard display resolutions.

FIG. **9** illustrates, according to an embodiment, one way in which an electrode may be disposed between two substrates as part of a process for forming micro-components.

FIG. **10** depicts the steps of another method for forming micro-components.

FIG. **11** shows an apparatus used in an embodiment of the present invention as part of a continuous process for forming micro-components similar to that of FIG. **4**, and including a mechanism for pretesting or pre-screening of micro-components prior to assembly in a panel.

FIG. **12** shows an apparatus used for batch conditioning of micro-components.

FIG. **13** shows an alternative embodiment of an apparatus used for batch conditioning of micro-components.

FIGS. **14***a* and **14***b* each depict a portion of a light-emitting panel showing a micro-component disposed in socket, further having a texturized portion and a black mask according to embodiments of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, the preferred embodiments are directed to a micro-component capable of being used in the light-emitting panel and at least partially disposed in at least one socket.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3**A-**3**J, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**. The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. Further, rare gas halide mixtures such as xenon chloride, xenon fluoride and the like are also suitable plasma-forming gases. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed above. This description is not intended to be limiting. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, barium fluoride or similar materials such as yttrium aluminum garnet, gadolinium gallium garnet, silicates, borates, silicate/borate mixtures, phosphates, these and other compounds in a glassy state, alumino-silica glasses, alkali silicate glasses, any polymeric-based material, magnesium oxide, and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. In FIG. **2**, a two electrode configuration is shown including a first sustain electrode **520** and an address electrode **530**. In FIG. **1**, a three electrode configuration is shown, wherein a first sustain electrode **520**, an address electrode **530** and a second sustain electrode **540** are disposed within a plurality of material layers **60** that form the first substrate **10**. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr or higher pressure as appropriate. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as bandpass filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may also work. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside of the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used.

To obtain an improvement in discharge characteristics, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated on the inside surface with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

Alternatively to the previously discussed phosphor which can be used to coat the micro-component, or alternatively, placed into a socket in a display panel in which the micro-components are placed, the micro-component material can be doped with a rare earth that is a frequency converter. The micro-component material to host such dopants can include barium fluoride or similar materials such as yttrium aluminum garnet, or gadolinium gallium garnet. These types of frequency converting doped materials serve to convert plasma light at the UV wavelength to visible light of red, blue or green color. The gasses in the micro-component in such cases will include rare gas halide mixtures such as xenon chloride, xenon fluoride and the like. Rare gas halides are efficient radiators having radiating wavelengths of approximately 300 to 350 nm, which is longer than that of pure xenon (147 to 170 nm). This results in an overall quantum efficiency gain, i.e., a factor of two or more, given by the mixture ratio. Still further, in another embodiment of the present invention, rare gas halide mixtures are also combined with other plasma-forming gases as listed previously. This description is not intended to be limiting. In the case when such frequency converting materials are used, instead of using a phosphor coating, they can be integrated as a dopant in the shell of the micro-component. For example, yttrium aluminum garnet doped with cerium can serve to convert UV wavelengths from rare gas halides into green light.

Further to the embodiments described above, wherein the shell of the micro-component, made of a material such as barium fluoride or similar materials such as yttrium aluminum garnet, gadolinium gallium garnet, silicates, borates, silicate/borate mixtures, phosphates, these and other compounds in a glassy state, alumino-silica glasses, alkali silicate glasses, is doped with a rare earth, frequency converting species such as europium 2+ for blue, europium 3+ for red, cerium 3+ for violet (deep blue), or cerium 3+ plus terbium 3+ for green, an additional embodiment of the invention includes texturizing the surface of the shell in order to allow trapped, emitted light out of the shell. In certain embodiments of the present invention, the smooth, doped shell acts as a waveguide, wherein the visible photons emitted from the dopant ions in the micro-component become trapped in the shell of the micro-component, which is on the order of 2-4 microns in thickness, by internal reflection. In order to exit the shell, the trapped photons must achieve an appropriate exit angle with the surface. In this additional embodiment of the present invention, the photons are able to achieve the appropriate exit angle when the exiting surface of the shell is texturized. Referring to FIG. **14***a*, substrate **10** encompasses micro-component **40** which includes texturized area **42** on the exit surface. Alternatively, the exit surface itself is not actually texturized, but is optically contacted to an overlay layer **44** shown in FIG. **14***b* that has a texturized surface area **46** nearby as described further below. An additional embodiment of the invention has a reflective element **48** under each micro-component to re-direct those emitted photons that do escape from the micro-component shell layer back toward the front of the panel.

In a first particular embodiment, a portion of the surface of the shell of each micro-component is texturized through a texturizing process such as etching, lithography, sandblasting or the like. The texturing process may take place at various stages in the continuous process for forming micro-components. For example, referring to the process described below with regarding to FIG. **4** of the present application, the texturizing process could take place while the micro-component is in the refining region **660**. Further the micro-component may be texturized either before or after the doping process.



Alternatively, referring to FIGS. **5**-**6** and **9**, the texturizing step could take place with respect to first substrate **200** in FIG. **5** and/or second substrate **210** in FIGS. **6** and **9**, prior to formation of the micro-components **250** and **270**, respectively or alternatively still, after formation of the micro-components **250** and **270**. Further, the micro-components may also be texturized after placement within the light emitting panels, i.e., after placement within their respect sockets. For example, referring to the processing steps described with regard to FIG. 12 of U.S. Pat. No. 6,612,889, which is incorporated herein by reference, the micro-components could be texturized after the "Micro-Component Placement Process" **850** and "Micro-Components in Sockets on Substrate with Electrodes" **440**, but before the "Substrate Application & Alignment Process" **870**. Also, referring to FIG. 10 of U.S. patent application Ser. No. 10/214,740, which is incorporated herein by reference, the micro-components could be texturized after step **210**, "Micro-component placement."

In this further embodiment, the surface of the doped micro-component is texturized using at least one process including etching, lithography, sandblasting or the like. The exact size of the texturized area varies with the size and spacing of the micro-components. For example, in a light-emitting panel wherein the micro-components are separated by hundreds of microns, e.g., 100 to 1000 microns, the diameter of the texturized portion of the micro-component is on the order of tens of microns in diameter, e.g., 20 to 300 microns. When the dopant ions in the micro-component material are stimulated by UV radiation from the plasma discharge within the micro-component, they emit visible radiation, some of which internally strikes the micro-component wall at an angle of incidence greater than the critical angle and therefore is totally reflected and initially trapped within the micro-component wall. Most of this trapped radiation is then emitted through the texturized portion of the micro-component and thus is concentrated. This concentrated luminosity contributes greatly to increased contrast ratio when viewing the light-emitting panel. In addition, contrast ratio is further increased with the use of a black mask **49** covering all but the texturized areas of the micro-components or texturized overlay as shown in FIGS. **14***a* and *b* and described further below. The use of enhancement materials, such as the black mask, are described in the patents and patent applications incorporated by reference above.

In still a further embodiment of the present invention, the texturized area is included on an overlay, as opposed to physically altering the texture of the micro-components. Referring, for example, to the processing steps described with regard to FIG. 12 of U.S. Pat. No. 6,612,889, which is incorporated herein by reference, the texturized overlay could be part of the second substrate, wherein the second substrate is texturized at step **820** along with the "Circuit & Electrode Printing Process" in the continuous process for forming a light emitting panel. Alternatively, the texturizing step could be performed before or after step **820**. In addition to having a texturized area for trapped light release, the overlay is indexed matched to the micro-component material at the point of optical contact, so as to maximize the amount of trapped radiation transferred from the micro-component to the overlay. Similarly, referring to FIG. 10 of U.S. patent application Ser. No. 10/214,740, which is incorporated herein by reference, the formation of the texturized areas may be included after curing of the protective layer **224**, i.e., through the techniques described above such as etching, lithography, sandblasting or the like.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material, either in two or more localized areas to provide separate electrode-like paths or in a way to produce anisotropic conductivity in the shell (high perpendicular conductivity, low in-plane conductivity), provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel. In this manner, shorting is avoided and two or more separate electrode paths are maintained to allow exciting of the gas.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

Several methods are proposed, in various embodiments, for making a micro-component for use in a light-emitting panel. It has been contemplated that each of the coatings and dopants that may be added to a micro-component **40**, as disclosed herein, may also be included in steps in forming a micro-component, as discussed herein.

In one embodiment of the present invention, a continuous inline process for making a micro-component is described, where a shell is at least partially formed in the presence of at least one plasma-forming gas, such that when formed, the shell is filled with the gas or gas mixture. In a preferred embodiment, the process takes place in a drop tower. According to FIG. **4**, and as an example of one of many possible ways to make a micro-component as part of a continuous inline process, a droplet generator **600** including a pressure transducer port **605**, a liquid inlet port **610**, a piezoelectric transducer **615**, a transducer drive signal electrode **620**, and an orifice plate **625**, produces uniform water droplets of a predetermined size. The droplets pass through an encapsulation region **630** where each water droplet is encased in a gel outer membrane formed of an aqueous solution of glass forming oxides (or any other suitable material that may be used for a micro-component shell), which is then passed through a dehydration region **640** leaving a hollow dry gel shell. This dry gel shell then travels through a transition region **650** where it is heated into a glass shell (or other type of shell depending on what aqueous solution was chosen) and then finally through a refining region **660**. While it is possible to introduce a plasma-forming gas or gas mixture into the process during any one of the steps, it is preferred in an embodiment of the present invention to perform the whole process in the presence of the plasma-forming gas or gas mixture. Thus, when the shell leaves the refining region **660**, the plasma-forming gas or gas mixture is sealed inside the shell thereby forming a micro-component.

In an embodiment of the present invention, the above process is modified so that the shell can be doped with either a secondary emission enhancement material and/or a conductive material, although other dopants may also be used. While it is contemplated that the dopants may be added to the shell by ion implantation at later stages in the process, in a preferred embodiment, the dopant is added directly in the aqueous solution so that the shell is initial formed with the dopant already present in the shell.

The above process steps may be modified or additional process steps may be added to the above process for forming a micro-component to provide a means for adding at least one coating to the micro-component. For coatings that may be disposed on the inside of the shell including, but not limited to a secondary emission enhancement material and a conductive material, it is contemplated in an embodiment of the present invention that those coating materials are added to the initial droplet solution so that when the outer membrane is formed around the initial droplet and then passed through the dehydration region **640** the coating material is left on the inside of the hollow dry gel shell. For coatings that may be disposed on the outside of the shell including, but not limited to, coatings used to convert UV light to visible light, coatings used as reflective filters and coatings used as band-gap filters, it is contemplated that after the micro-component leaves the refining region **660**, the micro-component will travel through at least one coating region. The coatings may be applied by any number of processes known to those skilled in the art as a means of applying a coating to a surface.

A further modification of the drop tower of FIG. **4** is illustrated in FIG. **11** with a continuous testing region **801**. The continuous testing region **801** includes a first optical detector **821** which detects individual micro-components as they are formed. This optical detector can detect such things as sphericity and size in a continuous process, typically operating at about 10 kilohertz sampling rate. Signals representing the micro-component detected are passed through line **823** to a control module **825**. If a micro-component does not meet certain minimum standards, a signal is sent from control module **825** to mechanical actuator **827** which activates a micro-component displacement device or arm **829** which is activated to remove the failed micro-component from the stream. A second region of the continuing testing device **801** includes, optionally, electrodes **805** which are excited through leads **807** by power supply **809** to generate a field which excites the plasma gas within the manufactured micro-components. As the micro-components are exited, a luminous output is generated and a second optical detector **811** serves to detect the luminous output and send a signal representing the luminous output for each individual micro-component through line **813** to a second control unit **815**. Additionally, with respect to the optional texturizing step after step **660** described above, the continuing testing device **801** can be configured to test the luminous output, i.e., amount and concentration, from the texturized portion of the micro-component.

If no luminous output is detected or a luminous output of less than a predetermined threshold or concentration is detected, the control unit **815** sends a signal to actuator **817** which then actuates a second micro-component displacement device or arm **819** to remove the failed micro-component from the stream.

With respect to the photo-detectors, they are conventional, and can be of the type, for example, which detect UV light. Alternatively, if the micro-component has been coated prior to the end of the fabrication process, for example, with phosphor, the detector may be of the type which is sensitive to a red light output. It should be noted that although the micro-component displacement devices or arms **819** and **829** have been described as mechanical in nature, they may also be non-mechanical, such as an intermittent fluid stream such as a gas or liquid stream or a light pulse such as a high-intensity laser pulse.

In another embodiment of the present invention, two substrates are provided, wherein at least one of two substrates contain a plurality of cavities. The two substrates are affixed together in the presence of at least one plasma-forming gas so that when affixed, the cavities are filled with the gas or gas mixture. In an embodiment of the present invention at least one electrode is disposed between the two substrates. In another embodiment, the inside, the outside, or both the inside and the outside of the cavities are coated with at least one coating. It is contemplated that any coating that may be applied to a micro-component as disclosed herein may be used. As illustrated in FIG. **5**, one method of making a micro-component in accordance with this embodiment of the present invention is to take a first substrate **200** and a second substrate **210** and then pass the first substrate **200** and the second substrate **210** through a first roller assembly and a second roller assembly, respectively. The first roller assembly includes a first roller with nodules **224** and a first roller with depressions **228**. The first roller with nodules **224** is in register with the first roller with depressions **228** so that as the first substrate **200** passes between the first roller with nodules **224** and the first roller with depressions **228**, a plurality of cavities **240** are formed in the first substrate **200**. As may be appreciated, the cavities may be in the shape desired for micro-components manufactured therewith such as hemispheres, capillaries, cylinders, etc. The second roller assembly, according to a preferred embodiment, includes two second rollers, **232** and **234**. The first substrate **200**, with a plurality of cavities **240** formed therein, is brought together with the second substrate **210** in the presence of a plasma-forming gas or gas mixture and then affixed, thereby forming a plurality of micro-components **250** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **210** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller **234**.

The nodules on the first roller with nodules **224** may be disposed in any pattern, having even or non-even spacing between adjacent nodules. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the distance between adjacent nodules is approximately equal. The nodules may also be disposed in groups such that the distance between one group of nodules and another group of nodules is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each nodule in a group of nodules may be used to form a micro-component that is configured for red, green, and blue, respectively.

While it is preferred that the second roller assembly simply include two second rollers, **232** and **234**, in an embodiment of the present invention as illustrated in FIG. **6**, the second roller assembly may also include a second roller with nodules **236** and a second roller with depressions **238** that are in registration so that when the second substrate **210** passes between the second roller with nodules **236** and the second roller with depressions **238**, a plurality of cavities **260** are also formed in the second substrate **210**. The first substrate **200** and the second substrate **210** are then brought together in the presence of at least one gas so that the plurality of cavities **240** in the first substrate **200** and the plurality of cavities **260** in the second substrate **210** are in register. The two substrates are then affixed, thereby forming a plurality of micro-components **270** integrally formed into a sheet of micro-components. While the first substrate **200** and the second substrate **240** may be affixed by any suitable method, according to a preferred embodiment, the two substrates are thermally affixed by heating the first roller with depressions **228** and the second roller with depressions **238**.

In an embodiment of the present invention that is applicable to the two methods discussed above, and illustrated in FIG. **9**, at least one electrode **280** is disposed on or within the first substrate **200**, the second substrate **240** or both the first substrate and the second substrate. Depending on how the electrode or electrodes are disposed, the electrode or electrodes will provide the proper structure for either an AC or DC (FIG. **7**) light-emitting panel. That is to say, if the at least one electrode **280** is at least partially disposed in a cavity **240** or **260** then there will be a direct conductive path between the at least one electrode and the plasma-forming gas or gas mixture and the panel will be configured for D.C. If, on the other hand, the at least one electrode is disposed so as not to be in direct contact with the plasma-forming gas or gas mixture, the panel will be configured for A.C.

In another embodiment of the present invention, at least one substrate is thermally treated in the presence of at least one plasma-forming gas, to form a plurality of shells **50** filled with the plasma-forming gas or gas mixture. In a preferred embodiment of the present invention, as shown in FIG. **10**, the process for making a micro-component would entail starting with a material or material mixture **700**, introducing inclusions into the material **710**, thermally treating the material so that the inclusions start forming bubbles within the material **720** and those bubbles coalesce **730** forming a porous shell **740**, and cooling the shell. The process is performed in the presence of a plasma-forming gas so that when the shell cools the plasma-forming gas **45** is sealed inside the shell **50**. This process can also be used to create a micro-component with a shell doped with a conductive material and/or a secondary emission enhancement material by combining the appropriate dopant with the initial starting material or by introducing the appropriate dopant while the shell is still porous.

In a yet still further method of manufacture, the micro-components can be manufactured using any of the above-mentioned methods, but not in the presence of a plasma-forming gas, and either in a vacuum, air or other atmosphere such as an inert atmosphere. They can be fabricated with one or two openings, and the initial gas inside can be drawn out, for example, through injection of plasma-forming gas through one opening, forcing the gas therein out the other opening. The openings can then be sealed conventionally.

In yet another alternative method, a device having one or more micro-pipettes can create the micro-components much like conventional glass blowing. The gas used to effect the glass-blowing operation can be one of the aforementioned plasma-forming gasses.

In yet still another alternative, an optical fiber extrusion device can be used to manufacture the micro-components. Like an optical fiber, which is solid, the device can be used to extrude a capillary which is hollow on the inside. The capillary can then be cut, filled with plasma-forming gas and sealed.

With respect to the selection of materials and dimensions for the micro-components manufactured in the manner described herein, they are manufactured to meet requirements for various standard display resolutions. FIG. **7** illustrates an example of calculation of pixel size and micro-component size, in the case where the micro-components are spheres, for 42-inch and 60-inch high definition television display having a 16:9 aspect ratio. FIG. **8** is a table showing numbers of pixels for various standard display resolutions, and using the process for manufacturing in accordance with the invention herein, such standards can be easily met.

In a further aspect, once the micro-components are manufactured, it is desirable to condition them prior to assembly into a plasma display panel. By conditioning is meant exciting them for a time and at an excitation sufficient to cause those micro-components which are likely to fail a short time after assembly in a plasma display panel, to fail prior to assembly. In this manner the yield relative to non-defective micro-components which are eventually assembled into a plasma display panel is significantly increased. Examples of devices for achieving said conditioning are shown in FIGS. **11** and **12**. As shown in the conditioning device **951** of FIG. **11** the manufactured and pretested micro-components **959** can be assembled between two conducting metal plates **957** which are powered through leads **955** by a voltage source **953** which can take various forms as illustrated therein. The micro-components **959** are subjected to a field sufficient to excite the plasma gas contained therein, and preferably at a level higher than any excitation level achieved when assembled in a plasma display panel. This is done for a period of time sufficient such that any micro-components which are prone to fail, will fail during the conditioning phase, typically five to ten hours.

As may be appreciated, an alternative system is illustrated by FIG. **13** which shows a conditioning device **901** which further includes a container **909** for confining and containing micro-components **911**. The container **909** may be placed between parallel plates or electrodes **903** which are powered through leads **905** by a power source **907** such as a voltage source of the type previously discussed with reference to FIG. **11**. The advantage of such a system is that by having container **909**, the micro-components are easily contained. After the conditioning period, the individual micro-components can then be dropped through a system such as pretesting device **801** shown in FIG. **11** without the presence of manufacturing drop tower **600**, and tested previously described for the method during which the micro-components are assembled. In this manner, those micro-components which failed the conditioning are eliminated and only fully-functioning micro-components can then be assembled into a plasma display panel as heretofore described.

With respect to micro-components manufactured as discussed with reference to FIGS. **5**, **6**, and **9**, once assembled, they may be cut from the sheets on which they are formed. They can be pretested with a device such as shown in the lower half of FIG. **11** at **801** and **803**. They can then be pre-conditioned as previously described with reference to FIGS. **12** and **13**, and then retested with the device of the lower half of FIG. **11** at **801** and **803**.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

What is claimed is:

**1**. A web fabrication process for manufacturing a plurality of light-emitting panels, the process comprising the steps of:
providing a first substrate;
disposing a plurality of micro-components on the first substrate, each of the micro-components comprising a shell filled with a plasma-forming gas or gas mixture;
texturizing a portion of each of the plurality of micro-components;
disposing a second substrate over the first substrate such that the plurality of micro-components are sandwiched between the first substrate and the second substrate; and
dicing the first substrate and the second substrate to form individual light-emitting panels.

**2**. The process of claim **1**, wherein texturizing a portion of each of the plurality of micro-components is achieved by sandblasting the shell of the micro-component.

**3**. The process of claim **1**, wherein texturizing a portion of each of the plurality of micro-components is achieved by etching the shell of the micro-component.

**4**. The process of claim **1**, wherein texturizing a portion of each of the plurality of micro-components is achieved through lithography.

**5**. A web fabrication process for manufacturing a plurality of light-emitting panels, the process comprising the steps of:
providing a first substrate;
disposing a plurality of micro-components on the first substrate, each of said micro-components comprising a shell;
texturizing a portion of each of the plurality of micro-components, wherein said texturizing is achieved by sandblasting the shell of the micro-component;
disposing a second substrate over the first substrate such that the plurality of micro-components are sandwiched between the first substrate and the second substrate; and
dicing the first substrate and the second substrate to form individual light-emitting panels.

**6**. A web fabrication process for manufacturing a plurality of light-emitting panels, the process comprising the steps of:
providing a first substrate;
disposing a plurality of micro-components on the first substrate, said micro-components comprising a shell;
texturizing a portion of each of the plurality of micro-components, wherein said texturizing is achieved by etching the shell of the micro-component;
disposing a second substrate over the first substrate such that the plurality of micro-components are sandwiched between the first substrate and the second substrate; and
dicing the first substrate and the second substrate to form individual light-emitting panels.

**7**. A web fabrication process for manufacturing a plurality of light-emitting panels, the process comprising the steps of:
providing a first substrate;
disposing a plurality of micro-components on the first substrate, said micro-components comprising a shell;
texturizing the shell of each of the plurality of micro-components, wherein said texturizing is achieved through lithography;
disposing a second substrate over the first substrate such that the plurality of micro-components are sandwiched between the first substrate and the second substrate; and
dicing the first substrate and the second substrate to form individual light-emitting panels.

* * * * *

US007796103B2

(12) **United States Patent**
**Doane et al.**

(10) **Patent No.: US 7,796,103 B2**
(45) **Date of Patent: Sep. 14, 2010**

(54) **DRAPABLE LIQUID CRYSTAL TRANSFER DISPLAY FILMS**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 913 days.

(21) Appl. No.: **10/587,591**

(22) PCT Filed: **Jan. 28, 2005**

(86) PCT No.: **PCT/US2005/003239**

§ 371 (c)(1), (2), (4) Date: **Jul. 28, 2006**

(87) PCT Pub. No.: **WO2005/072455**

PCT Pub. Date: **Aug. 11, 2005**

(65) **Prior Publication Data**

US 2007/0152928 A1 Jul. 5, 2007

**Related U.S. Application Data**

(63) Continuation of application No. 11/006,100, filed on Dec. 7, 2004, which is a continuation of application No. 10/782,461, filed on Feb. 19, 2004.

(60) Provisional application No. 60/539,873, filed on Jan. 28, 2004, provisional application No. 60/565,586, filed on Apr. 27, 2004, provisional application No. 60/598,163, filed on Aug. 2, 2004.

(51) **Int. Cl.**
*G09G 3/36* (2006.01)

(52) **U.S. Cl.** .......................................... **345/87**; 345/31

(58) **Field of Classification Search** ............. 345/30–32, 345/87–100; 349/90, 110, 113

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,600,060 A 8/1971 Churchhill

(Continued)

FOREIGN PATENT DOCUMENTS

CN 1271427 10/2000

(Continued)

OTHER PUBLICATIONS

*Reflective display with photoconductive layer and a bistable reflective cholesteric mixture*, Hidefumi Yoshida et al., Journal of the SID 5/3, 1997, pp. 269-274.

(Continued)

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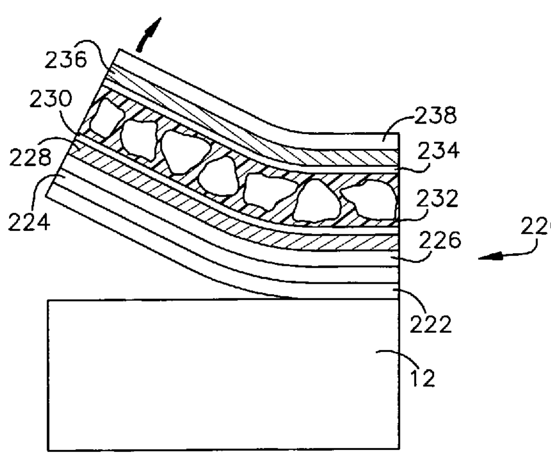
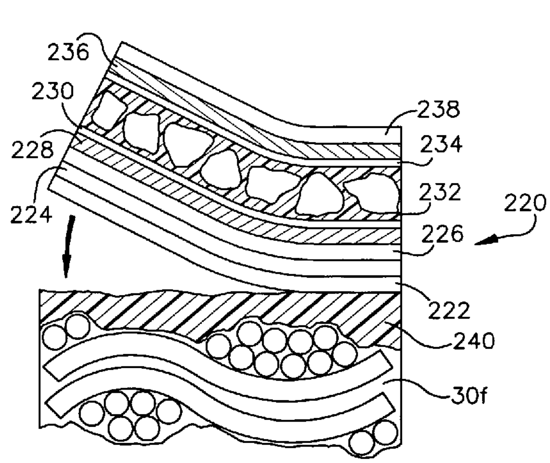
(57) **ABSTRACT**

The present invention relates to a display film that may be transferred by lamination or otherwise onto a substrate. The display film is formed of a stack of layers that can include different types, arrangements, and functionality within the stack depending upon factors including the characteristics of the substrate (e.g., upper or lower, transparent or opaque, substrates) and addressing of the display (e.g., active or passive matrix, electrical or optical addressing). The layers of the stacked display film include one or more electrode layers and one or more liquid crystal layers and, in addition, may include various combinations of an adhesive layer, preparation layer, casting layer, light absorbing layer, insulation layers, and protective layers. The liquid crystal layer can include cholesteric or other liquid crystal material. The liquid crystal layer can be a dispersion of liquid crystal in a polymer matrix formed by a variety of techniques. The display film may interact with components mounted on or laminated to the substrate, including a solar cell, active matrix backplane and electrodes. The display film may be mounted onto flexible or drapable substrates such as fabric and can itself be drapable. Thus, the invention offers substantial flexibility in fabrication and design that has not been previously possible in the display industry.

**35 Claims, 14 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | | |
|---|---|---|---|---|---|
| 3,680,950 | A | | 8/1972 | Haas et al. | |
| 4,362,903 | A | | 12/1982 | Eichelberger et al. | |
| 4,510,188 | A | | 4/1985 | Ruggeri | |
| 4,566,935 | A | | 1/1986 | Hornbeck | |
| 4,642,250 | A | | 2/1987 | Spector | |
| 4,680,579 | A | | 7/1987 | Ott | |
| 4,684,771 | A | | 8/1987 | Wuthrich | |
| 4,688,900 | A | | 8/1987 | Doane et al. | |
| 4,747,413 | A | | 5/1988 | Bloch | |
| 4,890,902 | A | | 1/1990 | Doane et al. | |
| 4,896,946 | A | | 1/1990 | Suzuki et al. | |
| 4,948,232 | A | | 8/1990 | Lange | |
| 5,007,872 | A | | 4/1991 | Tang | |
| 5,061,553 | A | | 10/1991 | Olsen, Jr. | |
| 5,161,479 | A | | 11/1992 | Mahr | |
| 5,172,108 | A | | 12/1992 | Wakabayashi et al. | |
| 5,200,845 | A | | 4/1993 | Crooker et al. | |
| 5,360,503 | A | | 11/1994 | Coffy | |
| 5,376,699 | A | | 12/1994 | Sage | |
| 5,437,811 | A | | 8/1995 | Doane et al. | |
| 5,453,863 | A | | 9/1995 | West et al. | |
| 5,493,430 | A | | 2/1996 | Lu et al. | |
| 5,530,457 | A | | 6/1996 | Helgeson | |
| 5,625,477 | A | | 4/1997 | Wu et al. | |
| 5,636,044 | A | | 6/1997 | Yuan et al. | |
| 5,644,330 | A | | 7/1997 | Catchpole et al. | |
| 5,668,614 | A | | 9/1997 | Chien et al. | |
| 5,691,795 | A | | 11/1997 | Doane et al. | |
| 5,734,155 | A | | 3/1998 | Rostoker | |
| 5,748,277 | A | | 5/1998 | Huang et al. | |
| 5,751,257 | A | | 5/1998 | Sutherland | |
| 5,815,136 | A | | 9/1998 | Ikeda et al. | |
| 5,847,798 | A | | 12/1998 | Yang et al. | |
| 5,889,572 | A | | 3/1999 | Takahashi et al. | |
| 5,981,408 | A | | 11/1999 | Nakagawa et al. | |
| 5,996,897 | A | | 12/1999 | Prancz | |
| 6,017,468 | A | * | 1/2000 | Chung et al. | 252/299.5 |
| 6,034,752 | A | | 3/2000 | Khan et al. | |
| 6,061,107 | A | | 5/2000 | Yang et al. | |
| 6,072,619 | A | | 6/2000 | Kiryuschev et al. | |
| 6,096,666 | A | | 8/2000 | Jachimowicz et al. | |
| 6,133,895 | A | | 10/2000 | Huang | |
| 6,147,741 | A | * | 11/2000 | Chen et al. | 349/202 |
| 6,154,190 | A | | 11/2000 | Yang et al. | |
| 6,224,964 | B1 | | 5/2001 | Kawai et al. | |
| 6,253,190 | B1 | | 6/2001 | Sutherland | |
| 6,268,839 | B1 | | 7/2001 | Yang et al. | |
| 6,268,841 | B1 | | 7/2001 | Cairns et al. | |
| 6,269,342 | B1 | | 7/2001 | Brick et al. | |
| 6,270,783 | B1 | | 8/2001 | Slavtcheff et al. | |
| 6,271,898 | B1 | | 8/2001 | Clikeman et al. | |
| 6,277,439 | B1 | | 8/2001 | Painter | |
| 6,278,429 | B1 | | 8/2001 | Ruth et al. | |
| 6,307,605 | B1 | | 10/2001 | Bailey | |
| 6,316,278 | B1 | | 11/2001 | Jacobsen et al. | |
| 6,320,563 | B1 | | 11/2001 | Yang et al. | |
| 6,359,673 | B1 | | 3/2002 | Stephenson | |
| 6,377,321 | B1 | | 4/2002 | Khan et al. | |
| 6,423,368 | B1 | | 7/2002 | Stephenson et al. | |
| 6,433,849 | B1 | | 8/2002 | Lowe | |
| 6,452,590 | B1 | | 9/2002 | Awamoto et al. | |
| 6,459,467 | B1 | | 10/2002 | Hashimoto et al. | |
| 6,468,638 | B2 | | 10/2002 | Jacobsen et al. | |
| 6,483,563 | B2 | | 11/2002 | Khan et al. | |
| 6,518,944 | B1 | | 2/2003 | Doane et al. | |
| 6,532,052 | B1 | | 3/2003 | Khan et al. | |
| 6,556,262 | B1 | | 4/2003 | Stephenson et al. | |
| 6,585,849 | B2 | | 7/2003 | Smith et al. | |
| 6,603,259 | B1 | | 8/2003 | Kiryuschev et al. | |
| 6,608,438 | B2 | | 8/2003 | Topelberg et al. | |
| 6,618,114 | B1 | | 9/2003 | Freeman | |
| 6,624,565 | B2 | | 9/2003 | Topelberg | |
| 6,628,256 | B2 | | 9/2003 | Nishimura | |
| 6,639,578 | B1 | | 10/2003 | Comiskey et al. | |
| 6,654,080 | B1 | | 11/2003 | Khan et al. | |
| 6,655,788 | B1 | | 12/2003 | Freeman | |
| 6,657,620 | B2 | | 12/2003 | Oishi et al. | |
| 6,697,191 | B2 | | 2/2004 | Kiryuschev et al. | |
| 6,710,760 | B1 | | 3/2004 | Johnson et al. | |
| 6,723,479 | B2 | | 4/2004 | van de Witte et al. | |
| 6,727,197 | B1 | | 4/2004 | Wilson et al. | |
| 6,788,362 | B2 | | 9/2004 | Stephenson et al. | |
| 6,811,815 | B2 | | 11/2004 | He et al. | |
| 6,819,310 | B2 | | 11/2004 | Huang et al. | |
| 6,836,259 | B2 | | 12/2004 | Topelberg | |
| 6,850,217 | B2 | | 2/2005 | Huang et al. | |
| 6,864,435 | B2 | | 3/2005 | Hermanns et al. | |
| 6,902,454 | B1 | | 6/2005 | Petruchik | |
| 6,977,099 | B2 | | 12/2005 | Umeya et al. | |
| 7,009,666 | B2 | | 3/2006 | Khan et al. | |
| 7,061,559 | B2 | | 6/2006 | Khan et al. | |
| 7,072,095 | B2 | | 7/2006 | Liang et al. | |
| 7,170,481 | B2 | * | 1/2007 | Doane et al. | 345/87 |
| 7,236,151 | B2 | * | 6/2007 | Doane et al. | 345/87 |
| 2001/0015712 | A1 | | 8/2001 | Hashimoto | |
| 2001/0020935 | A1 | | 9/2001 | Gelbman | |
| 2001/0043295 | A1 | | 11/2001 | Chen | |
| 2002/0030776 | A1 | | 3/2002 | Khan et al. | |
| 2002/0030786 | A1 | | 3/2002 | Stephenson | |
| 2002/0167500 | A1 | | 11/2002 | Gelbman | |
| 2002/0186182 | A1 | | 12/2002 | Stephenson et al. | |
| 2003/0001987 | A1 | | 1/2003 | Trapani et al. | |
| 2003/0011549 | A1 | | 1/2003 | Murahashi et al. | |
| 2003/0016329 | A1 | | 1/2003 | Smith et al. | |
| 2003/0019575 | A1 | | 1/2003 | Smith et al. | |
| 2003/0031845 | A1 | | 2/2003 | Umeya et al. | |
| 2003/0034945 | A1 | | 2/2003 | Mi et al. | |
| 2003/0063245 | A1 | | 4/2003 | Bowley et al. | |
| 2003/0071791 | A1 | | 4/2003 | Hanson et al. | |
| 2003/0085380 | A1 | | 5/2003 | Schuhmacher et al. | |
| 2003/0117548 | A1 | | 6/2003 | Stephenson | |
| 2003/0155151 | A1 | | 8/2003 | Hermanns et al. | |
| 2003/0160912 | A1 | | 8/2003 | Stephenson | |
| 2003/0169221 | A1 | | 9/2003 | Stephenson et al. | |
| 2003/0184569 | A1 | | 10/2003 | Koga et al. | |
| 2003/0202136 | A1 | | 10/2003 | Stephenson et al. | |
| 2003/0206147 | A1 | | 11/2003 | Mi et al. | |
| 2003/0214471 | A1 | | 11/2003 | Topelberg | |
| 2003/0214612 | A1 | | 11/2003 | Freeman | |
| 2003/0222139 | A1 | | 12/2003 | Stephenson et al. | |
| 2004/0032545 | A1 | | 2/2004 | Stephenson et al. | |
| 2004/0080477 | A1 | | 4/2004 | Capurso et al. | |
| 2004/0101988 | A1 | | 5/2004 | Roman et al. | |
| 2004/0105061 | A1 | | 6/2004 | Andry et al. | |
| 2004/0169912 | A1 | | 9/2004 | Liang et al. | |
| 2004/0228106 | A1 | | 11/2004 | Stevenson et al. | |
| 2005/0001797 | A1 | | 1/2005 | Miller, IV et al. | |
| 2005/0003144 | A1 | | 1/2005 | Buttgen et al. | |
| 2005/0007336 | A1 | | 1/2005 | Albert et al. | |
| 2005/0036077 | A1 | | 2/2005 | Khan et al. | |
| 2005/0079386 | A1 | | 4/2005 | Brown, Jr. et al. | |
| 2005/0083284 | A1 | | 4/2005 | Huang et al. | |
| 2005/0088079 | A1 | | 4/2005 | Daniels | |
| 2005/0162606 | A1 | | 7/2005 | Doane et al. | |
| 2005/0179678 | A1 | | 8/2005 | Nose et al. | |
| 2005/0195354 | A1 | | 9/2005 | Doane et al. | |
| 2006/0066803 | A1 | | 3/2006 | Aylward et al. | |
| 2006/0124899 | A1 | | 6/2006 | Welter | |
| 2006/0204675 | A1 | | 9/2006 | Gao et al. | |
| 2007/0026163 | A1 | * | 2/2007 | Schneider et al. | 428/1.1 |
| 2007/0059901 | A1 | | 3/2007 | Majumdar et al. | |

2007/0285385 A1 12/2007 Albert et al.

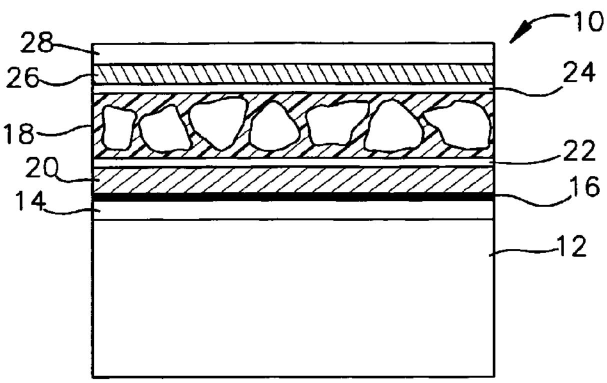
FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| CN | 1406341 | 3/2003 |
| EP | 1058147 | 12/2000 |
| JP | 3168613 | 7/1991 |
| WO | 9209065 | 5/1992 |
| WO | 92/11311 | 7/1992 |
| WO | 02093240 | 11/2002 |
| WO | 2004029708 | 4/2004 |
| WO | 2005/072447 | 8/2005 |
| WO | 2005072455 | 8/2005 |
| WO | 2005/081779 | 9/2005 |

OTHER PUBLICATIONS

*Photostable tilted-perpendicular alignment of liquid crystals for light valves*, Anna Lackner et al., Proceedings of the SID, vol. 31/4, 1990, pp. 321-326.
*Transparent phase images in photoactivated liquid crystals*, J.S. Margerum et al., Applied Physics Letter, vol. 19, No. 7, Oct. 1, 1971, pp. 216-218.
*16.3: Development of a flexible electronic display using photographic technology*, Stanley W. Stephenson et al., SID 04 Digest, pp. 774-777.
*A fully flexible colour display*, Peter Slikkerveer et al., SID 04 Digest, pp. 770-773.
*Robust Flexible LCD's with Paintable Technology*, Joost P.A. Vogels et al., SID 04 Digest, pp. 767-769.
*10.1: Invited paper: What is electronic paper? The expectations*, Makoto Omodani, SID 04 Digest, pp. 128-131.
*Effect of woven fabric anisotropy on drape behaviour*, V. Sidabraite et al., ISSN 1392-1320, Materials Science, vol. 9, No. 1, 2003, pp. 111-115.
*The characterization of the static and dynamic drape of fabrics*, G.K. Stylios et al., J. Text. Inst., 1997, 88 Part 1, No. 4, pp. 465-475.
*Modelling the fused panel for a numerical simulation of drape*, Simona Jevsnik et al., Fibers & Textiles in Eastern Europe, Jan./Mar. 2004, vol. 12, No. 1, pp. 47-52.
*Mechanics of elastic performance of textile materials*, Chauncey Chu et al., Textile Research Journal, Aug. 1950, pp. 539-548.
*The dependence of fabric drape on bending and shear stiffness*, G.E. Cusick, J. Textile Institute 36, 11, 1965, pp. T597-T-607.
*Liquid crystal dispersions*, Paul S. Drzaic, World Scientific, Series on Liquid Crystals, vol. 1, pp. xi-xv, 1995.
*6.3: Plastic VGA reflective cholesteric LCDs with dynamic drive*, G.M. Podojil et al., SID proceedings, 1998, pp. 51-54.
*13.1: Invited Paper: Reflective color display using cholesteric liquid crystals*, K. Hashimoto et al., SID 98 Digest, pp. 897-900.
*Black and white photo-addressable electronic paper using encapsulated cholester liquid crystal and organic photoconductor*, T. Kakinuma et al., IDW 2002, pp. 1345-1348.
*Characterization of "Peas in a Pod", a novel idea for electronic paper*, S. Maeda et al., IDW 2002, pp. 1353-1356.
*Holographic polymer-dispersed liquid crystals (H-PDLCs)*, T.J. Bunning et al., Annu. Rev. Mater. Sci 2000, 30:83-115, pp. 83-115.
*Reflective multicolor display using cholesteric liquid crystals*, M. Okada et al., Proc, SID 97 Digest, pp. 1019-1022.
*Multiple color high resolution reflective cholesteric liquid crystal display*, D. Davis et al., Proc IDRC (242) 1997.
*Full color (4096 Colors) reflective cholesteric crystal display*, X. Huang et al., Proceedings of Asia Display 98, pp. 883-886 (1998).
Jing-Jou Tang et al., *A 30-V Row/Column Driver for PSCT LCD Using High-Voltage BiMOS Process*, Online Article, dated 1999.
http://www.us.semiconductors.philips.com/pip/PCF8578.html, LCD/row/column driver for dot matrix graphic displays, printed Jul. 8, 2003, pp. 1-3.
Doane, J. William and Khan, Asad; *Cholesteric Liquid Crystals for Flexible Displays*, in *Flexible Flat Panel Displays*, Ed. G. Crawford) John Wiley & Sons, England, Chapter 17 (2005) pp. 331-354.
Doane, J. William, "*Polymer Dispersed Liquid Crystal Displays*", in *Liquid Crystals: Applications & Uses*, Ed. Birendra Bahadur (World Scientific Pub. 1990), Chapter 14, pp. 361-395.
Office Action dated Mar. 8, 2006 for U.S. Appl. No. 11/046,487, filed Jan. 28, 2005, which is now Patent No. 7,170,481.
Notice of Allowance dated Aug. 28, 2006 for U.S. Appl. No. 11/046,487, filed Jan. 28, 2005, which is now Patent No. 7,170,481.
Office Action dated Mar. 8, 2006 for U.S. Appl. No. 11/006,100, filed Dec. 7, 2004, which is now Patent No. 7,236,151.
Notice of Allowance dated Dec. 28, 2006 for U.S. Appl. No. 11/006,100, filed Dec. 7, 2004, which is now Patent No. 7,236,151.
R.D. Sterling et al., "Video-Rate Liquid Crystal Light Valve using Amorphous Silicon Photoconductor" proceedings of the SID, XXI, 327-329 (1990).
N. Hiji et al., SID Digest of Papers, vol. XXXIV, 1560-1563, (2005).
E. Sackman, J. Chem. Phys. Soc., 93, 7088-7090 (1971).
T. Ikeda, J. Mater. Chem., 13, 2037-2057 (2003).
S. Pieraccini et al., Chem. Comm., 598-599 (2003).
S. Pieraccini et al., Chem. Eur. J., 10, 5632-5639 (2004).
B.L. Feringa et al., J. Chem. Soc. Chem. Comm., 288-290, (1993).
B.L. Feringa et al., Chemical Reviews, vol. 100, pp. 1789-1816 (2000).
Li et al., J. Am. Chem. Soc., 9 vol. 129, pp. 12908-12909 (2007).
A. Bobrovsky et al., Polymers for Advanced Technologies, vol. 13, pp. 595-600 (2002).
M. Brehmer et al., Advanced Materials, 10, 1438-1441 (1998).
P. van de Witte et al., Journal of Applied Physics, 85, 7517-7521 (1999).
J.W. Doane et al., Proceedings of Japan Display '92 (Hiroshima), pp. 73-76 (1992).
Fundamentals of Liquid Crystal Devices, D-K Yang and S.T. Wu, Chapter 1 (John Wiley & Sons, New York 2006).
Office Action/Examination Report from corresponding Application No. GB0616586.4, which has issued to United Kingdom Patent No. GB2428860B. Date of Report: Dec. 4, 2006.
Office Action/Examination Report from corresponding Application No. GB0615404.1, which has issued to United Kingdom Patent No. 2426371B. Date of Report: Nov. 29, 2006.
First Notification of Office Action issued May 23, 2008 from corresponding Chinese Application No. 200580003397.9, which has issued to Chinese Patent No. ZL 2005 8 003397.9.
Non Final Office Action from corresponding U.S. Appl. No. 10/587,548 filed on Jul. 28, 2006.
Submission of Prior Art document for Reexamination of Patent No. 7,170,481 issued on Jan. 30, 2007.
Submission of Prior Art document for Reexamination of Patent No. 7,236,151 issued on Jun. 26, 2007.
Second Office Action from corresponding Chinese Application No. 2005800033964. Office Action issued on Jan. 29, 2010.

* cited by examiner

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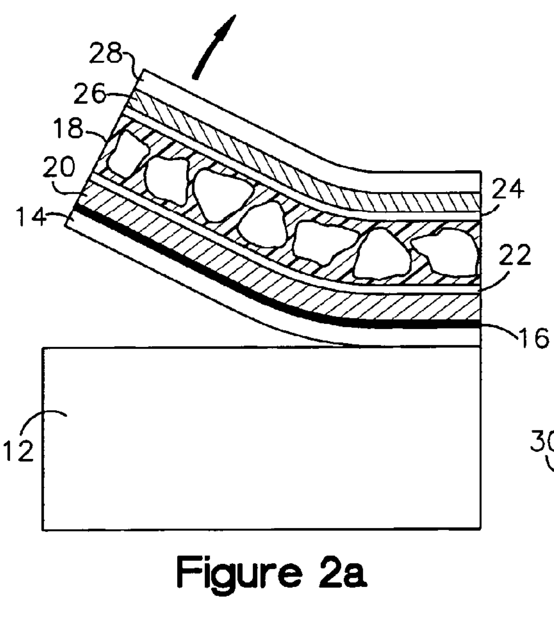


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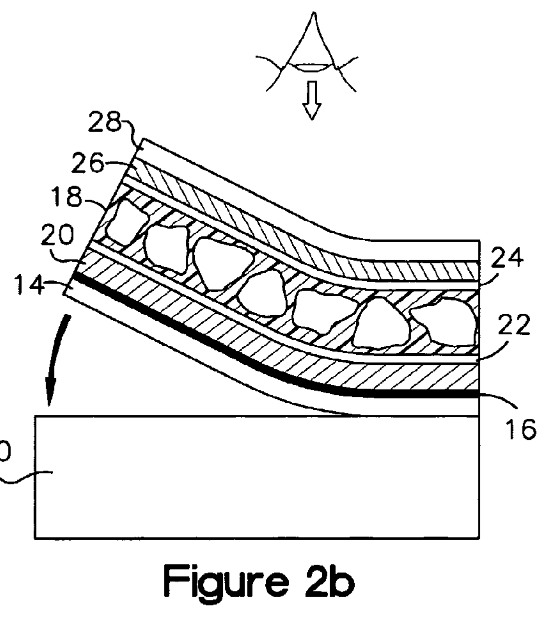
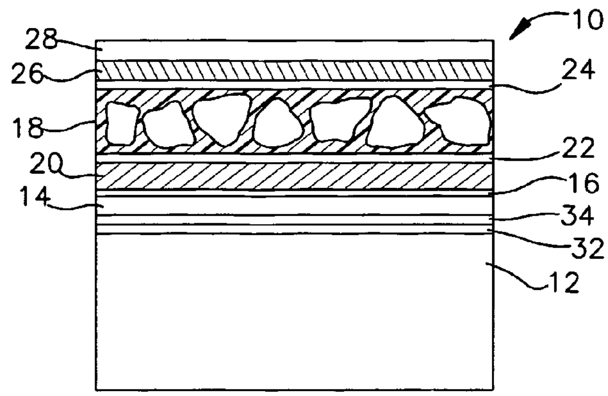



Figure 2b

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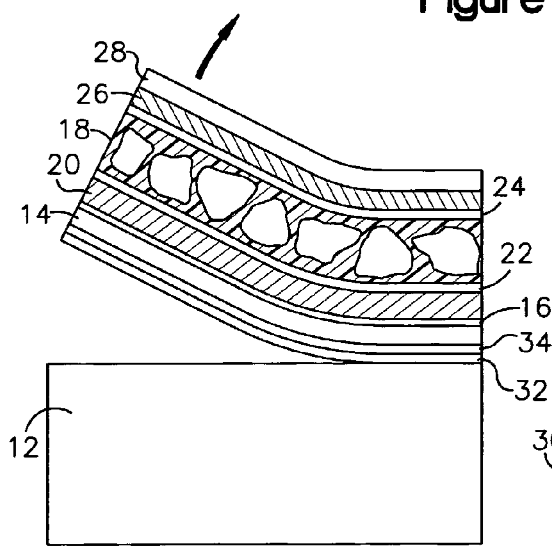


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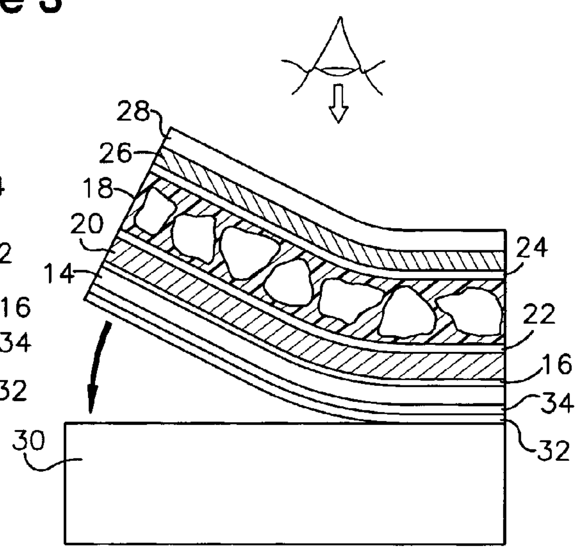



Figure 4b

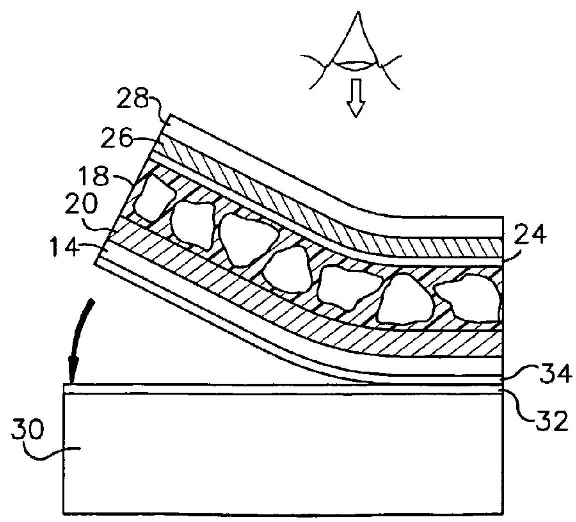
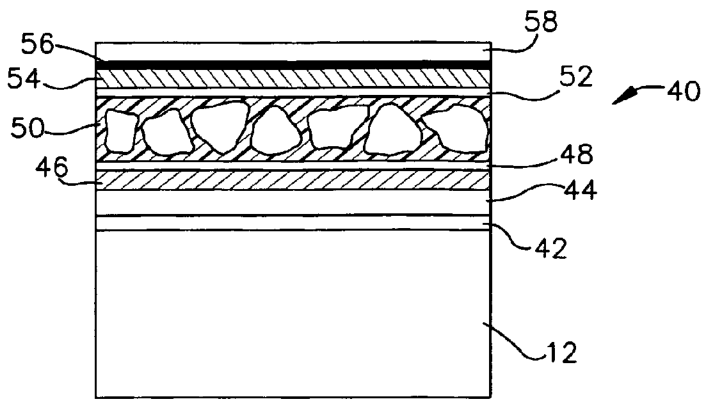



Figure 4c

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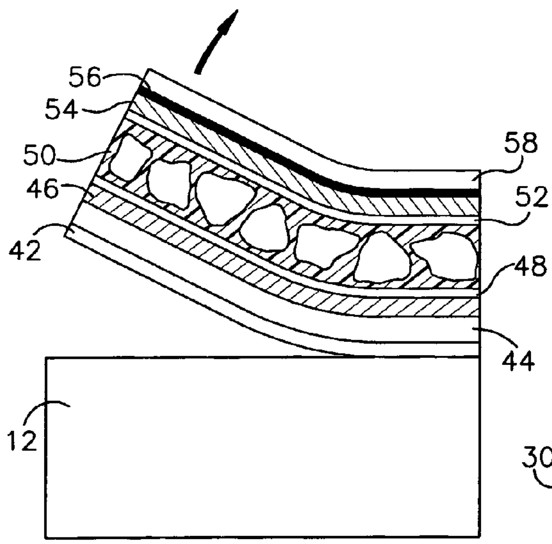


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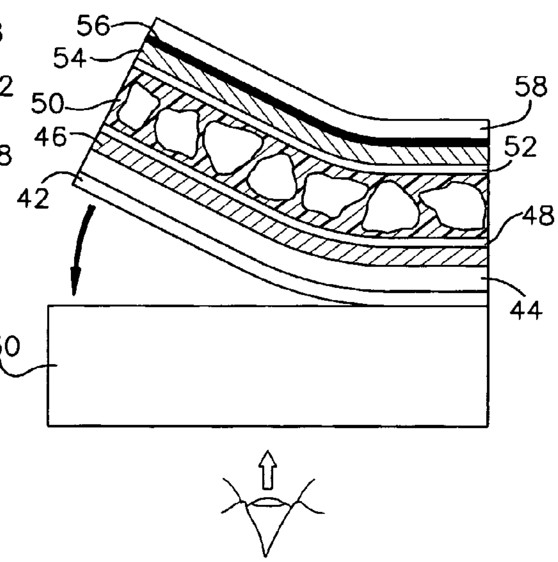


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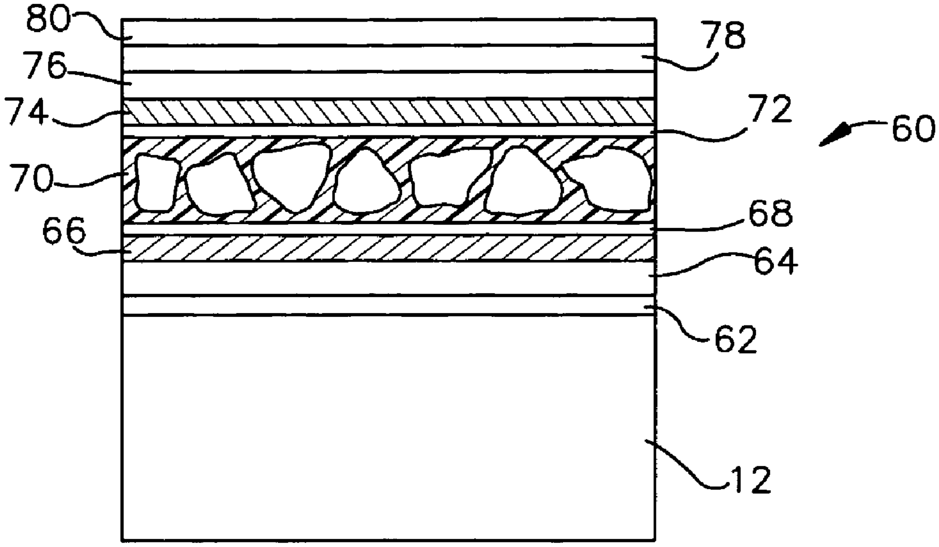


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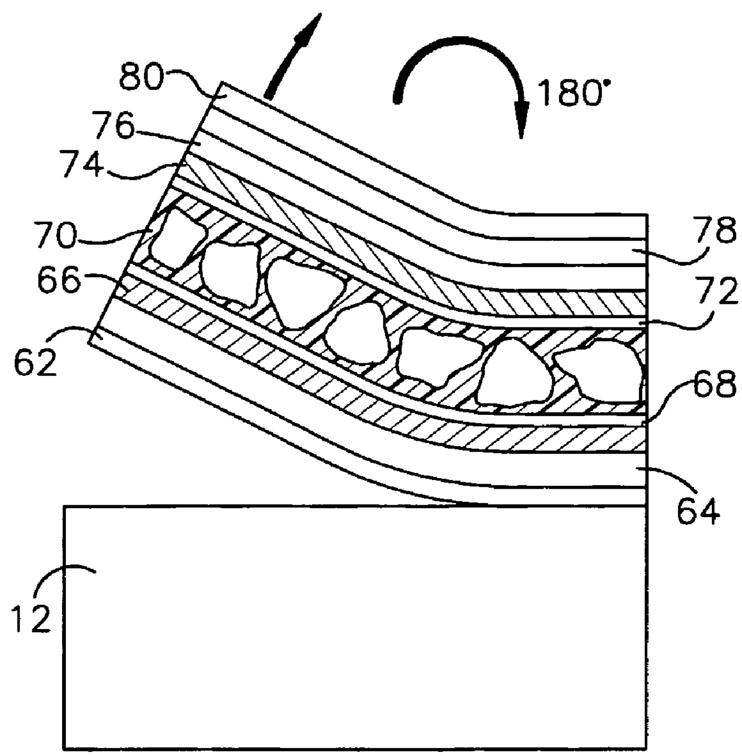


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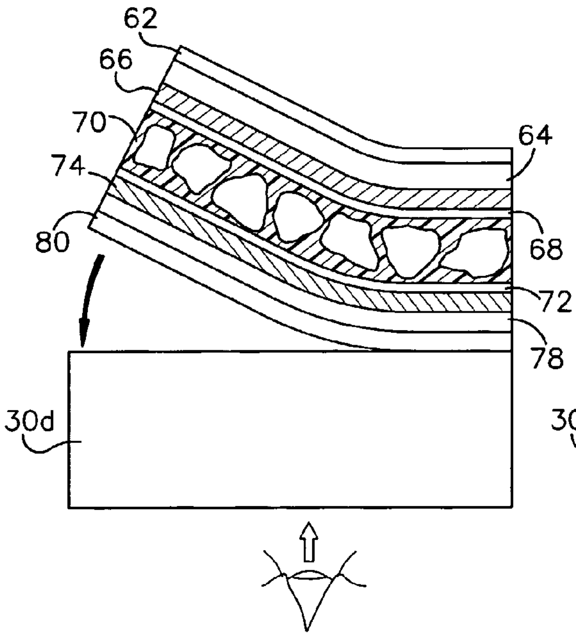


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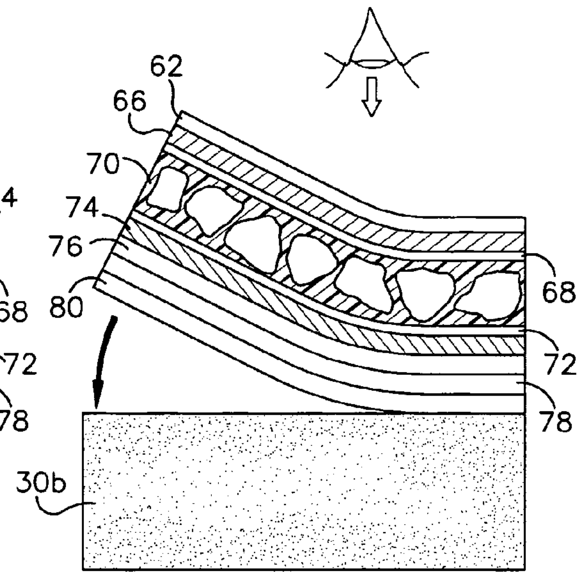
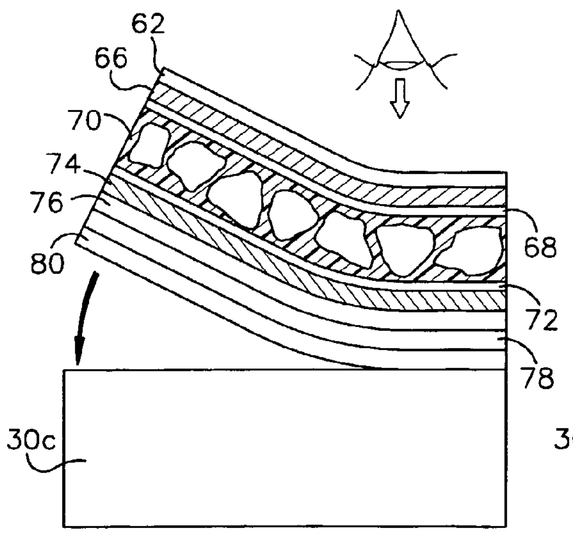



Figure 9b

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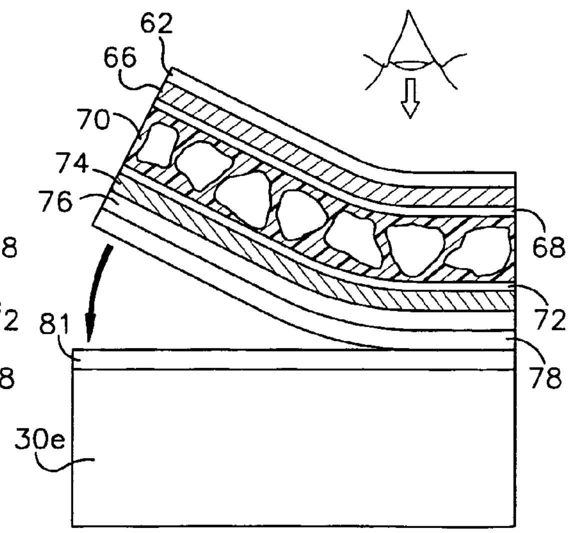



Figure 9d

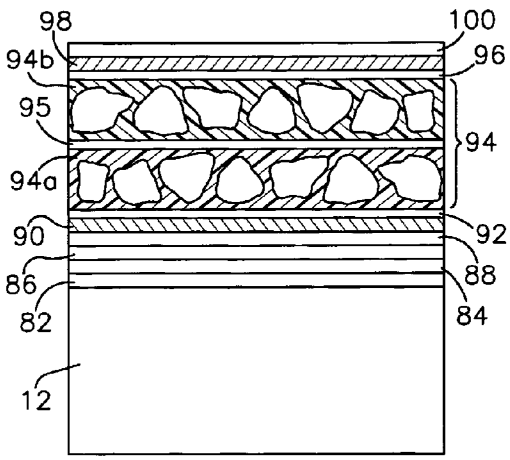
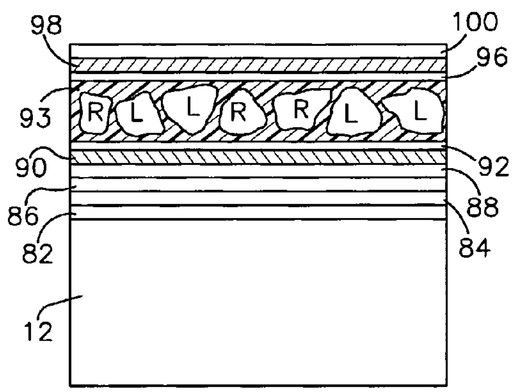



Figure 10

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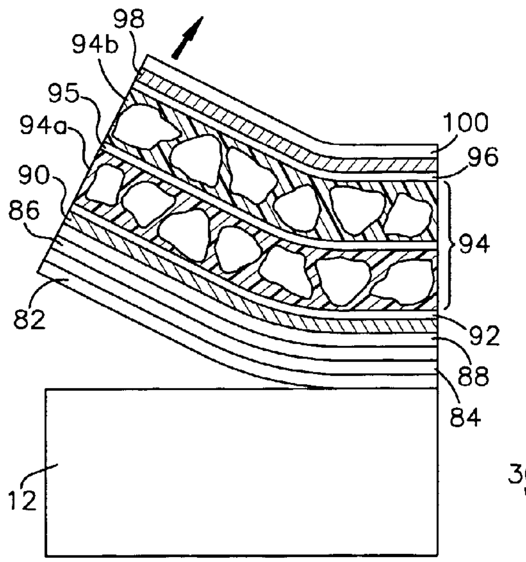


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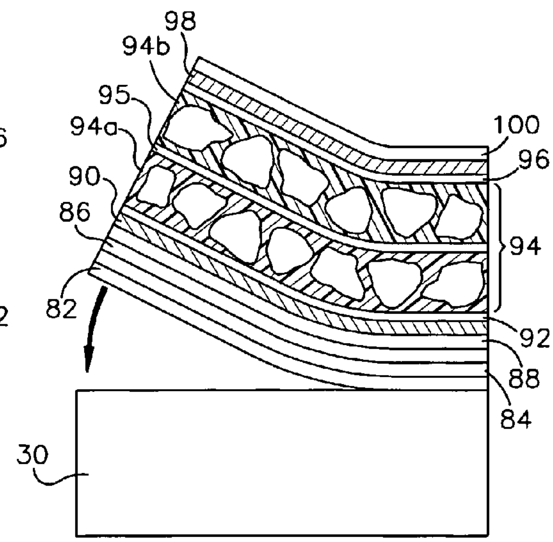


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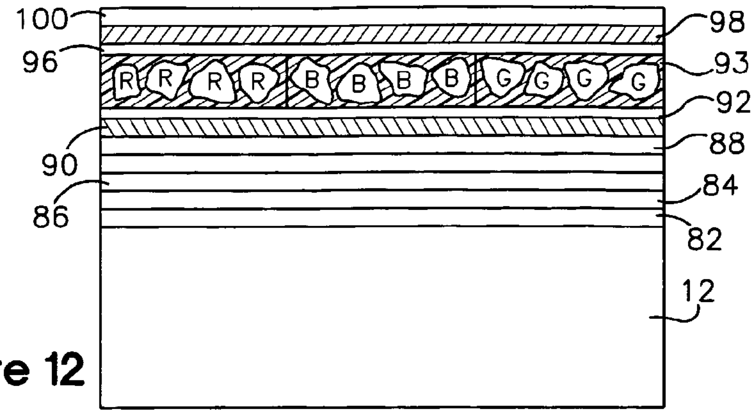


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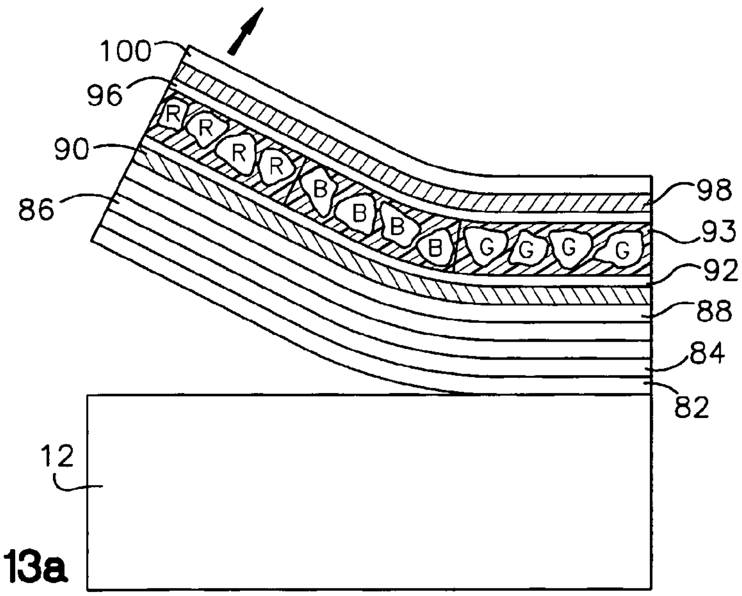


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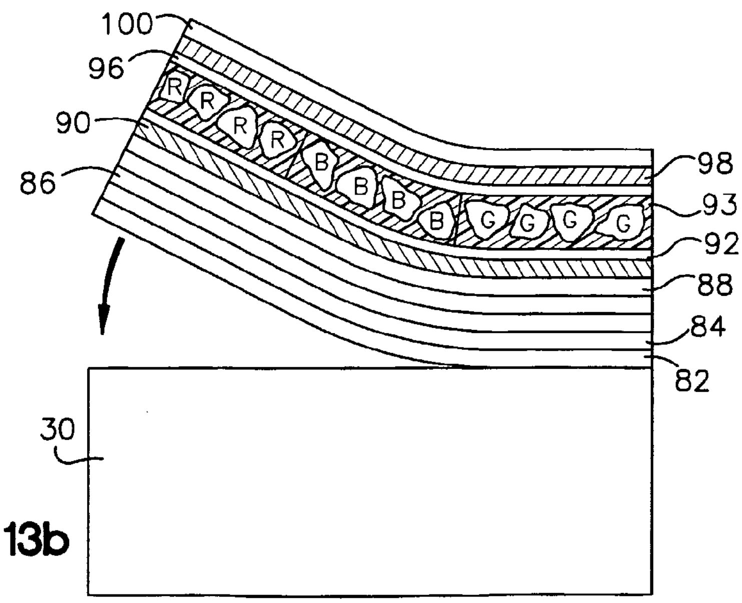


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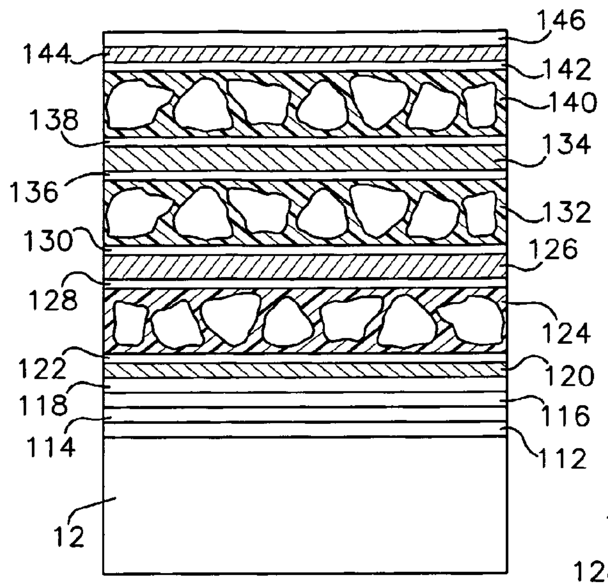


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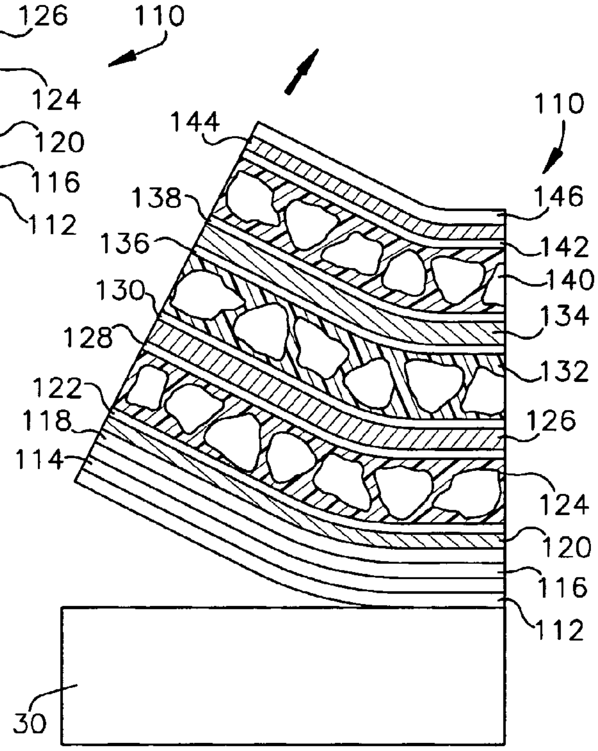


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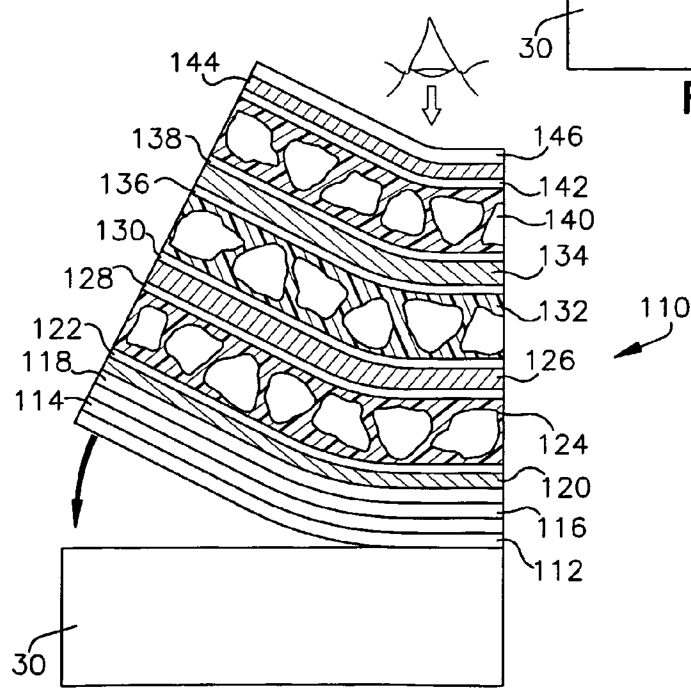


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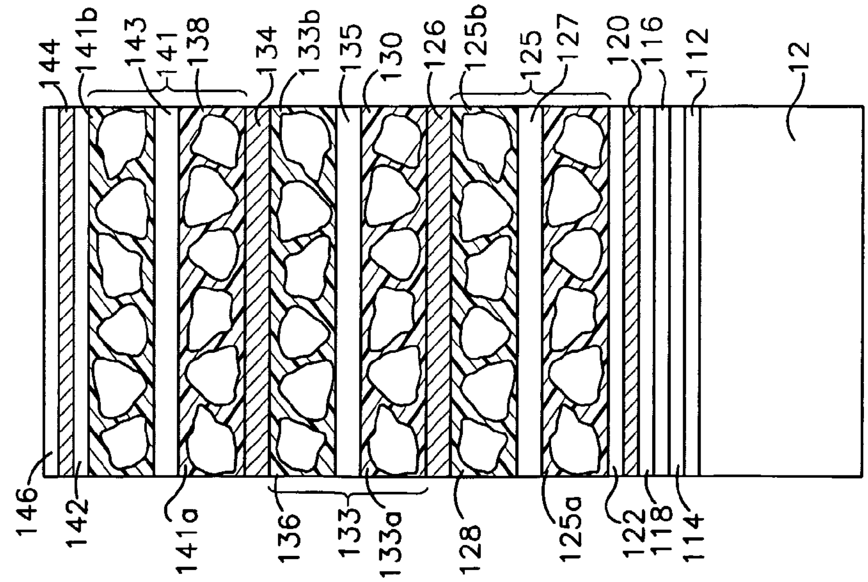


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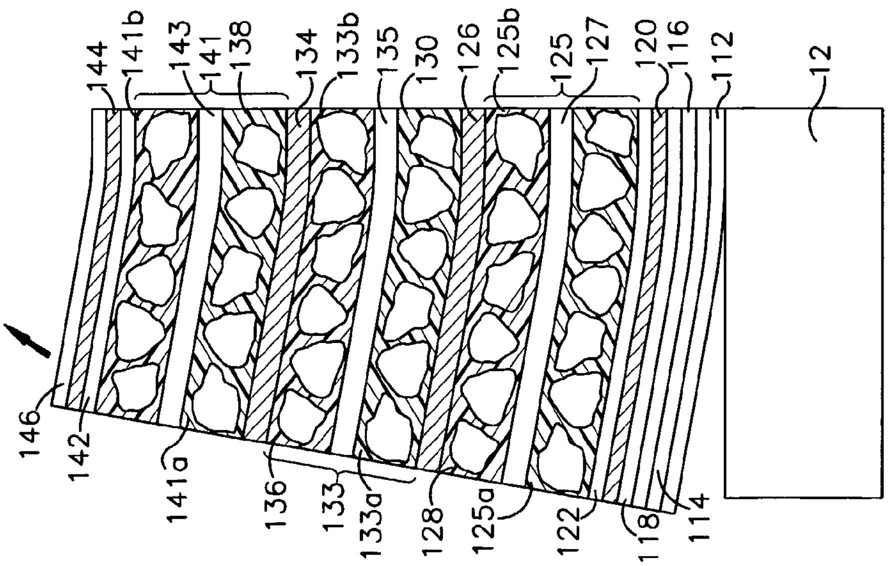



Figure 17a

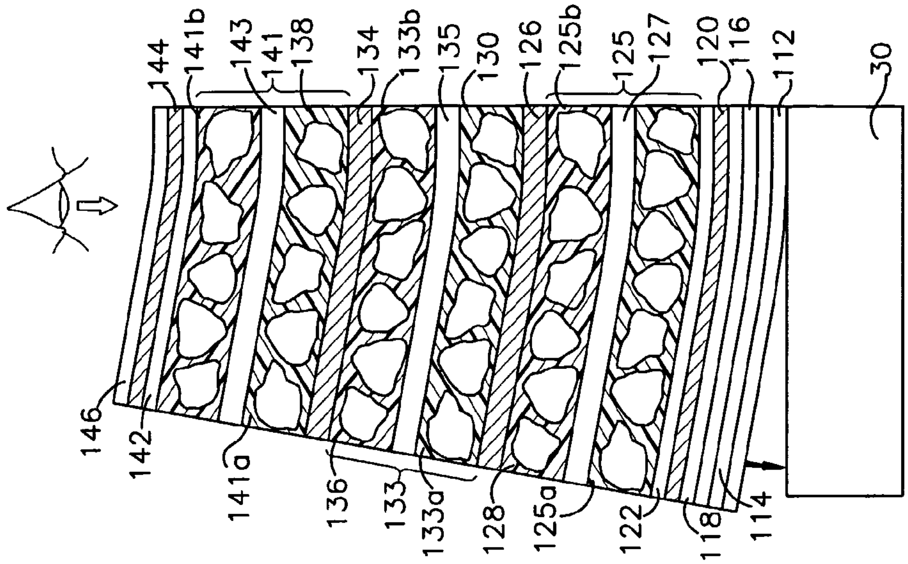
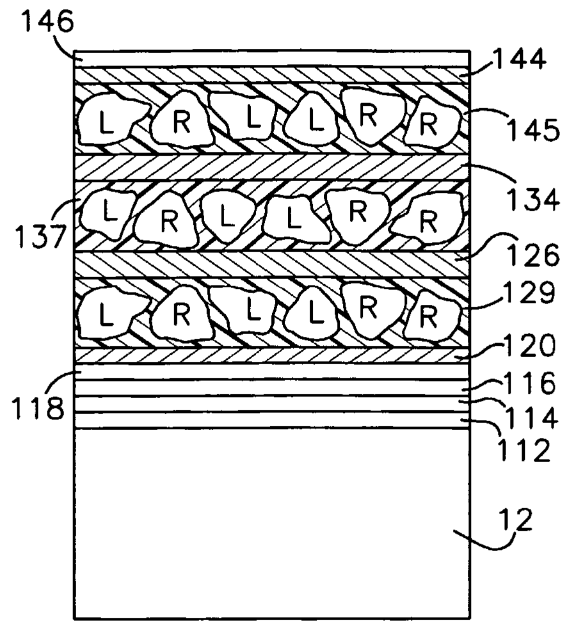



Figure 17b

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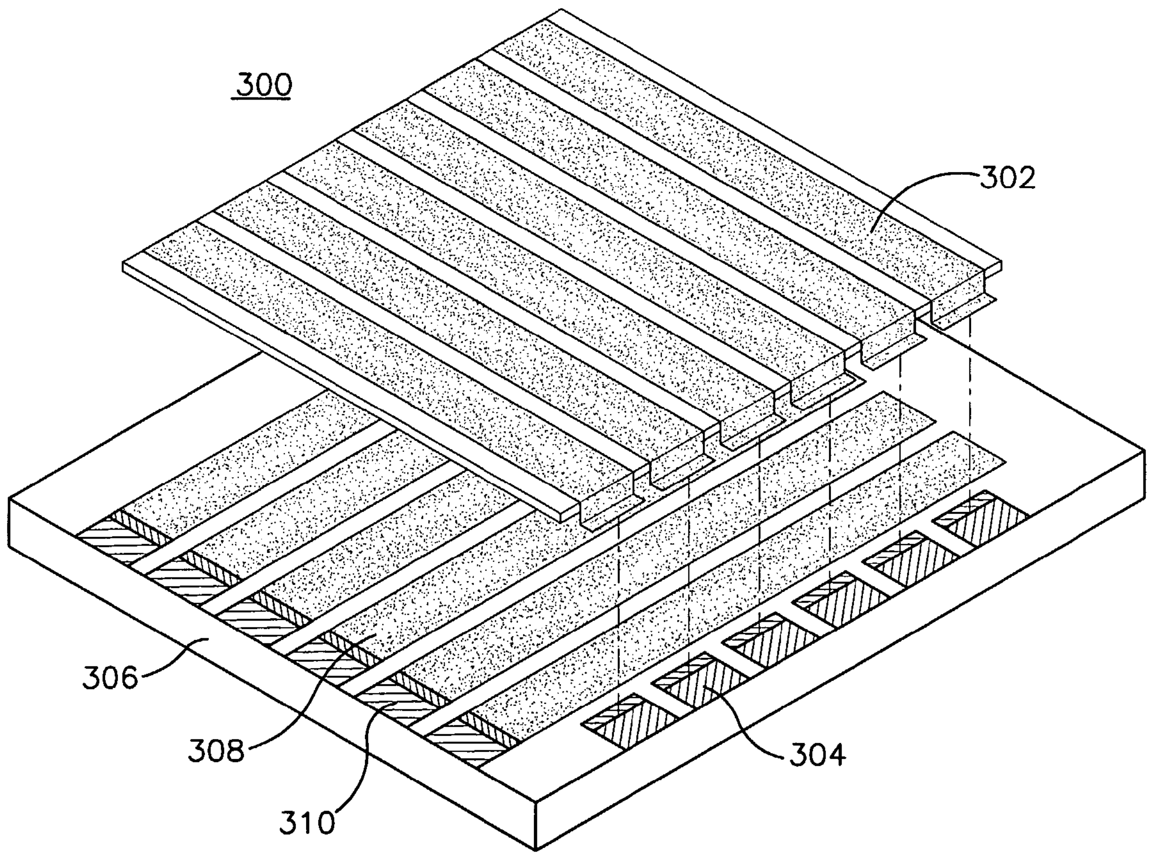


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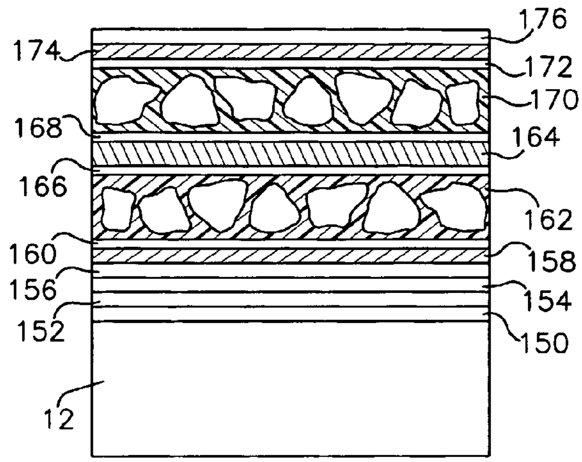


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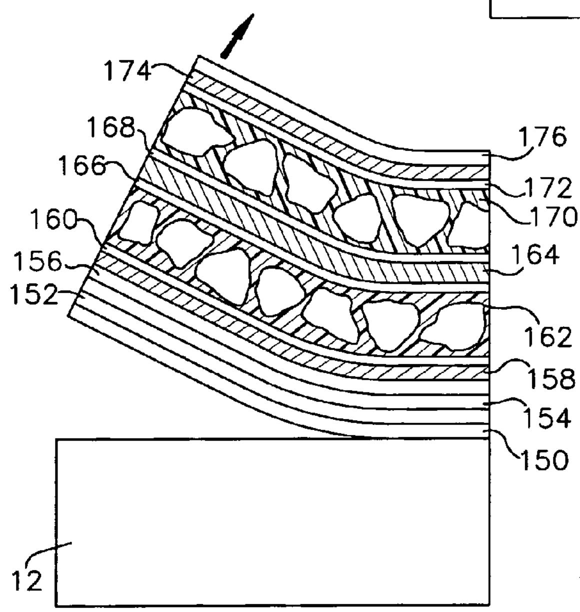



Figure 19a

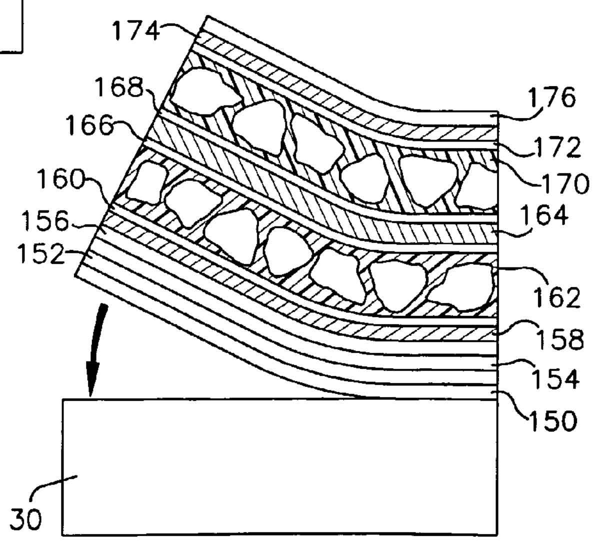
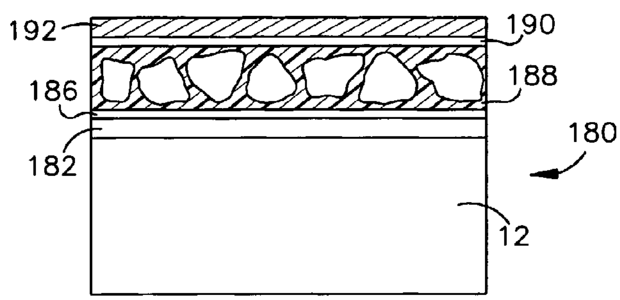



Figure 19b

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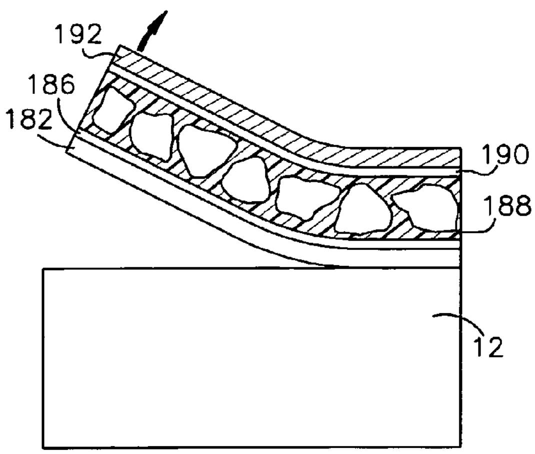


Figure 21a

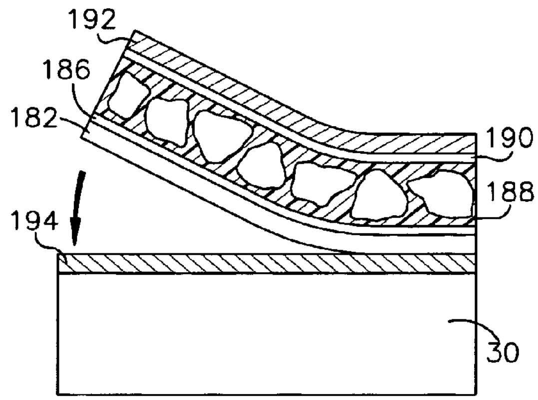


Figure 21b

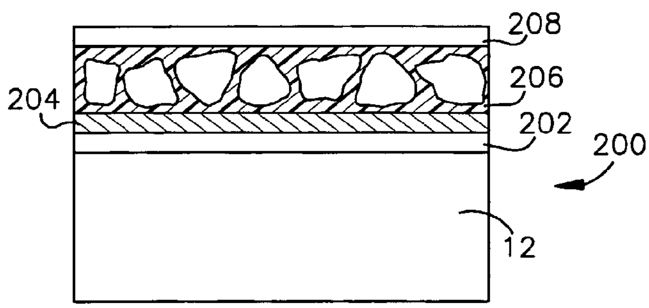


Figure 22

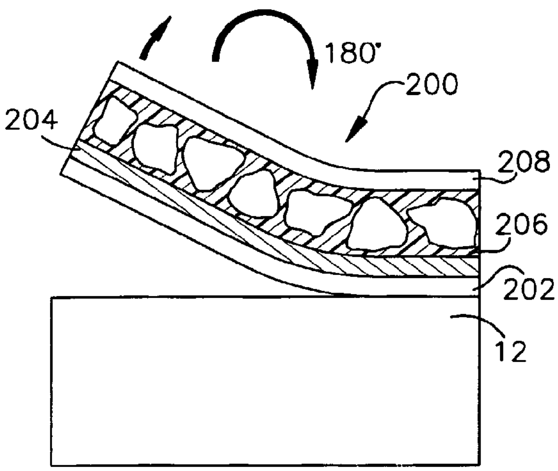


Figure 23a

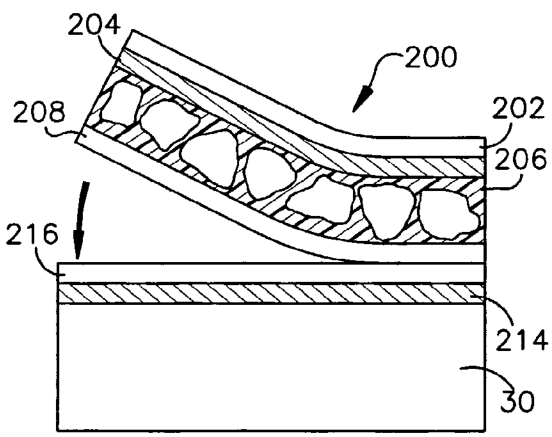


Figure 23b

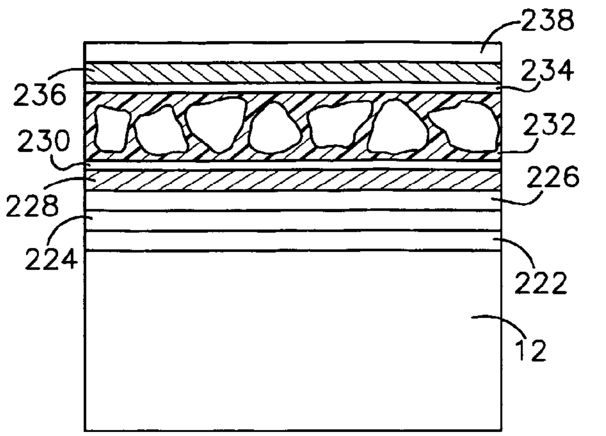


Figure 24

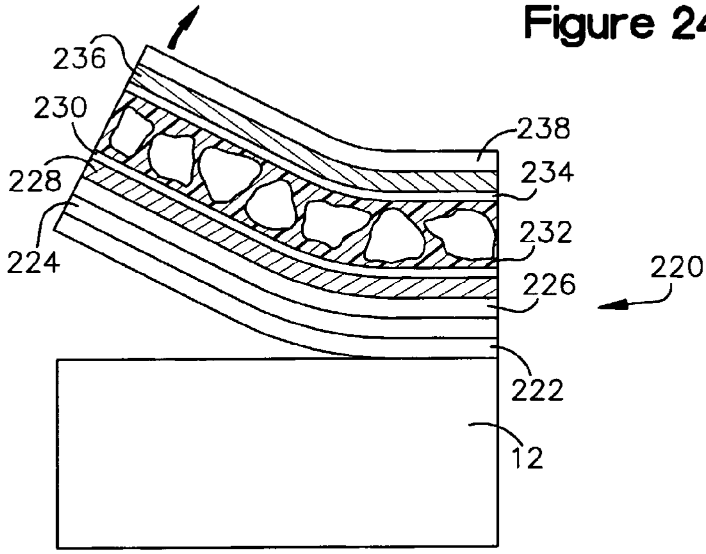


Figure 25a

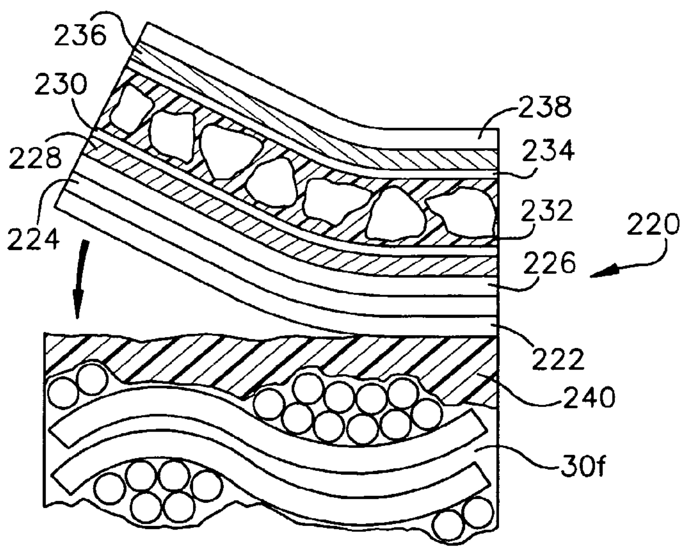


Figure 25b

# DRAPABLE LIQUID CRYSTAL TRANSFER DISPLAY FILMS

## I. GOVERNMENT SUPPORT

This application was made in part with United States Government support under cooperative agreement No. DAAB 07-03-C-J406 awarded by the Department of Defense. The government may have certain rights in this invention.

## II. RELATED APPLICATIONS

The present application is a 371 of U.S. patent application Ser. No. PCT/US2005/003239, which was published in English on Aug. 11, 2005, which is a continuation of U.S. patent application Ser. Nos. 11/006,100, filed Dec. 7, 2004; 10/782,461, filed Feb. 19, 2004; and claims the benefit of co-pending U.S. provisional patent application Ser. Nos. 60/539,873, filed Jan. 28, 2004; 60/598,163, filed Aug. 2, 2004; and 60/565,586, filed Apr. 27, 2004, all of which are incorporated herein by reference in their entireties.

## III. FIELD OF THE INVENTION

The present invention relates to the field of liquid crystal displays and, in particular, to the fabrication of such displays.

## IV. BACKGROUND OF THE INVENTION

A revolution in the information display technology began in the early 1970s with the invention of the liquid crystal display (LCD). Because the LCD is a flat-panel display of light weight and low power which provides a visual read out that conforms to the small size, weight and battery demands of a handheld electronic device, this display technology enabled a new broad class of handheld and other portable products. Commercially, the LCD first appeared in volume as a digital readout on wrist watches, then on instruments and, later, enabled the laptop computer, personal data assistant and many other digital devices. Today LCD technology is even replacing cathode ray tubes in televisions and PCs.

Nearly every commercial LCD display manufactured and sold today is on glass substrates. Glass offers many features suitable for the manufacture of LCDs. It can be processed at high temperatures, it is rigid and suitably rugged for batch processing methods used in high volume manufacturing, its surface can be made very smooth and uniform over large areas and it has desirable optical properties such as high transparency. There are many applications, however, where glass is far from being the ideal substrate material. Glass substrates cannot be made very flexible and are not very rugged, being unsuitable for web manufacturing and subject to easy breakage. As a result there is a large worldwide effort to develop displays on more flexible and rugged substrates that can not only conform to three-dimensional configurations but which can also be repeatedly flexed. A display is desired that has the flexibility of a thin plastic sheet, paper or fabric, so that it can be draped, rolled up or folded like paper or cloth. This would not only make the display more portable and easier to carry, it would expand its potential applications well beyond those of the typical flat panel information displays known today: A display worn on the sleeve; the back of a bicyclists coat that shows changing direction signals; textile that changes its color or design are but a few examples.

While the ability of an electrically addressable liquid crystal display to be flexible and deform like cloth or paper would be advantageous for any LCD technology, it is especially



advantageous in applications suited to cholesteric liquid crystal displays. Cholesteric displays can be made highly reflective such that they can be seen in bright daylight or a dimly lit room without the aid of a heavy and power consuming backlight. Since cholesteric liquid crystals can be made to be bistable they require power only when being addressed, further adding to the power savings associated with such displays. Cholesteric liquid crystalline materials are unique in their optical and electro-optical features. Of principal significance, they can be tailored to Bragg reflect light at a preselected wavelength and bandwidth. This feature comes about because these materials posses a helical structure in which the liquid crystal (LC) director twists around a helical axis. The distance over which the director rotates 360° is referred to as the pitch and is denoted by P. The reflection band of a cholesteric liquid crystal is centered at the wavelength, $\lambda_O=0.5(n_e+no)P$ and has the bandwidth, $\Delta\lambda=(n_e-n_o)P$ which is usually about 100 nm where ne and no are the extra-ordinary and ordinary refractive indices of the LC, respectively. The reflected light is circularly polarized with the same handedness as the helical structure of the LC. If the incident light is not polarized, it will be decomposed into two circularly polarized components with opposite handedness and one of the components reflected. The cholesteric material can be electrically switched to either one of two stable textures, planar or focal conic, or to a homeotropically aligned state if a suitably high electric field is maintained. In the planar texture the helical axis is oriented perpendicular to the substrate to Bragg reflect light in a selected wavelength band whereas in the focal conic texture it is oriented, on the average, parallel to the substrate so that the material is transparent to all wavelengths except for weak light scattering, negligible on an adjacent dark background. These bistable structures can be electronically switched between each other at rapid rates on the order of milliseconds. Gray scale is also available in that only a portion of a pixel can be switched to the reflective state thereby controlling the reflective intensity.

The bistable cholesteric reflective display technology was introduced in the early 1990's as a low power, sunlight readable technology intended primarily for use on handheld devices. Such portable devices demand long battery lifetimes requiring the display to consume very little power. Cholesteric displays are ideal for this application as the bistability feature avoids the need for refreshing power and high reflectivity avoids the need for power-consuming backlights. These combined features can extend battery life times from hours to months over displays that do not have these features. Reflective displays are also easily read in very bright sunlight where backlit displays are ineffective. Because of the high reflective brightness of a cholesteric display and its exceptional contrast, a cholesteric display can be easily read in a dimly lit room. The wide view angle offered by a cholesteric display allows several persons to see the display image at the same time from different positions. In the case of cholesteric materials possessing positive dielectric anisotropy, modes of operation other than a bistable mode are possible by applying a field to untwist the cholesteric material into a transparent, homeotropic texture. Quick removal of the field transforms the material into the reflective planar texture. The more fundamental aspects of such modern cholesteric displays are disclosed in, for example, U.S. Pat. Nos. 5,437,811 and 5,453,863, incorporated herein by reference.

Bistable cholesteric liquid crystal displays have several important electronic drive features that other bistable reflective technologies do not. Of extreme importance for addressing a matrix display of many pixels is the characteristic of a voltage threshold. A threshold voltage is essential for multiplexing a row/column matrix without the need of an expensive active matrix (transistor at each pixel). Bistability with a voltage threshold allows very high-resolution displays to be produced with low-cost passive matrix technology.

In addition to bistable cholesteric displays with liquid crystalline materials having a positive dielectric anisotropy, it is possible to fabricate a cholesteric display with liquid crystalline materials having a negative dielectric anisotropy as, for example, described in the U.S. Pat. No. 3,680,950 to Haas et al., or U.S. Pat. No. 5,200,845 to Crooker et al., incorporated herein by reference. These "negative materials" like the "positive" materials are chiral nematic liquid crystals that are prepared from nematic materials that have been twisted into a helical molecular arrangement by the addition of chiral compound or collection of chiral compounds. The negative and positive materials are prepared from nematic liquid crystals with either a negative or positive dielectric anisotropy respectively.

Negative type cholesteric displays can operate in a bistable mode where the material is switched into the stable planar (e.g., color reflective) texture with an AC pulse or into the stable focal conic (e.g., transparent) texture with a DC pulse as described by U.S. Pat. No. 3,680,950. There are other modes of operation such as has been disclosed by Crooker where a droplet dispersion of negative cholesteric materials is switched into the planar, color reflective texture with an applied electric field, but relaxes back into a transparent texture when the field is removed.

Some cholesteric materials possess a dielectric anisotropy that can be negative under an applied electric field of one frequency but positive at another frequency. This feature can be used to drive a bistable display using a dual frequency drive scheme as described in U.S. Pat. No. 6,320,563, incorporated herein by reference.

Another important feature of cholesteric materials is that the layers reflecting red, green, and blue (RGB) colors as well as IR night vision can be stacked (layered) on top of each other without optically interfering with each other. This makes maximum use of the display surface for reflection and hence brightness. This feature is not held by traditional displays where the display is broken into pixels of different colors and only one third of the incident light is reflected. Using all available light is important for observing a reflective display in a dimly lit room without a backlight. Gray scale capability allows stacked RGB, high-resolution displays with full-color capability where as many as 4096 colors have been demonstrated. Because a cholesteric display cell does not require polarizers, low cost birefringent plastic substrates such a PET can be used. Other features, such as wide viewing-angles and wide operating temperature ranges as well as fast response times make the cholesteric bistable reflective technology, the technology of choice for many low power applications.

Cholesteric liquid crystals are particularly well suited for flexible substrates. Such cholesteric displays have been reported by Minolta Co. Ltd. and by Kent Displays, Inc. involving two plastic substrates filled with cholesteric liquid crystal materials (Society for Information Display Proceedings, 1998, pp 897-900 and 51-54, respectively). While the substrates themselves are flexible, the assembled displays are much less flexible because of the lamination of two substrates together. Minolta has developed procedures for manufacturing flexible displays with two substrates as seen in U.S. Pat. No. 6,459,467.

Greater flexibility can be achieved if only one substrate is used and the display materials are coated or printed on the substrate. Cholesteric liquid crystals are made suitable for standard coating and printing techniques by forming them into polymer droplet dispersions. As droplet dispersions, the materials are made insensitive to pressure and shear such that an image on a bistable cholesteric display is not readily erased by flexing the substrate. Recently, Stephenson et al., at Kodak fabricated flexible bistable reflective displays with polymer dispersions of cholesteric liquid crystals on a single transparent plastic substrate using photographic methods (U.S. Published Application No. US 2003/0202136 A1 and U.S. Pat. No. 6,788,362 B2). This process involves a sequence of depositions on transparent polyester plastic whereby the end product is a display where the images are viewed through the substrate. Such a process requires substrate materials that are transparent such as a clear plastic sheet.

In view of the foregoing, it is desirable to provide a reflective display that does not require a transparent substrate, making available a broader range of substrate materials such as fabrics made of fibers that can be deformed such as by bending, rolling, draping or folding. These added features offer many advantages and open up many new display applications. Use of flexible and drapable substrates can bring to the market place new displays that have the physical deformability of fabric so that they can be an integral part of clothing and have the feel and appearance of cloth because they can be draped and folded.

## V. DISCLOSURE OF THE INVENTION

The present invention features a novel concept in liquid crystal display technology: a display that is a manufactured film. The invention is a display film that is fabricated, lifted off a release liner and then transferred to any desired substrate. The display film may be fabricated by applying a plurality of layers in sequence to include all display components or can be fabricated with some components and later laminated together to complete the display device.

A. Display Film

1. General

The display includes a plurality of coated, printed or laminated layers that form a film that has the elements of a reflective display including liquid crystal material, transparent conducting electrodes, insulation layers to prevent electrical shorts, and protective layers for providing ruggedness. All of the layers are stacked together in a veneered or laminated film forming the framework of the display. The layers are each cast, in sequence or simultaneously, on a release surface (e.g., a release liner), cured or dried and then lifted off of the release liner. This forms a lift-off display element itself without any substrate. Other components may be added such as drive circuitry and connections thereto. The display film may be transferred to some desired substrate in which case it is referred to as a transfer display film. The display film can be transferred onto any desired surface, rough or otherwise, that can contain the interconnecting electrodes to the driving circuitry. The interconnects can be added before or after lamination. Once the display film is connected to electrical drive circuitry it can be electronically updated to produce images from the display.

A substrate as defined herein is a structure that supports components of a liquid crystal display including a liquid crystal layer that is electrically addressed to produce images. The substrate need not be rigid but can be flexible or drapable as disclosed in U.S. application Ser. No. 11/006,100, filed Dec. 7, 2004, which are incorporated herein by reference in their entirety. Glass, metal, polymer, paper and fabric or textile can all be used as substrate materials. The substrate is a generally thin layer, but is often significantly thicker than other components of the display. As defined herein and consistent with U.S. Pat. No. 6,788,362 owned by Kodak, a substrate is a layer that has a thickness of at least 20 microns and, in particular, at least 50 microns. Substrates of liquid crystal displays on the market today can have a thickness of 100 microns or more and substrates such as fabrics can be substantially thicker exceeding 1000 microns. The substrate can be formed of or have various components attached to it such as electrodes, an active matrix backplane, solar cell, photovoltaic device and the like. The present invention is usable in connection with displays employing one, two, or more substrates. A casting layer as defined herein is a film layer of the inventive multilayer film applied on or near the release liner on which other film layers of the display may be printed or coated. The invention may employ various layers that function as casting layers including a preparation layer, electrode layer, adhesive layer, planarization layer, liquid crystal layer, isolation layer and combinations thereof. The multifunctionality of the layers of the inventive display film is discussed in more detail below.

In some cases, it may be desirable for the display film to only contain some of the elements of the display for transfer onto a substrate that already contains other display elements. For example, the transfer display film may contain one layer of printed electrodes, a liquid crystal droplet dispersion layer, and a protective layer that is lifted off of a release liner then transferred onto a substrate having the other conducting electrodes of a passive matrix or an active backplane.

The display film can be electrically addressed by adding suitable electrical interconnects during or after lamination or after removal from the release surface. The electrical interconnects allow drive electronics to be connected to the electrodes of the display film. The display film may be laminated onto a substrate already containing electrodes such as the column or row electrodes of a passive matrix, the pixel electrodes of an active matrix backplane or drive electronics.

While the invention will be described herein primarily in conjunction with the preferred use of cholesteric liquid crystals, any liquid crystal material that can be adapted for use in connection with the foregoing substrates will be suitable in the present invention. Such materials include, by way of example only, nematic, chiral nematic (cholesteric), smectic and ferroelectric smectic liquid crystal materials. They include materials that are bistable and those that are not bistable. They include cholesteric or chiral nematic liquid crystals having positive or negative dielectric anisotropy or a combination of negative and positive with a crossover frequency suitable for dual frequency addressing. They include cholesteric materials having pitch lengths reflecting in the visible spectrum as well as those having pitch lengths reflecting outside the visible spectrum, including ultraviolet and infrared. Preferred liquid crystal materials for use in the present invention are bistable cholesteric (chiral nematic) liquid crystals having positive dielectric anisotropy and planar and focal conic textures that are stable in an absence of an electric field. Especially preferred materials are nematic materials with a high birefringence and dielectric anisotropy with a chiral additive to twist the material to a pitch length to reflect in the visible spectrum such as BL061, BL048 and BL131 from EM Industries of Hawthorne, N.Y.

Cholesteric liquid crystal layers are stackable as discussed in more detail below. Light is inherently reflected by the cholesteric liquid material at preselected wavelengths and bandwidth and is transparent to other wavelengths, allowing the entire area of the display to be used as a reflection surface and making maximum use of available light for brightness. Cholesteric materials can be tuned to reflect at any desired wavelength ($\lambda$) or color and bandwidth ($\Delta\lambda$) for full color displays with stacks of the primary colors red, green and blue (RGB). One can also employ dispersions containing cholesteric liquid crystal-containing droplets in a polymer matrix that reflect red, green and blue light in a single layer.

As will be apparent to those of ordinary skill in the art in view of the instant disclosure, the liquid crystal material will preferably be present in the displays of the invention in the form of liquid crystalline layers each comprised of a liquid crystal dispersion and, most preferably, a cholesteric dispersion. There are many different approaches to the formation of a liquid crystal dispersion, some of which have been used for cholesteric liquid crystals. To form such a liquid crystal layer, the liquid crystal can be microencapsulated or formed into emulsified droplets of liquid crystal, as discussed in more detail below.

As noted, the liquid crystal layer will, in the preferred embodiments, be bounded by conducting electrodes. The electrodes need not be identical. For example, in many embodiments, the electrode on the non-viewing side of the liquid crystal will be black or some other color, while the electrode on the viewing side will be transparent. In other embodiments, the electrodes on both sides of the liquid crystal layer will be transparent. In other embodiments still, an electrode or array of electrodes can be formed integrally with the substrate or the substrate itself can form one of the electrodes. An advantage to being able to use fabric substrates as discussed below, is that it enables greater flexibility in the manner in which the display can be configured.

There are potentially many methods of applying and patterning the conductors. The conductors may be printed in some specified pattern using ink jet, screen or off-set printing. Alternatively, the conducting materials may be sprayed or coated onto the underlying surface (such as the dye layer, protective layer, casting layer or substrate) using a mask, stencil or pretreating the surface to form a chemical mask which allows the electrode material to only adhere to certain areas. In some cases it may be desirable to first lay down a uniform conducting coat and subsequently pattern the layer by chemically or mechanically deactivating regions of conductive material. In fact, it is contemplated that even the substrate itself can be manufactured as the conductor. For example, some flexible plastic materials are manufactured with an indium tin oxide (ITO) coating that may be patterned for use as electrodes. Suitable electrode materials for application to the substrates of the invention will be apparent to those of ordinary skill in the art in view of the instant disclosure and include conducting polymers, carbon nanotubes, metal or carbon conductive inks, ITO and the like. Electrode materials which are self leveling and which can be used in suitable thicknesses to obviate the need for a planarization layer are particularly desirable. Examples of materials for use as conducting electrodes in accordance with the present invention include Agfa conducting polymers ELP-3040, S300, and S2500 available from Agfa-Gevaert N.V., Belgium; Carbon Nanotube materials are available from EiKos, Inc., Franklin Mass. The aforementioned electrodes can be patterned, formed into pixels of varying shapes or sizes, aligned into rows and columns so as to form a passive matrix and so on, all as will be apparent to those of ordinary skill in the art in view of the instant disclosure.

Any means for addressing the liquid crystal known in the art, and preferably adaptable to a display having deformability may be used. In the preferred electrically addressable displays, the means for addressing the liquid crystal will be drive and control electronics operatively linked to the electrodes for application of driving voltages across the liquid crystal material in accordance with any suitable drive scheme known to those of ordinary skill in the art. Examples of suitable drive schemes and electronics include, but are not limited to, the conventional drive scheme disclosed in U.S. Pat. No. 5,644,330 implemented with either bipolar or unipolar drive chips, the dynamic drive scheme disclosed in U.S. Pat. Nos. 5,748,277 or 6,154,190 for faster or lower temperature response, the cumulative drive scheme disclosed in U.S. Pat. No. 6,133,895, for near video response, and the Multi-configuration Display Driver disclosed in the patent application Ser. No. 10/782,461, all of which are incorporated herein by reference. Alternatively, the means for addressing can be an optical method whereby the image is written on the display with white light or laser light in a manner such as disclosed in H. Yoshida et al., Journal of the SID, Vol. 5/3, 269-274, (1997), also incorporated herein by reference. In these embodiments, the displays can be fabricated without patterned electrodes. The ledges of substrates where the ends of electrodes are located are left accessible for interconnecting the drive electronics and electrode layers may extend beyond the periphery of the other layers of the display for interconnecting the drive electronics, such as disclosed in U.S. Patent Application entitled "Stacked Display with Shared Electrode Addressing," filed Jan. 28, 2005, which is incorporated herein by reference in its entirety.

In a preferred configuration, a high resolution display device in accordance with the invention is configured where the first conducting polymer is printed or otherwise patterned in the form of parallel strips to form rows of parallel conducting electrodes. The droplet dispersion is then coated on top of the rows of conductors, followed by a transparent conductor which is then printed, or otherwise coated and patterned on top of the droplet dispersion in the form of conductive strips (columns) in a direction perpendicular to the rows of conductors that are under the dispersion. In this way, a row and column matrix of electrodes is formed with the cholesteric dispersion in between. Voltage pulses are then multiplexed in such a way to selectively address each of the pixels of the display formed by the intersection of each row and column. When a high-resolution image is addressed on the display film and the voltage removed, the image will be retained indefinitely until readdressed to form another image.

In carrying out the invention, it will often be desirable to employ an electrical insulation layer or layers between the electrodes in order to insulate the conductors from each other and thereby minimize the potential for shorting. Accordingly, for purposes of the instant invention it is desirable to select materials that can be coated, printed, sprayed or otherwise laid down in a layer before and/or after the electro-optically responsive liquid crystal layer. The insulation layer must not significantly detract from the deformability or optics of the display. In accordance with preferred embodiments of the invention, materials such as gelatin or latex are employed. Some particularly preferred insulating materials are polyurethane latex materials such as WITCOBOND W232 (available from Crompton Corporation, Conn.). Although an insulation layer such as gelatin is optional, experiments show that it leads to a decrease in the switching voltage on the order of 10-15 volts (frequency=250 Hz) when the liquid crystal layer is a cholesteric droplet dispersion. Without being bound by theory, this may be because the gelatin layer is enhancing the dielectric properties of the emulsion through the increase of the dielectric constant.

The use of one or more durable protective coatings (e.g., top coats) obviates the need to use a substrate, thereby enhancing both the flexibility and durability of the display film. Desirable protective coatings will be materials that will provide a tough, scratch and wear-resistant coating over at least a portion, and preferably all, of the uppermost surface of the display, but do not materially interfere with the optics of the system. Likewise, the most desirable protective coating materials will maintain the deformability of the system. Those of ordinary skill in the art will be able to select suitable protective coating materials in view of the instant disclosure; preferred materials include acrylic or silicone paints, UV curable adhesives, PVA, latex materials and the like. Because some protective coatings will include solvents or other components which may be harmful to the electrodes or other elements of the display, in carrying out the invention it may be desirable to select an isolation layer material that will protect the other display elements from harmful components of the adjacent coat. The laminated display film of the present invention includes within its scope various additional layers in different sequences, numbers and locations throughout the display.

As will be apparent to those of ordinary skill in the art, displays according to the invention can be formed in many different configurations using some or all of the foregoing component layers. For example, the display materials may only appear on one side of a fabric substrate leaving the other side untouched, or portions of the display may be partially imbibed into and integrally formed with the substrate. The minimum requirements for the electrically addressable transfer display films of the invention are at least one liquid crystal layer and at least one adjacent conducting electrode layer; the liquid crystal layer is sandwiched between the film electrode layer and another conducting electrode layer that is a component of the display film or a conductive electrode layer that is applied to, on or imbibed into the substrate. Beyond this, there are multiple possible configurations and combinations which can effectively take advantage of the flexibility and/or drapability of the substrates according to the invention as will be apparent to those of ordinary skill in the art in view of the present disclosure.

The fabrication of the inventive display film involves printing, coating or other deposition means to form the liquid crystal material, display electrodes as well as any insulating, isolation or other coatings. These layers in a preferred embodiment are built on a casting layer that is removed from the release surface once the multi-layered laminate has been dried or cured. In view of the instant disclosure those of ordinary skill in the art will be able to select and employ suitable coating, printing and deposition techniques including, but not limited to, air brushing, ink jet, spin coating and spray printing, optionally in conjunction with various masks or stencils known in the art, screen printing, photolithography, chemical masking and so on, depending upon the particular layers, substrates or display elements used. It is contemplated that any contact or non-contact method of applying coatings and conductors known in the art will be suitable for use in accordance with the instant disclosure.

2. Liquid Crystal Dispersions

An encapsulation process involves emulsification of a cholesteric liquid crystal in water with a waterborne polymer. Encapsulation of cholesteric liquid crystals by emulsification was practiced even before the invention of bistable cholesteric displays. As early as 1970, cholesteric materials were emulsified for making cholesteric thermal and electrical responsive coatings as discussed in U.S. Pat. No. 3,600,060, incorporated herein by reference. More recently, emulsification methods have been refined by Stevenson et al., at Kodak to make cholesteric droplets that are very uniform in size, as disclosed in U.S. Pat. No. 6,423,368 B1, incorporated herein by reference. The most common emulsification procedure basically involves a liquid crystal being dispersed in an aqueous bath containing a water-soluble binder material such as de-ionized gelatin, polyvinyl alcohol (PVA) or latex. Water acts as a solvent and dissolves the polymer to form a viscous solution. This aqueous solution does not dissolve the liquid crystal, and they phase separate. When a propeller blade at a sufficiently high speed stirs this system, micron size liquid crystal droplets are formed. Smaller liquid crystal droplets form at higher stirring speeds as disclosed in P. Drzaic, *Liquid Crystal Dispersions*, World Scientific Publishing Co., Singapore (1995), incorporated by reference. The molecular weight of the water-soluble polymer is also a factor affecting the droplet size. After the droplets are formed, the emulsion is coated on an underlying layer or substrate and the water is allowed to evaporate. There are many different emulsification procedures. In preferred embodiments, one or more of PVA, gelatin and latex, preferably urethane based latex, are used to form the binder. The emulsification method has the advantage that the droplet dispersions may contain a very high percentage of cholesteric material. Those of ordinary skill in the art will be able to select suitable materials and methods for providing emulsified liquid crystal droplet layers for use in accordance with the present invention in view of the instant disclosure.

Microencapsulation is a yet another process for preparing droplet dispersions as seen, for example, in U.S. Pat. No. 6,271,898, incorporated herein by reference. While this procedure can be more complex and material sensitive, it can nonetheless provide more control over droplet size and molecular anchoring conditions for the cholesteric liquid crystal. In this case the liquid crystal droplet is coated by a shell isolating it from the binder. It may be possible to process the droplet particles in the form of a dry powder which is later dispersed in a suitable binder for coating. Other types of dispersions may be a regular array of polymer pockets filled with liquid crystalline material and sealed on the top by a phase separation process as disclosed in, for example, D. J. Broer et al, Society for Information Display 2004 Proceedings, pp 767.

3. Multiple Liquid Crystal Layers

The inventive display film can be fabricated by coating two or more cholesteric liquid crystal dispersion layers over one another. One or more conducting electrode layers are located between adjacent liquid crystal layers. A full color display can be made by stacking three liquid crystal layers having pitch lengths that reflect red, green and blue light, respectively. With only one electrode layer between each liquid crystal layer, the display is electronically addressed by a shared electrode addressing scheme possible with bistable cholesteric dispersions as disclosed in the U.S. Patent Application entitled "Stacked Display with Shared Electrode Addressing,". An infrared reflective display is possible where at least one of the droplet dispersion layers reflects in the infrared, such as might be used for night vision purposes. For color, enhanced brightness or infrared applications such as those described in U.S. Pat. No. 6,654,080, incorporated herein by reference, stacks of coatings arranged as disclosed therein can be employed in accordance with the instant invention. A multiple color display can also be prepared with a single dispersion layer wherein each pixel is divided into different primary colors such as red, green and blue, for additive color mixing. The patterned colors can be achieved as described, for example, in U.S. Pat. No. 5,668,614, incorporated herein by reference.

In order to increase brightness of a cholesteric liquid crystal layer of the display, both the left and right circular components of the incident light should be reflected. There are two methods to accomplish this: to layer a cholesteric material of one handedness on top of the other or to insert a half wave plate in between two layers of the same handedness. One aspect of the invention coats sublayers of cholesteric materials of different handedness (left hand-LH and right hand-RH) on top of one another in the formation of the liquid crystal layer reflecting a certain wavelength of electromagnetic radiation. The coatings are immiscible so that the droplet structures of the two different materials are not destroyed in the coating or drying process. The encapsulant surrounding the droplets is impermeable to the cholesteric material to limit molecular diffusion in that cholesteric material of one handedness dissolving into the other will destroy its desired optical properties. An optional barrier layer is disposed between LC sublayers. In the case of the full color display, each of the red, green and blue reflecting liquid crystal layers may be composed of LH/RH sublayers to increase brightness.

4. Compositions and Layer Thicknesses

The layers of the multilayer film can have various compositions as would be apparent to those skilled in the art in view of this disclosure. By way of example only, and without limiting the present invention, suitable compositions of the various layers of the multilayer film include solvent-based, water-based and water-borne polymers for the planarization layer; solvent-based, water-based and water-borne polymers and thin plastic sheets, including PET, PC, PEN for the casting layer; water-borne polymers, including polyurethane and acrylic latexes, water-soluble polymers, including gelatin, polyvinyl alcohol, and polyvinyl acetate for binder material which surrounds the liquid crystal droplets; cross-linking agents, including materials based on aziridine, lactic acid chelates, formaldehyde, glutaraldehyde as additives to binder material to control binder properties and various surfactants, including surfactants based on silicone polyether copolymers, alkylaryl polyethers, alcohol ethoxylates (Triton X-100, Triton CF-10, DC 5098, alkanol) as additives to binder material to control binder properties.

The layers of the multilayer film can have various magnitudes of thickness and relative thicknesses to one another. Those skilled in the art will appreciate in view of this disclosure various layer thicknesses that may be suitable for use in the present invention. By way of example only, and without limiting the present invention, suitable thicknesses of the casting layer are less than 20 microns and, in particular, in a range of 5 to 15 microns. Suitable thicknesses of the adhesive layer are in a range of 10 microns to 75 microns and, in particular, less than 25 microns. Suitable thicknesses of the electrode layer are governed, for example, by the transparency and resistivity of the conducting polymer. Normally the desired resistivity is less that 1000 Ohms per square and transparencies above 90% are desired. This typically results in a thickness less than 1.0 micron for the electrode layer.

B. Transfer Display Film

1. General

Liquid crystal displays sold in the marketplace today are fabricated by building the display on a substrate that forms a part of the display. Conventional displays include two substrates that sandwich the liquid crystal material in between. Lines of electrodes may be patterned onto the substrates. The substrates may include treatment such as rubbing of chemicals applied to the substrates to affect the alignment of the liquid crystals. In contrast, the inventive lift off (e.g., transfer) display film includes some or all of the components of a typical liquid crystal display, but is built up on a release liner during fabrication and a substrate need not be incorporated as an element of the display film. The display film is then lifted off the release liner and transferred onto a substrate. The transfer display film can be made with some of the components that make up a complete display, for example, with one or two electrode layers on either side of the liquid crystal. For example, a transfer display film containing a single electrode layer can be transferred to a substrate having the other electrode layer on it and the drive electronics can be added when the transfer film is laminated onto the substrate. On the other hand, the transfer display film may include all elements of an operable display except for some elements of the drive electronics, and then transferred onto a substrate containing drive electronics. Those skilled in the art will appreciate that these and other variations in the number and types of components and when they are added during the steps of the fabrication process, fall within the scope of the present invention.

The transfer display film may include a layer that facilitates binding of the transfer film to the substrate. This can include an adhesion layer as a part of the transfer display film. Instead of or in addition to the adhesion layer, the transfer display film may include a preparation layer that enables binding to an adhesion layer. The preparation layer may match indices of refraction of adjacent layers. If the adhesion layer is formed on the substrate to which the transfer display film will be transferred, the transfer display film may include a preparation layer that accommodates the solvent of the substrate adhesion layer.

A transfer display film as described above has the following advantages. It can be laminated on a rough surface such as cloth, paper or other uncommon substrates for commercially available liquid crystal displays. The lamination process will not alter the uniform spacing between the electrodes. The substrate on which the film will be laminated can be manufactured independently of the display film, making available a wide variety of materials or shapes not available for substrate use before. The manufacturing facility of the display film can be simplified and of lower cost since it does not have to be specific to the substrate. The transfer display film can be laminated on substrates that otherwise could not contain a display in that they cannot be processed in a clean room environment. The display film can be transferred onto a backplane that contains a portion of the display elements and/or drive electronics such as, for example, an active matrix backplane or the orthogonal row or column conductive lines of a passively driven display.

An advantage of the invention is that the manufacturing process is independent of the substrate, unlike any display manufacturing process being currently used. Another advantage is that the display film may be transferred onto any of a wide variety of substrates, such as cloth, which was not possible before. The substrate may possess a rough surface. However, the film can be laminated so that the electrode spacing is maintained and the display is functional so long as the surface does not rupture the display film. The display film can be made pliable and rugged. The inventive display film can be stretched or rolled up, is suitable for lamination on plastic, woven fabric material, etc. or may even be specifically designed for lamination on an active matrix substrate.

Cholesteric materials are particularly well suited for a display film in that they can be made as droplet dispersions that can be coated or printed and are self-sealing to contain the cholesteric liquid crystal in the film. Cholesteric liquid crystal materials may be bistable, possessing planar and focal conic textures that are stable without application of an electric field. Once an image is formed, no electric field is required to maintain the image. That is to say, a voltage below threshold voltage can be applied to the liquid crystal layer without changing its planar or focal conic textures. The image will remain indefinitely until it is updated by additional voltage pulses applied to the pixels above the threshold voltage. Cholesteric materials are field driven, as opposed to current driven, requiring near negligible current to change their optical state. As such, the conducting electrodes can be composed of such materials as conducting polymer or carbon nanotubes that can be printed or coated into a film, which generally possess low transparency/conductivity ratios. Other droplet dispersion systems such as nematics and ferroelectrics also offer the possibility for use as a transfer film.

2. Drapable Liquid Crystal Transfer Display Film

One aspect of the display film of the present invention is that the lift-off film itself is flexible and can be drapable. Also, the lift-off film can be transferred onto a drapable substrate. This invention involves a substantial advance in addressable liquid crystal displays wherein, by forming the displays as a drapable film or combining the transfer display film with a drapable substrate, the display itself is drapable. Such substrates include textiles or fabrics made of natural or manmade fibers such as cloth or paper, as well as non-fibrous materials such as flexible or even drapable thin polymeric sheets or films. Advantageously, the substrate need not be transparent. With deformable substrates, cholesteric or other liquid crystal displays are made flexible, rugged and can even be sewn into or onto clothing to provide a wearable display. In fact, the display itself can form the material used to make the clothing or other fabric construct. A display with the drapability of cloth provides a new dimension to display technology enabling display applications that were not previously possible. Such displays can conform to three dimensional structures or flex and fold with a garment or other fabric construct containing the display. To this end, the displays according to the invention are operatively deformable, meaning that they will function even though they are or have been deformed. In preferred applications, the displays according to the invention will be operatively drapable such that they can have folds and possess a measurable drape coefficient.

The formability of the display film and of fabric or other drapable substrate material onto which the display film is transferred, can be defined as its ability to re-form from a two-dimensional shape to a simple or complex three-dimensional shape. The drape coefficient is used to describe the degree of 3-D deformation when the fabric specimen is draped over a drapemeter as described, for example, in the publication: "Effect of Woven Fabric Anisotropy on Drape Behavior," *ISSN* 1392-1320, *Materials Science* (*Medziagotyra*), Vol. 9, No. 1, pp. 111-115 (2003) by V. Sidabraitre and V. Masteikaite, or "Modeling the Fused Panel for a Numerical Simulation of Drape" *Fibers and Textiles*, Vol. 12, pages 47-52 (2004), by S. Jevsnik and J. Gersak, incorporated herein by reference. Drapability is a phenomenon that occurs when a material such as a curtain, flag, table cloth or flared skirt hangs from an object. The drape coefficient, DC, describes any deformation between draped and undraped material. In terms of percentage, it is described by the ratio: $DC=100(S_P-R_1^2)/(R_2^2-R_1^2)$ were $R_2$ is the radius of a circular cut of non-deformed fabric; $R_1$, the radius of a horizontal disc holding the fabric, and $S_P$ the projected area of the draped specimen, including the part covered by the horizontal disc. The value of DC varies between zero and 100%. Since the value of DC can depend on the values selected for $R_1$ and $R_2$ of the drapemeter, we follow others in taking $R_1$=9 cm and $R_2$=15 cm. The larger the value of the drape coefficient, the stiffer the fabric and more difficult to reform. Alternatively, the lower the value of DC, the easier to reform and adapt to shapes. Some examples of desirable fabric substrate materials include silk, cotton, nylon, rayon, polyester, Kevlar, or similar materials made of fibrous material formed by woven and non-woven means having the deformability of cloth. Some examples of fabrics having the desired drapability are shown in Table I, which shows measured values of the drape coefficient, DC, for various fabric materials made with $R_2$=15 cm and $R_1$=9 cm. The data on the materials identified with an asterisk (*) were obtained from the publication "The Dependence of Fabric Drape on Bending and Shear Stiffness, *J. Textile Institute*, Vol. 56, pp. 596-606 (1965) by G. E. Cusick, incorporated herein by reference. The other materials were obtained from Jo-Ann Fabrics, Cuyahoga Falls, Ohio and Hudson, Ohio, and the DC values measured.

TABLE I

| Fabric | Weight ($g/m^2$) | Thickness (mm) | DC(%) |
|---|---|---|---|
| *Woven dress fabric, spun viscose rayon | 231 | 0.36 | 67.8 |
| *Woven dress fabrics, spun viscose rayon | 142 | 0.41 | 36.9 |
| *Plain woven 1.5 den spun viscose rayon | 196 | 0.45 | 32.6 |
| *Plain woven continuous-filament acetate and rayon | 226 | 0.46 | 24.7 |
| *Woven dress fabric cotton | 115 | 0.20 | 75.5 |
| *Woven dress fabric cotton | 105 | 0.31 | 97.2 |
| *Plain woven, continuous-filament polyester fiber | 96 | 0.20 | 49.9 |
| Polyester from Jo-Ann Fabrics | 186 | 0.3 | 14 |
| Polyester-65%, nylon 35% from Jo-Ann Fabrics | 116 | 0.17 | 49 |
| Polyester, satin from Jo-Ann Fabrics | 128 | 0.21 | 52 |

As will be apparent to those of ordinary skill in the art in view of the present disclosure, any deformable material having the desired flexibility or drapability and capable of supporting the display elements as disclosed herein will be suitable for use in the invention. In some preferred embodiments, the fabric substrate may be a composite or, more preferably, a fiber reinforced composite such as cotton and polyisoprene. An example of such composites is a raincoat where the cotton provides the feel and drapability of cloth and polyisoprene provides water resistance. Another example is rayon and neoprene used as a light shield against laser light such as that obtained by Thorlabs, Inc. (NJ) catalog # BK5. Composites can be useful substrate materials for many of the preferred displays of the invention.

In many preferred embodiments, the substrate material is non-transparent. While black is a preferred color, other colors such as dark blue, green or some other color may be used to additively mix with the reflective color of the cholesteric liquid crystal to provide the desired color of text or other image addressed on the display. The substrate material itself may be substantially clear or transparent but the substrate made non-transparent by adding a black coating or dye to render it opaque, translucent or non-transparent as required for the background of the display. The image on a reflective cholesteric display is viewed against the background. It is therefore important that the background absorb unwanted light and not provide light that competes with or washes out light reflected from the cholesteric liquid crystal. Most fabrics are non-transparent. There are many examples of deformable sheet materials that are not made of fibers such as polymer films. If the sheet is thin enough, these films may also be drapable. An example of a polymer film that is non-transparent and very drapable is black static cling polyvinyl chloride sheet material from Graphix Plastics, Cleveland Ohio. Other examples of non-fibrous and drapable plastic sheets having the desired drapability are shown in Table II, which shows measured values of the drape coefficient, DC, for various non-fibrous sheet materials ($R_1$=9 cm and $R_2$=15 cm). The value of the drape coefficient was measured by photographing from above, the drape of the specimen of radius $R_2$ draped over a pedestal of radius $R_1$ under a weighed disk of the same radius. The areas of the projected image of the drape in the circle of radius $R_2$ were obtained from the digital photograph. In all cases, the drape showed the characteristic folds.

TABLE II

| Sheet Material | Weight (g/m2) | Thickness (mm) | DC(%) |
|---|---|---|---|
| Black polyvinyl chloride from Graphix Plastics | 189 | 0.15 | 52 |
| Clear DuraLar (general purpose polyester) | 18.1 | 0.013 | 68 |
| Clear DuraLar (general purposed polyester) | 32.9 | 0.025 | 95 |
| Clear DuraLar (general purpose polyester) | 73.7 | 0.050 | 98 |

Sheet materials which are too thick do not exhibit drape but may bend or be flexed about one axis such as, for example, being rolled up. An example is 5 mil (0.125 mm thick) Clear DuraLar (polyester) or 5 mil thick Teijin Limited polycarbonate ITO coated foil (SS120-B30). Such 2-D deformation materials can be rolled up but do not reflect the nature of drape. It should be noted, however, that these and similar films will be suitable for certain embodiments of the invention where drapability is not required. For example, where only a flexible display is desired, such films can be rendered black or otherwise non-transparent for use as a substrate by coating it with a black Krylon paint.

It will be apparent from the following that while advantages of the invention are realized by the presentation of a deformable liquid crystal display, a principal contributor to the realization of this advantage is the provision of an electrically addressable liquid crystal display on a single substrate. Electrically addressable displays on the market today employ at least two substrates which, as noted above, are generally rigid, with the liquid crystal sandwiched between them. These displays are, in general, manufactured by batch processing methods.

In accordance with preferred embodiments of the present invention, a display film is fabricated by a sequence of layers on a release liner by coating, printing or lamination techniques suitable for the web processing methods necessary for low cost, high volume production. Fundamentally, these layers consist of a first conductive layer followed by a layer of an electrically responsive droplet dispersion such as a polymer dispersed cholesteric liquid crystal, followed next by a transparent conductive layer. Insulation coatings are often needed between the cholesteric dispersion and electrodes to avoid electrical shorts between the electrodes. A durable protective layer is coated to finalize construction of the display film. In some cases an isolation layer is required between some of the coatings to avoid damage by subsequent coatings, such as may be caused by a chemical reaction between coating solvents or other components. Likewise, preparation coatings between various layers may be necessary to promote wetting and adhesion of the subsequent coat. In some embodiments, the coatings often serve multiple functions, such as where the first conductive coat may also serve as a preparation coat to smooth the surface.

As noted, the liquid crystal layer will, in the preferred embodiments, be bounded by conducting electrodes. The electrodes need not be identical. For example, in many embodiments, the electrode on the non-viewing side of the liquid crystal will be black or some other color, while the electrode on the view side will be transparent. In other embodiments, the electrodes on both sides of the liquid crystal layer will be transparent. In other embodiments still, an electrode or array of electrodes can be formed integrally with the substrate or the substrate itself can form one of the electrodes. The multilayer film is then lifted off the release liner and transferred to a flexible substrate.

Transferring the film onto rough textiles, other rough fabrics or other rough substrates or layers could employ a planarization coating to at least partially smooth the surface. This may be followed by a preparation coating or sequence of such coatings to further smooth the surface of the fabric as well as adjust its color, resistivity, wetting and adhesive properties with respect to the first conductive layer. However, it is believed that the inventive display film can be applied to all but the roughest surfaces without the need for planarization of the surface. The inventive transfer film exhibits good durability and toughness during the fabrication process and maintains the gap thickness of the liquid crystal layer between adjacent electrode layers. Typically, only those surfaces that are so rough that they could puncture the liquid crystal layer, would include a planarization layer on the rough surface.

Planarization of rough surfaces can be conducted in various ways as disclosed in the U.S. application Ser. Nos. 60/565,586 and 11/006,100. A preferred manner of planarizing a surface in accordance with the invention is the addition of a planarization layer. A planarization layer is a coating of material which, when applied to the rough substrate or other rough layer such as to a rough casting layer, will tend to smooth out the most dramatic fluctuations in the rough surface so as to provide a generally smooth, though not necessarily flat, surface onto which to deposit the next layer. Preferred materials for use as a planarization layer in accordance with the invention are gelatin, neoprene and latex materials such NeoRez R967 available from NeoResins, MA. The planarization layer also may be a polymeric sheet such as PET.

As will be apparent to those of ordinary skill in the art, display films according to the invention can be formed in many different configurations using some or all of the foregoing component layers. For example, the display film may only appear on one side of the fabric leaving the other side untouched, or the display film may be partially imbibed into and integrally formed with the flexible substrate, as by transferring the display film onto a heated fabric substrate.

3. Other Substrates

A self-powered display may be achieved by using a solar panel as the substrate or a component of the substrate whereby light that is not reflected by the cholesteric material can be absorbed in the solar panel for conversion into electrical power for powering the display.

It is also conceived that an active matrix substrate could be employed to create an actively driven cholesteric display, whereby the various display elements of the transfer film are laminated onto the active backplane.

Further still, an optically addressed display is achieved by placing a photoconductive sheet over the lower conducting electrode. With a continuous voltage applied to the electrodes, light impinging the display film will locally alter the resistivity of the photoconductor and drive the display film. Such a display construction avoids the need of patterning the electrodes. The display can include an upper and lower unpatterned electrode. The display can be addressed by an image suitably focused on the film, or written with a scanned laser beam as described in the publication "Reflective Display with Photoconductive Layer and Bistable Reflective Cholesteric Mixture" *Journal of the SID*, Vol. 5/3, pages 269-274 (1997) by J. Yoshida et al., incorporated herein by reference. Of course, other veneered stacks are possible depending on desired display.

## VI. SUMMARY OF THE INVENTION

In general, one embodiment of the present invention features a drapable liquid crystal transfer display film comprised of a plurality of layers that are prepared on, cured and lifted from a release surface and then transferred to a drapable substrate. The plurality of stacked layers comprise at least one liquid crystal layer and at least one electrically conductive layer near the liquid crystal layer. More specifically, the stacked layers of the display film are stacked in a sequence comprising a casting layer, a first electrically conductive layer, the liquid crystal layer and a second electrically conductive layer. In another aspect of the invention, the display film comprises a casting layer applied on or near the release surface on which the other layers of the display are prepared, the casting layer being selected from the group consisting of a preparation layer, the at least one electrically conductive layer, an adhesive layer, a planarization layer, the at least one liquid crystal layer, an isolation layer and combinations thereof. More specifically, the drapable transfer display film includes an adhesive layer for adhering the plurality of layers to the substrate. A preparation layer is adapted to bond the plurality of layers to an adhesive.

In particular, a liquid crystal display comprising the drapable transfer display film and the drapable substrate to which it is transferred, has a drape coefficient less than 100%, less than about 98%, or less than about 95%. Also featured is a liquid crystal display device comprising the drapable transfer display film and drapable substrate, wherein the substrate is selected from the group consisting of a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper.

The liquid crystal layer comprises a dispersion of liquid crystal in a polymer matrix. The liquid crystal layer may comprise liquid crystal that is bistable and/or can be contained in droplets. For example, suitable liquid crystal material is cholesteric liquid crystal material that is bistable in the display film, i.e., it exhibits planar and focal conic textures that are stable in an absence of an electric field. A preferred dispersion includes such cholesteric liquid crystal material dispersed in the polymer matrix. The dispersion is selected from at least one of an emulsion and microencapsulated liquid crystal material.

The liquid crystal display film may include one, two, three or more liquid crystal layers. The layers reflect visible and/or infrared electromagnetic radiation. The display can include liquid crystal that reflects red, green and blue light to form a full color liquid crystal display. The full color display can comprise stacked red, green and blue reflecting liquid crystal layers. The display film may also include three coplanar regions that include droplets containing red, green and blue reflecting liquid crystal material. The display film may exhibit improved brightness through the use of cholesteric liquid crystal material having right and left handed twist sense. This liquid crystal material having both right and left handed twist sense may be located in a single layer or in two layers that may be separated by a barrier layer that prevents diffusion between the layers. If the display film includes two or more liquid crystal layers, a barrier layer may be used to prevent diffusion of liquid crystal material between the layers. This barrier layer could also function as an electrically insulating layer.

Referring to specific aspects of the layers of the inventive display film, an optical layer is located between the casting layer and the liquid crystal layer that matches indices of refraction of adjacent layers. A light absorbing layer is used when the portion of the display downstream of the lowermost liquid crystal layer (e.g., the substrate) is not sufficiently light absorbing. At least one of the electrically conductive layers can comprise an electrical conductor formed of a conductive polymer or carbon nanotube material. An electrical insulation layer is disposed between a liquid crystal layer and an adjacent electrically conductive layer. A protective layer may be employed over the second electrically conductive layer, which strengthens the display film. The protective layer can be optically clear or opaque. The display film may be mounted to the substrate near the side of the film where the protective layer is located or on the other side of the display film. The display film may include an adhesive layer. A preparation layer may be disposed between the adhesive layer and the other layers of the display film. The electrically conductive layers can be patterned or unpatterned. One electrically conductive layer contains parallel lines of row or column conductors and another electrically conductive layer contains parallel lines of the other of row and column conductors. A liquid crystal layer is sandwiched between the electrically conductive layers. The lines of row conductors are arranged orthogonal to the lines of column conductors. The display film may include one electrically conductive layer and the substrate may include another electrically conductive layer, whereby the liquid crystal layer is sandwiched between the film electrically conductive layer and the substrate electrically conductive layer. Of course, the liquid crystal layer may also be sandwiched between adjacent electrically conductive layers of the display film. The liquid crystal layer can be electrically addressed by drive electronics connected to the electrically conductive layers effective to produce images from the display.

Many additional features, advantages and a fuller understanding of the invention will be had from the accompanying drawings and the detailed description that follows. It should be understood that the above Summary of the Invention describes the invention in broad terms while the following Detailed Description describes the invention more narrowly and presents preferred embodiments that should not be construed as necessary limitations of the broad invention as defined in the claims.

## VIII. BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** and **2***a* are side cross-sectional views of the fabrication of one aspect of a display film constructed in accordance with the invention and FIG. **2***b* is a side cross-sectional view of the display film of FIG. **2***a* transferred onto a substrate;

FIGS. **3** and **4***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **4***b* is a side cross-sectional view of the display film of FIG. **4***a* transferred onto a substrate, while FIG. **4***c* is a side cross-sectional view of a variation of the display shown in FIG. **4***b;*

FIGS. **5** and **6***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **6***b* is a side cross-sectional view of the display film of FIG. **6***a* transferred onto a substrate;

FIGS. **7** and **8** are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIGS. **9***a*-**9***c* are side cross-sectional views of the display film of FIG. **8** transferred onto various substrates, while FIG. **9***d* is a side cross-sectional view showing a variation of the display of FIG. **8**;

FIGS. **10** and **11***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **11***b* is a side cross-sectional view of the display film of FIG. **11***a* transferred onto a substrate, while FIG. **10***a* is a side cross-sectional view of a variation of the display of FIG. **10**;

FIGS. **12** and **13***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **13***b* is a side cross-sectional view of the display film of FIG. **13***a* transferred onto a substrate;

FIGS. **14** and **15***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **15***b* is a side cross-sectional view of the display film of FIG. **15***a* transferred onto a substrate;

FIGS. **16** and **17***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **17***b* is a side cross-sectional view of the display film of FIG. **17***a* transferred onto a substrate, while FIG. **16***a* is a side cross-sectional view of a variation of the display of FIG. **16**;

FIGS. **18** and **19***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **19***b* is a side cross-sectional view of the display film of FIG. **19***a* transferred onto a substrate;

FIGS. **20** and **21***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **21***b* is a side cross-sectional view of the display film of FIG. **21***a* transferred onto a substrate;

FIGS. **22** and **23***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **23***b* is a side cross-sectional view of the display film of FIG. **23***a* transferred onto a substrate;

FIGS. **24** and **25***a* are side cross-sectional views of the fabrication of another aspect of a display film constructed in accordance with the invention and FIG. **25***b* is a side cross-sectional view of the display film of FIG. **25***a* transferred onto a substrate; and

FIG. **26** is a perspective exploded view illustrating the fabrication of the conductive electrode layers of the inventive display and mounting to a substrate.

## VIII. DETAILED DESCRIPTION

One embodiment of the invention is a monochrome bistable cholesteric reflective lift off or transfer display film that can be transferred to fabric, polymer, or other substrate that is transparent or opaque. FIG. **1** shows a display film **10** containing various layers that make up the film. The film is fabricated by coating or casting each of the layers on a surface that can serve as a release liner **12** in the following sequence. An optional casting layer **14** is first coated or laminated onto the release liner **12**. The casting layer serves several purposes. The casting layer is a film that, once dried or cured can be removed from the release liner. The casting layer also provides a suitable surface for wetting the next coating in the sequence which can be an optional opaque light absorbing layer **16** to serve as a dark background. Alternatively, if a dark background is not used, the next layer may be one of the display electrode layers. The casting layer is sufficiently rugged to be lifted off the release liner and subsequently laminated onto a substrate.

The light absorbing layer **16**, usually black in color, is coated onto the casting layer. The light absorbing layer adheres to the casting layer and, in this embodiment, serves to absorb unwanted light passing through cholesteric liquid crystal layer **18**. The resulting display is observed from above in the direction of the arrow (FIG. **2***b*). The material of the light absorbing layer serves to wet the next coating in the sequence, the lower conductive electrode layer **20**.

The lower conductive electrode layer **20** is coated or printed and suitably patterned on the light absorbing layer. In this embodiment, the conducting material does not have to be transparent but is desired not to be reflective. Carbon based materials and conducting polymers are suitable as long at they provide sufficient conductivity, for example, less than 1000 Ohms/square resistivity, a parameter also controlled by the thickness of the layer. Carbon based materials and conducting polymers might be suitable in that, often they can be printed to form a desired electrode pattern.

An optional electrical insulation layer **22** over the conducting electrodes is advantageous in preventing electrical shorting. However, if the cholesteric liquid crystal is dispersed in a binder or polymer matrix that is itself sufficiently electrically insulating, the insulation layer may be omitted. The insulation layer is preferably less than 1.0 micron thick in order to maintain suitable drive voltages.

The cholesteric liquid crystal layer **18**, which is in the form of a dispersion composed of liquid crystal dispersed in a polymer matrix, is then coated over the insulation layer. The liquid crystal dispersion can be made from any of several different processes such as emulsification or microencapsulation processes. A preferred dispersion is prepared from a latex emulsion since these binders possess desired wetting and adhesion properties for coating. For the cholesteric liquid crystal, the droplet size should be large enough, for example, greater than 1.0 micron, to allow bistability. The term, droplet, used herein can have any of a variety of shapes including spherical, elliptical, and amorphous shapes. The thickness of this liquid crystal coating determines the drive voltage of the display as well as the display brightness. To optimize brightness, it is desired that this layer be at least 4.0 microns in thickness; however, to maintain moderate to low drive voltages, the layer should be less that 15 microns thick depending on the physical properties of the liquid crystal material.

A second optional electrical insulation layer **24** is advantageous in preventing electrical shorts. This layer may also serve as an isolation or wetting layer for the transparent conducting layer **26**.

The transparent conducting layer **26** is printed or coated and suitably patterned to serve as the upper electrode. Transparent conducting polymers or carbon nanotube materials are suitable for this purpose. The transparency-to-conductivity ratio depends on the thickness of the coating. If response speed of the display is not an issue, a resistivity as high as a few thousand Ohms/square is suitable.

An optional clear protective layer **28** is applied to the transparent conductive layer **26**. The clear protective layer or "clear coat" **28** is advantageous in ruggedizing the display and protecting it from the environment. The term "clear coat" finds analogy to clear coats used as outer protective coatings on the paint finish of automobiles.

The display film is cured. Then, as shown in FIG. **2***a* the cured display film is lifted from the release liner **12**. As shown in FIG. **2***b*, the display film is then transferred or laminated onto a substrate **30**.

Another aspect of the invention is similar to the foregoing display film but employs an adhesive layer **32** and/or preparation layer **34**. This display film is shown in FIG. **3** where like reference numerals describe similar components throughout the several views. Display components hereafter that are the same or similar to those previously described, will not be described in detail again, it being understood that the previous detailed description of materials, characteristics and features of the display components applies equally to subsequent display components. The only difference between the display film shown in FIG. **3** and the display film shown in FIG. **1**, is the addition of an adhesion layer and an optional preparation layer sometimes needed to present a smooth surface between the adhesion layer and the next layer in the display which may be a casting layer, if needed, or the conductive electrode. The preparation layer may also serve as an isolation layer to isolate the other display elements from solvents in the adhesion layer.

As shown in FIG. **4***a*, once the display film has cured it is lifted from the release liner. The adhesive layer **32**, albeit having the ability to possess relatively strong adhesive properties, nonetheless does not bind to the release liner **12** with high adhesion. The release liner may have a waxy or other surface that the adhesive of the adhesion layer does not bind strongly or the adhesive and release liner materials may have compositions that prevent wetting of the adhesive material to the release liner. As shown in FIG. **4***b*, the display film is then transferred or laminated onto a substrate **30**. The adhesive layer **32** binds the display film to the substrate **30** with a desired level of adhesion.

In a specific design, the adhesive layer **32** is composed of pressure sensitive adhesive and has a thickness, for example, of about 25 microns. The layer **34** is a preparation or casting layer. One suitable composition of the casting layer **34** is PET having a thickness, for example, of about 12 microns. A particularly preferred thickness of the casting layer is less than 20 microns and, in particular, in a range of 5-15 microns.

Referring to FIG. **4***c*, as an illustration of one of the many variations that are possible in the present invention, the stacked display film does not require insulating layers because the polymer matrix in the liquid crystal layer is sufficiently electrically insulating to prevent shorts between the electrode layers. The display film also lacks a light absorbing layer because the layers below the liquid crystal layer including the substrate are not reflective or are sufficiently light absorbing. The display film includes the optional preparation layer **34**, not the adhesive layer **32**. The adhesive layer is laminated onto the substrate and could have adhesive properties on one or both sides.

The cured stacked display film is lifted from the release liner (not shown). The stacked display film is then transferred onto the substrate **30**. In particular, the optional preparation layer (or casting layer if no preparation layer is used) bonds to the adhesive layer.

Referring to FIG. **5**, another embodiment of the invention is directed to a monochrome reflective transfer display film that is transferred onto a clear substrate such as a transparent polymer or glass. In this case, the transfer film does not include a dyed or light absorbing layer. The "lower" conductor (at the time of transferring the display film to the substrate) is either a transparent conductor or may not be part of the transfer film if the lower conductor is on the substrate. The upper conductor in the sequence in which the stacked layers are transferred to the substrate may be an opaque conductor in which case the clear coat is replaced by a black coat. Thus, during fabrication of the transfer display film, either the lower or the upper part of the film in relation to the release liner can be ultimately near the top or bottom of the operational display after transfer to the substrate. In addition, the top and bottom of the stacked display film can be either clear or opaque. It will be appreciated that terms such as upper, lower, outer and the like are used to assist in describing features of the invention. These terms are relative and change with the orientation of the display, the display film and the layers of the display film and thus, these terms should not be used to limit the present invention.

In particular, the display film **40** is fabricated by laminating or casting each of the layers on a surface that can serve as the release liner **12** in the following sequence. An optional adhesion layer **42** is first coated or laminated onto the release liner **12**. An optional casting layer **44** is laminated onto the adhesion layer. A conductive electrode layer **46** (that will be the upper electrode layer in the finished display) is then coated or printed and suitably patterned on the underlying layer. In this embodiment, the conducting material is transparent. Carbon based materials and conducting polymers are suitable as long at they provide sufficient conductivity; for example, less than 1000 Ohms/square resistivity, a parameter also controlled by the thickness of the layer. Conducting polymers and carbon based materials might be suitable in that, often they can be printed to form a desired electrode pattern.

An optional electrical insulation layer **48** printed or coated over the electrode layer **46** is advantageous in preventing electrical shorting. However, if the cholesteric liquid crystal is dispersed in a binder or polymer matrix that is itself sufficiently electrically insulating, the insulation layer may be omitted. The insulation layer is preferably less than 1.0 micron thick in order to maintain suitable drive voltages.

The cholesteric liquid crystal layer **50**, which is in the form of a dispersion composed of liquid crystal dispersed in a polymer matrix, is then coated over the insulation layer. The liquid crystal dispersion material can be made from any of several different processes such as emulsion or microencapsulation processes.

A second optional electrical insulation layer **52** may be advantageous in preventing electrical shorts.

A transparent or nonreflective conductive layer is then printed or coated and suitably patterned to serve as the conductive electrode layer **54** (that will be the lower electrode layer of the finished display). Transparent conducting polymers or carbon nanotube materials are suitable for this purpose. The transparency-to-conductivity ratio depends on the thickness of the coating. If response speed of the display is not an issue, a resistivity as high as a few thousand Ohms/square is suitable.

An optional light absorbing layer **56** is printed or coated onto the electrode layer and will be located near the bottom of the finished display.

Finally, an optional protective coating **58** is printed or coated onto the light absorbing layer to ruggedize the display. This layer forms the bottom of the finished display, which can be mounted to a housing of the display device.

The display film is cured. Then, as shown in FIG. **6***a* the cured display film is lifted from the release liner **12**. As shown in FIG. **6***b*, the display film is then transferred or laminated onto the back side of a transparent substrate **30**. The adhesive layer adheres the display film to the substrate with a desired level of adhesiveness.

An embodiment of the invention laminates the transfer film "upside down," i.e., with the side of the uppermost protective layer on the stacked display film relative to the release liner, being transferred so as to be adjacent to the substrate. In this embodiment the uppermost protective layer of the stacked display film is replaced with a preparation coat that may itself function as an adhesive or as a layer that is effective to bind to an adhesive layer.

If the intended substrate is a bottom substrate that is not transparent, it may be desirable that the preparation layer is dyed to absorb light over some spectral band width and that the light absorbing layer (commonly added as one of the first layers during fabrication of the stacked display film) is removed. Furthermore, the lower conducting electrode as well as the layers adjacent the release liner would be transparent. If the substrate is intended to form an upper transparent substrate of the display device, the light absorbing layer would be coated as one of the first layers in the fabrication process as described in more detail below.

More specifically, referring to FIG. **7**, the display film **60** includes an optional casting layer **62** printed or coated on the release liner **12**. In this embodiment, the display film is flipped 180° in the process of transfer onto the substrate as described below. The casting layer may be transparent or need only be nonreflective depending on whether the substrate is an upper or lower substrate of the display device. Next, an optional light absorbing layer **64** is printed or coated. This light absorbing layer **64** would not be used when the display film is transferred onto a substrate **30***b*, **30***c* that is intended to form the bottom portion of the display device (FIGS. **9***b*, **9***c*). However, when the substrate **30***d* is intended to form a top portion of the display device (FIG. **9***a*), the light absorbing layer **64** would be used in the position shown.

Next, the conductive electrode layer **66** is printed, coated and suitably patterned onto the underlying layer. Upon transfer onto a transparent upper substrate **30***d* (FIG. **9***a*), the electrode layer **66** will be located as a lower electrode of the display device. In this case, the electrode layer need not be transparent but should be non-reflective. Upon transfer of the stacked display film to a bottom substrate **30***b*, **30***c* (FIGS. **9***b*, **9***c*), the electrode layer **66** is an upper electrode and should be transparent. An optional insulating layer **68** is printed or coated onto the underlying layer. Next, the cholesteric liquid crystal dispersion layer **70** is coated or printed onto an underlying layer of the stacked layers. An optional insulation layer **72** is printed or coated onto the liquid crystal layer.

Next, an electrically conductive electrode layer **74** is printed or coated and suitably patterned onto the underlying layer. If the intended substrate is a transparent upper substrate **30***d* (FIG. **9***a*), the electrode layer **74** is an upper electrode layer and should be transparent. If the intended substrate is a lower substrate **30***b*, **30***c* (FIGS. **9***b*, **9***c*), the electrode layer **74** is a lower electrode layer and need not be transparent but should be nonreflective.

Next, an optional light absorbing layer **76** is printed or coated onto the electrode layer **74**. If the intended substrate is a clear upper substrate **30***d* (FIG. **9***a*), no light absorbing layer **76** would be printed or coated onto the electrode layer at this location. If the intended substrate is a clear or insufficiently light absorbing, bottom substrate **30***c* (FIG. **9***c*) then the light absorbing layer **76** is used. If the intended substrate **30***b* is opaque and sufficiently light absorbing, the light absorbing layer **76** may be omitted. However, if improved contrast is desired, the light absorbing layer may be used even with opaque bottom substrate **30***b* (FIG. **9***b*). It should also be apparent to those skilled in the art that light absorbing layers may not only absorb all or some light of certain wavelengths but may also be designed to reflect different colors in this and any other embodiment of the present invention.

The next layer is an optional preparation or protective layer **78**. This is followed by an optional adhesive layer **80**. As shown in FIGS. **9***a*-*c*, the adhesive layer may directly bond to the substrate. The optional preparation layer may interact with or hold the adhesive layer to the rest of the stacked display film or provide other functions such as refractive index matching or to protect or ruggedize the display film and possibly act as an isolation layer to protect the dispersion from molecules in the adhesive.

In another aspect of the invention, an adhesive layer **81** could be applied to the substrate (FIG. **9***d*), in which case the adhesive layer **80** would not be needed on the stacked display film. The preparation or protective layer **78** of the display film would then be bonded to the substrate via the substrate adhesive layer **81**. In the case where no preparation or protective layer **78** is used, the next layer of the stacked display film would be bound to the substrate adhesive layer **81**.

In the case of transfer of the stacked display film to a transparent upper substrate (FIG. **9***a*), the preparation/protective and adhesive layers should be transparent. If the stacked display film is transferred to a lower substrate, the preparation/protective and adhesive layers need not be transparent but should not be reflective (FIG. **9***b* and **9***c*).

Another embodiment of the invention is directed to a monochrome cholesteric reflective display that possesses full reflective brightness, reflecting more than 50% of incident light. In this embodiment, the liquid crystal dispersion layer is made up of two stacked coatings, one of a left hand twist cholesteric liquid crystal and the other of right hand twist cholesteric liquid crystal, both tuned to the same pre-selected peak wavelength of reflection and bandwidth. Stacked layers of cholesterics of opposite handedness reflect both components of circular polarized light and as such can, theoretically, reflect all incident light at the Bragg wavelength of the films. Practically, some light is lost to scattering for defects in the dispersion and unwanted reflections and absorptions from the other layers in the stack. The total reflection can approach 80% of incident light as indicated in U.S. Pat. No. 6,320,563. Instead of two stacked layers, left and right handed microencapsulated droplets may be cast as one coating.

More specifically, the display film includes an optional adhesive layer **82** printed or coated on the release liner **12** and an optional preparation layer **84** printed or coated on the adhesive layer as illustrated in FIG. **10**. An optional casting layer **86** is printed or coated on the underlying layer. An optional light absorbing layer **88** is printed or coated on the casting layer. The light absorbing layer is used if the display film is mounted onto a substrate that is not sufficiently light absorbing in this display that is viewed from the side that is distal to the substrate. Next, an electrode layer **90** is printed or coated and suitably patterned onto the underlying layer. This is followed by an optional electrically insulating layer **92**.

The cholesteric liquid crystal dispersion layer **94** is printed or coated next. This is composed or two sublayers: sublayer **94***a* having a right or left hand twist sense and sublayer **94***b* having the opposite twist sense. An optional barrier layer **95** is coated in between to isolate the two sublayers. This provides the display with optimized brightness because both left and right hand circularly polarized light is reflected from the cholesteric layer **94**. The pitch length of each liquid crystal layer can be tuned to reflect light at the same wavelength of peak reflection, creating a monochrome display.

Next, an optional electrically insulating layer **96** is printed or coated on the liquid crystal layer. An electrode layer **98** is printed or coated and suitably patterned onto the underlying layer. Next, an optional protective layer **100** is printed or coated onto the electrode layer.

As shown in FIG. **11***a*, the cured display film is lifted from the release liner **12**. The display film is transferred onto the substrate **30** as shown in FIG. **11***b*. The adhesive layer **82** bonds to the substrate, retaining the display film on the substrate.

The display shown in FIG. **10***a* is the same as in FIG. **10** except that rather than using two LC sublayers of right and left handed twist sense and an optional barrier layer between them, the display uses a single LC layer **93** in which LC droplets of right and left handed twist sense are dispersed.

A full-color, single reflective dispersion layer is possible if the droplet dispersion layer is patterned with red (R), green (G) and blue (B) pixels within a single layer for additive color mixing (FIGS. **12**, **13***a*, **13***b*). The film is similar to the display film of FIG. **10**, except that the droplet dispersion has been patterned by a process such as UV irradiation of cholesteric material with a UV sensitive twisting power as disclosed in U.S. Pat. No. 5,668,614, which is incorporated herein by reference in its entirety.

Another embodiment of the invention is a full color display film **110** fabricated using a three layer RGB (red, green, blue) stack with a single conducting electrode layer in between each layer (FIGS. **14**, **15***a* **15***b*). Such a display is addressed by a shared electrode addressing scheme possible with bistable cholesteric dispersions, as disclosed in the U.S. Patent Application entitled "Stacked Display with Shared Electrode Addressing,".

In particular, an optional adhesive layer **112** is printed or coated onto the release liner **12**. This is followed by printing or coating of an optional preparation layer **114**. An optional casting layer **116** is then printed or coated onto the underlying layer. Next, an optional light absorbing layer **118** may be printed or coated. An electrode layer **120** is printed or coated and suitably patterned next onto the underlying layer. This is followed by an optional electrical insulation layer **122**.

Next, a first cholesteric liquid crystal dispersion layer **124** is printed or coated, reflecting one of the primary colors, e.g., red. A first electrode layer **126**, which is sandwiched between optional electrical insulation layers **128**, **130**, is printed or coated and suitably patterned next. This is followed by printing or coating a second cholesteric liquid crystal dispersion layer **132** reflecting a second primary color, e.g., green. A second electrode layer **134**, which is sandwiched between optional electrical insulation layers **136**, **138**, is printed or coated and suitably patterned next. A third cholesteric liquid crystal dispersion layer **140** reflecting the third primary color, e.g., blue, is printed or coated next. This is followed by an optional electrical insulation layer **142**. A third electrode layer **144** is printed or coated and suitably patterned next. An optional protective layer **146** is added to ruggedize the display. It will be appreciated by those skilled in the art that all of the layers upstream of the first liquid crystal layer in the direction of incident light, should be transparent and that the layers downstream of the first liquid crystal layer need not be transparent but should be non-reflective. Suitable modifications to the particular display shown can be made as would be apparent to one skilled in the art in view of this disclosure, such as to design the display film for transfer onto a clear upper substrate and to invert the display **110** after curing on the release liner during transfer to the substrate.

Added brightness may be achieved if each of the R, G and B layers contains a left twist and a stacked right twist sublayer (FIGS. **16**, **17***a*, **17***b*). This display is similar to that shown in FIGS. **14**, **15***a*, **15***b*. The difference in this display is that each of the liquid crystal layers is comprised of sublayers each having a different twist sense than the other sublayer but reflecting light at the same peak reflection and bandwidth as the other sublayer. Liquid crystal layer **125** is composed of sublayers **125***a*, **125***b*; liquid crystal layer **133** is composed of sublayers **133**a, **133**b; liquid crystal layer **141** is composed of sublayers **141**a, **141**b. Optional barrier layers **127**, **135** and **143** are disposed between sublayers. This provides the display with optimized brightness.

The display shown in FIG. **16**a is the same as in FIG. **16** except that rather than two LC sublayers of right and left handed twist sense and an optional barrier layer between them, the display uses a single LC layer **129**, **137**, **145** in which the LC droplets of right and left handed twist sense are dispersed and no such barrier layer.

Yet another embodiment of the invention features an infrared reflective display containing at least one droplet dispersion layer of the stack that reflects in the infrared such as might be used for night vision purposes (FIGS. **18**, **19**a, **19**b) as disclosed in U.S. Pat. No. 6,034,752. More specifically, an optional adhesive layer **150** followed by an optional preparation layer **152** are printed or coated onto the release liner. Next, an optional casting layer **154** is printed or coated onto the underlying layer. An optional light absorbing layer **156** is printed or coated onto the casting layer. An electrode layer **158** is printed or coated and suitably patterned next. Onto this is printed or coated an optional electrical insulation layer **160**. Next is printed or coated a cholesteric liquid crystal dispersion layer **162** having a pitch length effective to reflect infrared electromagnetic radiation. An intermediate electrode layer **164**, which is sandwiched between optional electrical insulation layers **166**, **168**, is printed or coated and suitably patterned onto the underlying layer. Another cholesteric liquid crystal dispersion layer **170** is disposed next, having a pitch length effective to reflect visible light. An optional electrical insulating layer **172** is printed or coated next. An electrode layer **174** is printed or coated and suitably patterned next. Finally, an optional protective coating **176** forms an outer surface of the display film.

A self-powered display may be achieved by laminating the transfer display film onto a solar panel as the substrate **30** (or on a substrate on which a solar panel is mounted), whereby light that is not reflected by the cholesteric material can be absorbed in the solar panel for conversion into electrical power for powering the display. One such transfer film could be that of FIG. **1** (display film **10**) where the light absorbing layer **16** is eliminated, so that light can be absorbed in the solar panel and used to power the display.

Another display film is mounted onto an active matrix backplane as shown in FIGS. **20**, **21**a, **21**b. The optional casting layer **182** is printed or coated onto the release liner **12**. An optional electrically insulating layer **186**, which may also serve as a casting layer, is printed or coated onto the release liner **12**. The next layer is a cholesteric liquid crystal dispersion layer **188**. The dispersion layer may also serve as the casting layer. An optional electrical insulation layer **190** is printed or coated next. Finally, an unpatterned protective/electrically conductive layer **192** is printed or coated onto the underlying layer.

The cured display film is lifted from the release liner (FIG. **21**a). The display film is then transferred onto a substrate **30** containing an active matrix backplane **194** (FIG. **21**b), which can electrically address individual pixels of the display.

FIGS. **22**, **23**a, **23**b show an embodiment of the invention in which some of the display components are located on the substrate. The display film **200** includes an optically transparent casting layer **202** printed or coated onto the release liner. An optically transparent conducting layer **204** is printed or coated and suitably patterned onto the casting layer. Next, a cholesteric liquid crystal dispersion layer **206** is printed or coated. Then, an optional adhesion layer **208**, which may also serve as an electrical insulating layer, is printed or coated onto the liquid crystal layer. As illustrated in FIG. **23**a, the film is lifted off of the release liner and flipped 180 degrees during transfer. As illustrated in FIG. **23**b, the film is laminated onto the substrate containing a printed or coated and suitably patterned conductor layer **214** such that the side of the transfer film containing the adhesion layer **208** (shown at an upper portion of the stack in FIG. **22**) is adjacent to the conductor **214** on the substrate (shown at a lower portion of the stack in FIG. **23**b). If the optional adhesion layer **216** is applied to the substrate, the adhesion layer **208** of the stacked display film may not be needed and vice versa. The electrode layer **204** of the multi-layer stack and the electrode layer **214** on the substrate sandwich the liquid crystal dispersion layer **206** therebetween and together form a completed display. The layer **202** serves not only as a casting layer during printing or coating the layers on the release liner, but also as a transparent outer protective layer once the display film has been laminated onto the substrate.

Another embodiment of the present invention is directed to the use of flexible substrates. FIG. **24** shows a display film **220** adapted for use on a fabric substrate. An optional adhesive layer **222** is printed or coated onto the release liner **12**. An optional preparation layer **224** is printed or coated onto the underlying layer. An optional casting layer **226** is printed or coated onto the underlying layer or, if none, onto the release liner **12**. An optional electrode layer **228** is printed or coated and suitably patterned next. In the case of application of the display film to a substrate that is sufficiently light absorbing, no light absorbing layer may be used. However, it should be apparent that a light absorbing layer could be added below the liquid crystal layer if the substrate is not sufficiently absorptive of light. An optional electrical insulation layer **230** is printed or coated next. Next, the cholesteric liquid crystal dispersion layer **232** is printed or coated on the underlying layer. Next, an optional electrical insulation layer **234** is printed or coated onto the liquid crystal layer. Then, an electrode layer **236** is printed or coated and suitably patterned onto the underlying layer. This is followed by printing or coating an optional protective layer **238** to ruggedize the display.

One suitable flexible substrate is in the form of a fabric **30**f. On the fabric, an optional planarization layer **240** may be disposed. This layer could include patterned electrodes in which case the electrode layer **228** would be omitted. Although it is not necessary for the fabric to be smooth for lamination of the display film onto the fabric substrate, if used, the planarization layer smooths the surface of a rough fabric substrate, in preparation of attachment of the transfer display film **220**. The cured display film is lifted from the release liner (FIG. **25**a). The display film is then transferred directly onto the fabric substrate **30**f (FIG. **25**b), or optionally onto the substrate made flat by the planarization layer. It will be appreciated that instead of the adhesive layer disposed on the display film, the adhesive layer could be disposed on the planarization layer (not shown).

Another embodiment features an optically addressable transfer display film to provide a display that can be optically addressed as disclosed in the publication "Reflective Display with Photoconductive Layer and Bistable Reflective Cholesteric Mixture" *Journal of the SID*, Vol. 5/3, pages 269-274 (1997) by Yoshida et al. This film eliminates the lower electrode and is transferred to a photoconductive sheet having an electrode underneath. While a continuous voltage is applied to the electrodes, light impinging on the display film will locally alter the resistivity of the photoconductor and drive the display film. The display can be addressed with an image suitably focused or projected on the film, or written with a scanned laser beam.

Transfer display films formed from other veneered stacks are possible depending on the desired application and fall within the scope of the present invention. For example, when sequences of display elements are listed, it will be apparent that the invention contemplates other elements interposed between the listed elements. In addition, whether the display film is placed on a light absorbing substrate or not affects the selection of the light absorbing layer in the multilayer stack. For example, laminating the display onto a transparent upper substrate, affects selection of whether and where a light absorbing layer will be used and affects selection of transparent or opaque conductors. In addition, variation in the invention is enabled by the use of an adhesive layer, preparation or protective layers. One or more of these layers may be disposed on the substrate, for example, a preparation layer on the multilayer film and the adhesive layer disposed on the substrate. The multilayer stack may include one, two or more electrode layers. If the substrate already has an electrode layer disposed on it, one less electrode layer may be formed in the multilayer stack. Transfer onto the substrate sandwiches the liquid crystal layer between the electrode layer in the display film and the electrode layer on the substrate. Also, in the case of other devices for applying a voltage to the liquid crystal layer, such as the active matrix backplane or device for optically addressing, the multilayer stack may omit an electrode layer. Finally, layers may have multi-functionality such as an electrode/planarization layer, a planarization/electrical insulation layer, an electrode/casting layer, an electrode/casting/protective layer, for example. Those skilled in the art in view of this disclosure will appreciate these and other variations to layer multi-functionality, layer and substrate type, to the sequence of the layers and to the orientation of the display film, which fall within the scope of the present invention. Accordingly, it will be apparent to those skilled in the art that the novel fabrication process of the present invention provides a myriad of variations in the design and use of the inventive display film, all without departing from the spirit and scope of the present invention.

FIG. **26** is a perspective drawing of a passive matrix display **300** illustrating, in an exploded view, how the conducting transparent electrodes **302** patterned as rows, may be electrically connected to conducting tabs **304** attached to the substrate **306**. The column electrodes **308** are electrically connected to tabs **310**, which are also attached to the substrate. The tabs are used for interconnecting drive electronics, not shown. Since the tabs for both of the columns **308** and rows **302** are disposed on the substrate, attaching the drive electronics is greatly simplified. It will be apparent that the intermediate layers of the display, including the cholesteric liquid crystal dispersion layer, are not shown in FIG. **26** for clarity.

In the case where there are multiple electrode layers, such as that of a full-color display with an RGB stack of three cholesteric liquid crystal dispersion layers, the column and row electrodes can likewise be connected to tabs located on the substrate. For example, the two outer conducting layers in the full-color stacked substrate can be connected to tabs located on two sides of the substrate as illustrated in FIG. 8 of the U.S. Patent Application entitled "Stacked Display with Shared Electrode Addressing,", while the two intermediate electrode layers associated with the full color stack can be connected to tabs located on the two remaining sides of the substrate. Electrical connections of the electrodes to the tabs can be made with conducting polymer material. The ends of the electrodes of the conducting layers are left exposed in the coating process to allow for connection to the tabs.

Particular aspects of the invention will now be described by reference to the following examples that are provided to improve understanding of the invention and should not be construed to limit the scope of the present invention as set forth in the appended claims.

## Example 1

An operable 16×16 pixel passive matrix, lift-off cholesteric display film was made by first coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The release liner was a neoprene sheet with a fabric support available from Thor Labs (Newton, N.J.). A casting layer of aqueous polyurethane dispersion, WITCOBOND W232 (available from Crompton Corporation, CT) was deposited on the release liner using a Meyer rod technique and allowed to dry at room temperature. The dry thickness of the casting layer was approximately 10-12 microns. A layer of conductive polymer (ELP-3040 available from Agfa-Gevaert, Belgium) was screen printed on the casting layer as 5 mm wide, 15 cm long strips spaced 1 mm apart to serve as the column electrodes of the passive matrix display. After casting, the conducting polymer was cured at 100° C. for 10 minutes. A thin insulation layer (1-2 μm) of polyurethane dispersion (e.g. WITCOBOND W232) was cast on the conductive layer using a doctor blade technique. A layer of encapsulated cholesteric liquid crystal in polymer binder was coated from a water-based emulsion on the insulation layer using a doctor blade having a 25 micron gap and allowed to dry for 1 hour at room temperature. The thickness of the encapsulated liquid crystal layer was approximately 8-10 μm. The ratio between liquid crystal and binder was from 4:1 to 5:1. The emulsion was prepared from 0.4 g of ChLC KLC19 (EM Industries, Hawthorne, N.Y.) and 0.27 g of NeoRez R967 available from NeoResins, MA were emulsified with a homogenizer (PowrerGen 700) at 1000 rpm for 3-4 minutes at room temperature. The emulsified ChLC formed droplets that were about 3-25 μm in diameter. After the emulsion layer dries at room temperature for 1 hour the droplet shape appeared to be flattened. Such droplet shape reduces light scattering and enhances the display brightness. A second conductive electrode was a highly transparent conductive polymer Dipcoat available from Agfa. A thin layer of conductive polymer was deposited using air brushing over a mask and cured at room temperature. The mask was patterned to provide 5 mm wide, 15 cm long strips spaced 1 mm apart to form the row electrodes of the passive matrix display. For protection of the display, a 5-10 micron clear coat was deposited on the top of the second conductive electrode using a doctor blade. Moreover, the use of the clear coat layer made of the polyurethane dispersion (e.g. WITCOBOND W232 or NeoRezR967) resulted in an increase in the transmission due to the refractive index matching.

The display film including all of the layers from the casting layer to the clear coat was lifted off from the release liner. The thickness of the lift-off display was around 30 microns. The lift-off display film was fully operational upon being electrically addressed by applying the appropriate voltages to the column and row electrodes. The bistable cholesteric material could be addressed to the planar (yellow reflective) by application of 135 volts or to the focal conic (non-reflective texture) with application of 105 volts. The appropriate voltages used to achieve the planar and focal conic states are dependent on the compositions and thicknesses of the layers of the display. Suitable such voltages may be selected by one of ordinary skill in the art in view of this disclosure based on the particular characteristics of the display layers. Pixels addressed to the planar and focal texture remained in their respective states even when the film was bent, twisted, folded, and even stretched. The display film had a contrast ratio of 12:1 and a brightness of 28%. The display film was very rugged and suitable for lamination on a substrate without damage. In this particular example, it is desired that the substrate be opaque and preferably black so that the focal conic state appears black and the reflective planar state appears a bright yellow and highly contrasting against the black.

## Example 2

An operable 16×16 pixel passive matrix, lift-off cholesteric display film was made by first coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The sequence of the layers was the same as in the Example 1 except that the insulation layer was made of polyurethane dispersion NeoRez R967.

## Example 3

An operable 16×16 pixel passive matrix, lift-off cholesteric display film was made by first coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The sequence of the layers was the same as in the Example 1 except that the casting layer was made of polyurethane dispersion NeoRez R967 and it did not have the insulation layer between the first conductive electrode and the layer of encapsulated liquid crystal.

## Example 4

The following is an example of preparation of the stacked layers of materials for a lift-off display film with adhesive and casting layers. An operable 4×1 pixel passive matrix cholesteric display lift-off film was made by first coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner forming the lift-off film for subsequent lamination on a fabric substrate. The release liner was the same as in Example 1. The casting layer was a 12.5 micron polycarbonate plastic sheet laminated with a pressure sensitive adhesive layer. The sequence of the layers is similar to that in the Example 1 with the exception of the casting and adhesion layers. Following the coating and drying of the layers the display film from the adhesion layer to the clear protective coat was lifted off from the release liner and laminated onto black soft cloth. The display was fully operational after transfer to the final substrate. The bistable cholesteric material was addressed to the planar (yellow reflective) by application of 110 volts or to the focal conic with application of 55 volts. The display film had a contrast ratio of 12:1 and a brightness of 30%.

## Example 5

The following is an example of preparation of the stacked layers of materials for a lift-off display with an adhesive and casting layer. The display had the same sequence of layers as in Example 1 except that the release liner was a paper sheet with a peel-off adhesive transparent layer that served as a casting layer (Avery laminating sheets 73602). To establish a black background for the reflective display a black paint (KRYLON) was coated on the casting layer by spraying and dried at room temperature. A 2×2 pixel display was prepared as follows. First, a layer of conductive polymer (ELP3040) was deposited with Meyer rod on the black paint and cured at 80° C. for 15 minutes. Next, a layer of encapsulated liquid crystal and second conductive electrode were deposited the same way as described in Example 1. The display did not have a clear coat layer as a top layer. The display film had a contrast ratio of 18:1 and brightness of 34%. The driving voltage was 95 V for achieving the planar state and 60 V for achieving the focal conic state.

## Example 6

An operable 1×7 pixel passive matrix cholesteric display with two electro-active layers was made by coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The release liner with casting layer, patterned conductive polymer layer, encapsulated ChLC layer and the second conductive electrode were the same as in Example 1 except that the second conductive electrode was not patterned and was deposited over a mask which provides a solid electrode. No clear coat layer was deposited on the second transparent electrode. Instead, a thin isolation layer coated from aqueous gelatin solution (HiPure gelatin, Norland Products) was deposited with a doctor blade. A second layer of yellow encapsulated ChLC in polyurethane binder (NeoRes R967) was coated from a water-based emulsion on the isolation layer with doctor blade. The thickness of the second encapsulated ChLC layer was approximately 8-10 μm. A third conductive transparent electrode made of conductive polymer Dipcoat was deposited over a mask using air brushing and cured at room temperature. The mask provides a patterned electrode of the passive matrix display. Finally, the top clear coat as in Example 1 was coated on the third conductive electrode. Each encapsulated ChLC layer can be addressed separately.

## Example 7

An operable 1×7 pixel passive matrix cholesteric display with two electro-active layers was made by coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The sequence of the layers is the same as in the Example 6 except that there is no isolation layer between the second conductive electrode and the second ChLC layer. The color of the first ChLC layer was red and the color of the second ChLC layer was green. In this Example the second. ChLC layer consisted of two sub-layers. The first sub-layer was an isolation layer and was coated from an aqueous emulsion of green microencapsulated ChLC on the second conductive electrode using the doctor blade. Microencapsulated ChLC droplets with sizes ranging from 2-20 microns had individual shells made of cross-linked gelatin and gum Arabic using complex coacervation process (LCR, MI). The purpose of this sub-layer was two-fold. It served as an isolation layer to prevent mixing of red and green ChLCs, and being electro-active improved the droplet fill factor and increased the display brightness. The second sub-layer was a major electro-optical layer of the green encapsulated ChLC, and was deposited from aqueous emulsion as in Example 6.

## Example 8

An operable 16×16 pixel passive matrix cholesteric display with two electro-active layers was made by coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The sequence of the layers is the same as in the Example 7 except that the first and third conductive electrodes were patterned to form rows and columns as in Example 1.

Example 9

An operable 1×7 pixel passive matrix cholesteric display with one electro-active layer was made by coating and printing the various display elements on a release liner to form a display film, then lifting the film off of the liner for subsequent lamination on a substrate. The sequence of the material layers is the same as in the Example 3 except that the casting layer was made of 0.5 mil clear PET film with optical pressure sensitive adhesive (PSA) layer on a release liner (from Grafix Plastic, Cleveland, Ohio). The display film including all of the layers from the casting layer with PSA layer to the clear coat was lifted off from the release liner and laminated on the fabric substrate. The display film had a brightness of 32%. The driving voltage was 110 V for the planar state and 55 V for the focal conic state.

Example 10

The sequence of the materials layers is the same as in the Example 9 except that the casting layer was made of 1 mil LB grade clear acetate film (from Grafix Plastic, Cleveland, Ohio). The display film had a brightness of 31%. The driving voltage was 120 V for the planar state and 60 V for the focal conic state.

Many modifications and variations of the invention will be apparent to those of ordinary skill in the art in light of the foregoing disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than has been specifically shown and described.

What is claimed is:

**1**. A drapable transfer display film comprised of a plurality of stacked layers that are prepared on, cured and lifted from a release surface and then transferred to a drapable substrate, wherein said plurality of stacked layers comprise at least one liquid crystal layer and at least one electrically conductive layer near said liquid crystal layer.

**2**. The drapable transfer display film of claim **1** comprising an adhesive layer for adhering said plurality of layers to said substrate.

**3**. The drapable transfer display film of claim **1** comprising a preparation layer adapted to bond said plurality of layers to an adhesive.

**4**. A liquid crystal display comprising said drapable transfer display film and said substrate of claim **1** having a drape coefficient less than 100%.

**5**. The display of claim **4** having a drape coefficient less than about 98%.

**6**. The display of claim **4** having a drape coefficient less than about 95%.

**7**. The drapable transfer display film of claim **1** comprising a casting layer applied on or near the release surface on which other said layers of the display are prepared, said casting layer being selected from the group consisting of a preparation layer, the at least one said electrically conductive layer, an adhesive layer, a planarization layer, the at least one said liquid crystal layer, an isolation layer and combinations thereof.

**8**. The drapable transfer display film of claim **1** wherein said plurality of stacked layers are stacked in a sequence comprising a casting layer, a first said electrically conductive layer, said liquid crystal layer, and a second said electrically conductive layer.

**9**. The drapable transfer display film of claim **8** wherein at least one of said first and second electrically conductive layers comprises a transparent electrical conductor formed of a conductive polymer or carbon nanotube material.

**10**. The drapable transfer display film of claim **8** comprising an electrical insulation layer located between said first electrically conductive layer and said liquid crystal layer.

**11**. The drapable transfer display film of claim **8** comprising an electrical insulation layer between said liquid crystal layer and said second electrically conductive layer.

**12**. The drapable transfer display film of claim **1** wherein said liquid crystal layer comprises a dispersion of liquid crystal in a polymer matrix.

**13**. The drapable transfer display film of claim **8** wherein said liquid crystal layer comprises a dispersion of liquid crystal in a polymer matrix.

**14**. The drapable transfer display film of claim **12** wherein said dispersion is at least one of an emulsion and microencapsulated liquid crystal material.

**15**. The drapable transfer display film of claim **1** wherein said liquid crystal comprises cholesteric liquid crystal exhibiting planar and focal conic textures that are stable in an absence of an electric field.

**16**. The drapable transfer display film of claim **8** wherein said liquid crystal layer comprises cholesteric liquid crystal exhibiting planar and focal conic textures that are stable in an absence of an electric field.

**17**. The drapable transfer display film of claim **8** comprising an optical layer located between said casting layer and said liquid crystal layer, said optical layer being adapted to match indices of refraction of adjacent said layers.

**18**. The drapable transfer display film of claim **8** comprising a light absorbing layer located between said casting layer and said liquid crystal layer.

**19**. The drapable transfer display film of claim **8** wherein said casting layer absorbs light.

**20**. The drapable transfer display film of claim **8** comprising a protective layer located over the second electrically conductive layer that provides strength to said transfer display film.

**21**. A liquid crystal display comprising the drapable transfer display film of claim **20** wherein said protective layer is optically clear, further comprising said drapable substrate attached to the transfer display film near said casting layer.

**22**. A liquid crystal display comprising the drapable transfer display film of claim **20** where said protective layer is optically opaque, further comprising said drapable substrate attached to the transfer display film near said protective layer.

**23**. The drapable transfer display film of claim **1** wherein the at least one said liquid crystal layer comprises at least one cholesteric liquid crystal dispersion layer reflective of visible or infrared electromagnetic radiation.

**24**. The drapable transfer display film of claim **23** wherein each said liquid crystal dispersion layer is reflective of a different wavelength of electromagnetic radiation.

**25**. The drapable transfer display film of claim **1** wherein the at least one said electrical conductive layer comprises a transparent electrical conductor located between adjacent said dispersion layers.

**26**. The drapable transfer display film of claim **23** wherein one said dispersion layer comprises left and right hand twist cholesteric materials, separated to prevent mixing.

**27**. The drapable transfer display film of claim **26** wherein said one dispersion layer comprises one sublayer including said left hand twist cholesteric material and another sublayer comprising said right hand twist cholesteric material.

**28**. The drapable transfer display film of claim **23** wherein the at least one said dispersion layer comprises one said dispersion layer reflective of red light, another said dispersion layer reflective of blue light and another said dispersion layer reflective of green light.

**29**. The drapable transfer display film of claim **1** wherein the at least one said liquid crystal layer comprises three generally coplanar and separated regions, a first said region comprising a plurality of droplets which contain cholesteric liquid crystal having a pitch length effective to reflect red light, a second said region comprising a plurality of droplets which contain cholesteric liquid crystal having a pitch length effective to reflect green light, and a third said region comprising a plurality of droplets which contain cholesteric liquid crystal having a pitch length effective to reflect blue light.

**30**. A liquid crystal display device comprising the drapable transfer display film and said drapable substrate of claim **1** and drive electronics that can electrically address said liquid crystal layer by applying an electric field between said electrically conductive layers effective to produce images from the display film.

**31**. A liquid crystal display device comprising the drapable transfer display film and said drapable substrate of claim **1**, and means for electrically addressing said liquid crystal layer between said electrically conductive layers to produce images from said liquid crystal layer.

**32**. A liquid crystal display device comprising the drapable transfer display film and the drapable substrate of claim **1**, wherein said substrate comprises at least one electrically conductive layer, further comprising drive electronics for electrically addressing said liquid crystal layer between said at least one electrically conductive layer of the transfer display film and said at least one electrically conductive layer of said substrate effective to produce images from said liquid crystal layer.

**33**. A liquid crystal display device according to claim **32**, wherein the at least one said electrically conductive layer of said transfer display film and the at least one said electrically conductive layer of said substrate contains parallel lines of row conductors and the other of the at least one said electrically conductive layer of said transfer display film and the at least one said electrically conductive layer of said substrate contains parallel lines of column conductors, said lines of row conductors being arranged orthogonal to said lines of column conductors.

**34**. A liquid crystal display device comprising the drapable transfer display film and said drapable substrate of claim **8**, wherein one of said first and second electrically conductive layers contains parallel lines of row conductors and the other of said first and second electrically conductive layers contains parallel lines of column conductors, said lines of row conductors being arranged orthogonal to said lines of column conductors.

**35**. A liquid crystal display device comprising the drapable transfer display film and drapable substrate of claim **1** wherein said drapable substrate is selected from the group consisting of a textile fabricated from natural or synthetic fibers, a sheet of polymeric material or paper, and combinations thereof.

* * * * *

US008043137B2

(12) **United States Patent**
**Green et al.**

(10) **Patent No.: US 8,043,137 B2**
(45) **Date of Patent: Oct. 25, 2011**

(54) **LIGHT-EMITTING PANEL AND A METHOD FOR MAKING**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 317 days.

(21) Appl. No.: **12/465,160**

(22) Filed: **May 13, 2009**

(65) **Prior Publication Data**

US 2009/0275254 A1 Nov. 5, 2009

**Related U.S. Application Data**

(60) Continuation of application No. 11/527,415, filed on Sep. 27, 2006, now abandoned, which is a division of application No. 10/614,049, filed on Jul. 8, 2003, now Pat. No. 7,125,305, which is a continuation of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**
*H01J 9/00* (2006.01)

(52) **U.S. Cl.** ........................................... **445/24**; 445/25

(58) **Field of Classification Search** .......... 313/581–587, 313/637–642; 445/23–27
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 1,923,148 A | | 8/1933 | Hotchner | 49/7 |
| 1,961,735 A | | 6/1934 | Braun | 40/130 |
| 2,036,616 A | | 4/1936 | Asch | 176/14 |
| 2,095,291 A | | 10/1937 | Schneider | 40/130 |
| 3,395,301 A | * | 7/1968 | Iannelli | 313/25 |
| 3,453,478 A | | 7/1969 | Shoulders et al. | 313/309 |
| 3,559,190 A | | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 A | | 2/1972 | Lay | 313/109.5 |
| 3,684,468 A | | 8/1972 | Bode et al. | 65/4 |
| 3,704,052 A | | 11/1972 | Coleman | 316/17 |
| 3,704,386 A | | 11/1972 | Cola | 313/108 R |
| 3,755,027 A | | 8/1973 | Gilsing | 156/67 |
| 3,755,704 A | | 8/1973 | Spindt et al. | 313/309 |
| 3,848,248 A | | 11/1974 | MacIntyre, Jr. | 340/324 M |

(Continued)

FOREIGN PATENT DOCUMENTS

JP 51-150272 12/1976

(Continued)

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42805, dated Dec. 21, 2004 (mailing date).

(Continued)

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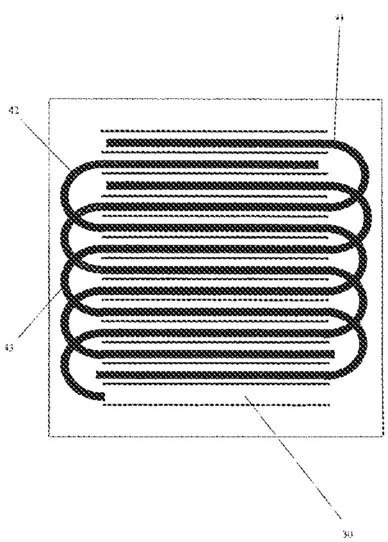
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous inline process.

**1 Claim, 22 Drawing Sheets**



U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 3,935,494 | A | 1/1976 | Dick et al. | 313/587 |
| 3,969,651 | A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 | A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 | A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 | A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 | A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | 1/1984 | Aboelfotoh | 340/701 |
| 4,459,145 | A | 7/1984 | Elsholz | 65/21.3 |
| 4,534,743 | A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,890,383 | A | 1/1990 | Lumbard et al. | 438/27 |
| 4,912,364 | A | 3/1990 | Hollóet al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Deschamps et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,482,486 | A | 1/1996 | Vaudaine et al. | 445/3 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,939,826 | A | 8/1999 | Ohsawa et al. | 313/582 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 385/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 6,527,964 | B1 | 3/2003 | Smith et al. | 216/19 |
| 6,545,422 | B1 | 4/2003 | George et al. | 315/169.3 |
| 6,570,335 | B1 | 5/2003 | George et al. | 315/169.3 |
| 6,612,889 | B1 | 9/2003 | Green et al. | 445/24 |
| 6,762,566 | B1 | 7/2004 | George et al. | 315/169.3 |
| 6,822,626 | B2 | 11/2004 | George et al. | 345/60 |
| 6,864,631 | B1 | 3/2005 | Wedding | 313/587 |
| 7,137,857 | B2 | 11/2006 | George et al. | 445/24 |
| 7,140,941 | B2 | 11/2006 | Green et al. | 445/24 |
| 2001/0008825 | A1 | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |

| | | | | |
|---|---|---|---|---|
| 2002/0195936 | A1 | 12/2002 | Kato et al. | 313/582 |
| 2003/0073372 | A1 | 4/2003 | Nakatake et al. | 445/25 |
| 2003/0094891 | A1 | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1 | 9/2003 | Green et al. | 313/582 |
| 2004/0175854 | A1 | 9/2004 | George et al. | 438/30 |
| 2005/0095944 | A1 | 5/2005 | George et al. | 445/3 |
| 2006/0205311 | A1 | 9/2006 | Green et al. | 445/24 |
| 2007/0015431 | A1 | 1/2007 | Green et al. | 445/24 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| JP | 53-063972 | 6/1978 |
| JP | 4-287397 | 10/1992 |
| JP | 10-3869 | 1/1998 |
| JP | 11-162358 | 6/1999 |
| KR | 1998-077351 | 11/1998 |
| WO | WO 00/36465 | 6/2000 |
| WO | WO 02/35510 | 5/2002 |

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US03/22868, dated Sep. 27, 2004 (mailing date).

International Search Report for Application No. PCT/US03/22868, dated Jun. 1, 2004 (mailing date).

Written Opinion for Application No. PCT/US01/42805, dated Apr. 2, 2004 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 22, 2003 (mailing date).

Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).

International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).

Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

Preliminary Examination Report for U.S. Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).

Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.

Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.

Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.

International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).

Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).

International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).

Sheats, James, "Introduction to Organic Light-Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.

Sauvante, Michael, "Roll-to-Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.

International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).

Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www-star.stanford.edu/~vlf/plasma_display/index.htm.

"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.

"Runco PlasmaWall PL-42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.

"Runco PlasmaWall P1-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.

"Runco PlasmaWall™ PL-6lcx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.

"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.1g.co.kr/English/company/electronic/index.jsp?code=A3.

"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.

"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.

"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.

"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.

"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.

"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.

"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.

"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.

Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21-25, 2001.

Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar. 2001, pp. 17-17-24.

Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.

"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.

Alien Technology Corporation's Technology Overview, Copyright © 2000, Alien Technology™ , http://www.alientechnology.com/d/technology/overview.html.

Anonymous, "Alien Technology Corporation White Paper—Fluidic Self Assembly," Alien Technology Corp., Oct. 1999, pp. 1-7.

Kurihara, M., Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372-1378.

Rauf, S., Kushner, M. J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10-11.

Shin, Y. K., Lee, J. K., Shon, C. H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 14-15.

"Transparent Conductive Coatings," Copyright 1998, 4 pp.

Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep. 1997, pp. 1241-.

Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.

"Flat Panel Displays in Perspective," 44 pp., Sep. 1995.

* cited by examiner

Fig. 1

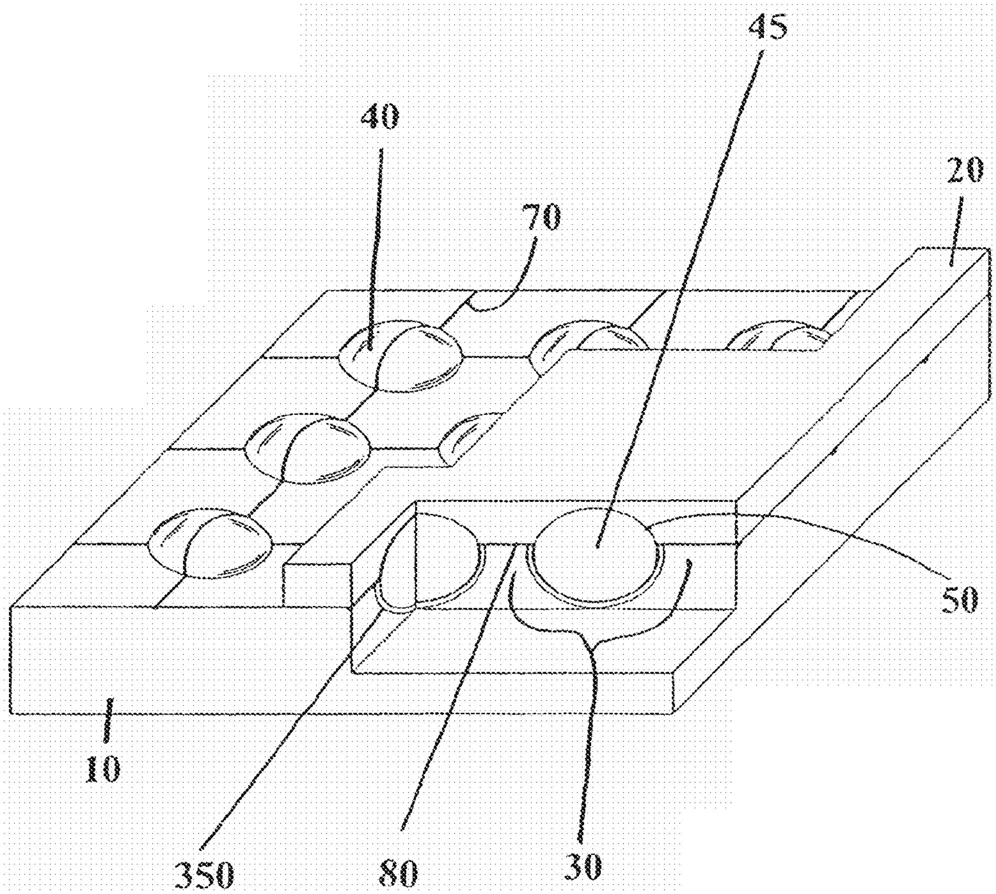
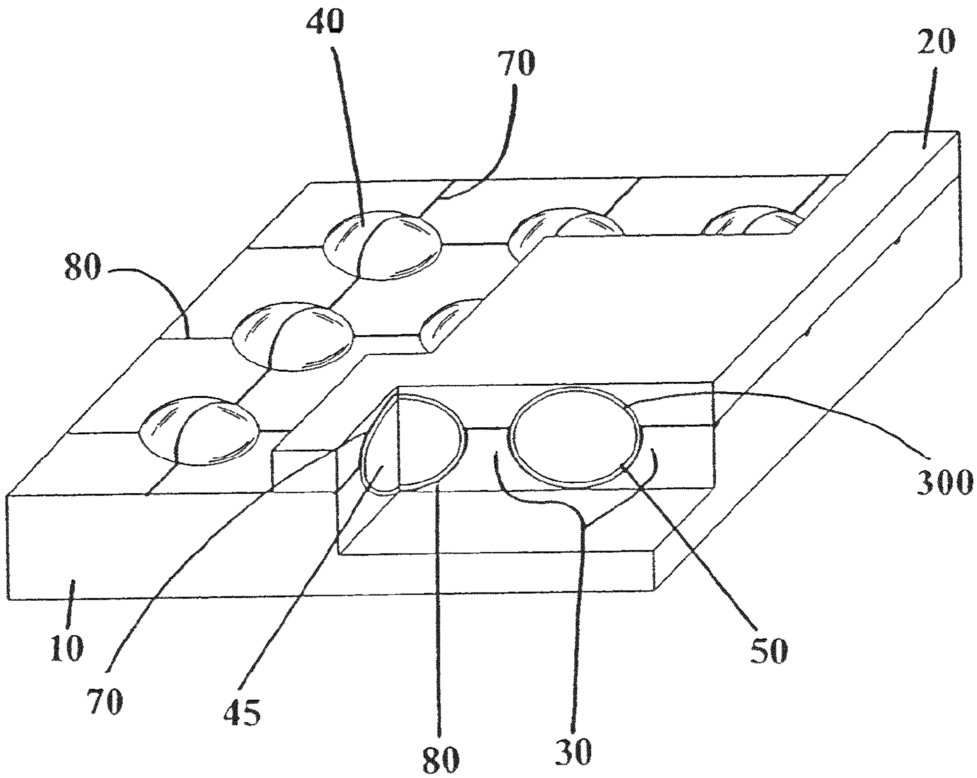


Fig. 2



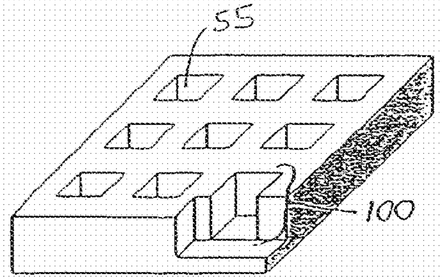


Fig. 3 A

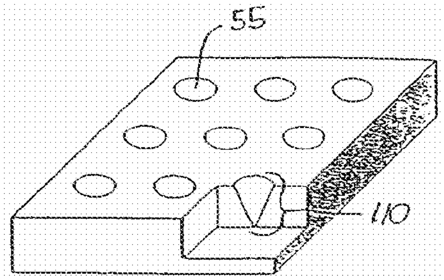


Fig 3B

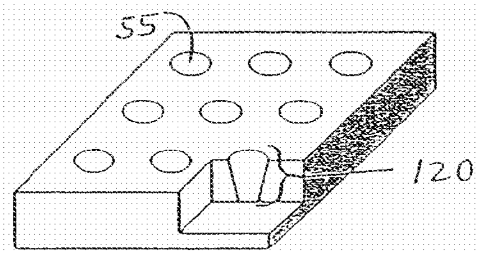


Fig 3C

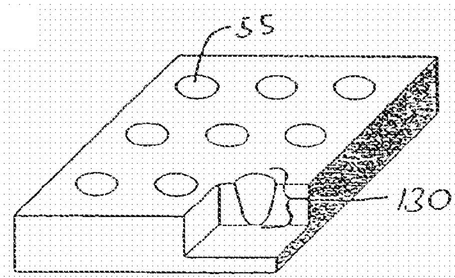
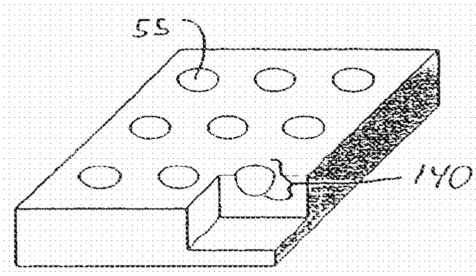


Fig 3D



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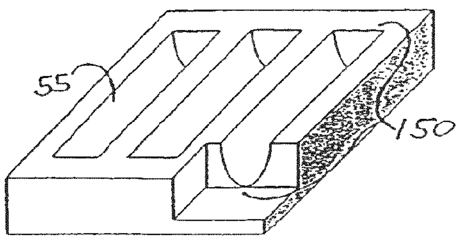



Fig. 3F

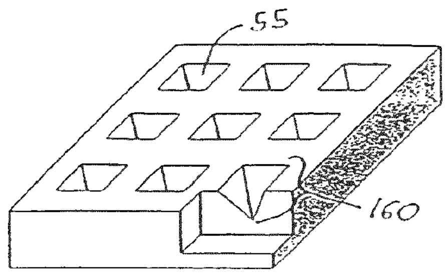



Fig. 3G

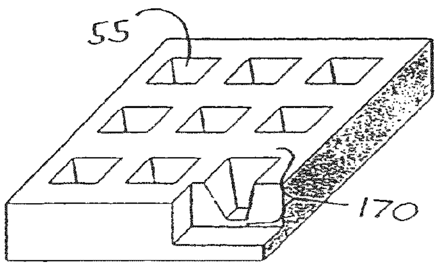



Fig. 3H

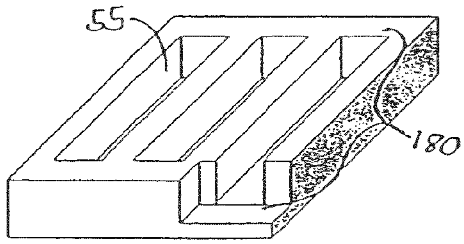



Fig. 3I

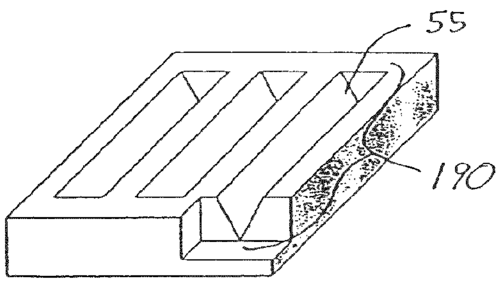



Fig. 3J

Fig. 4

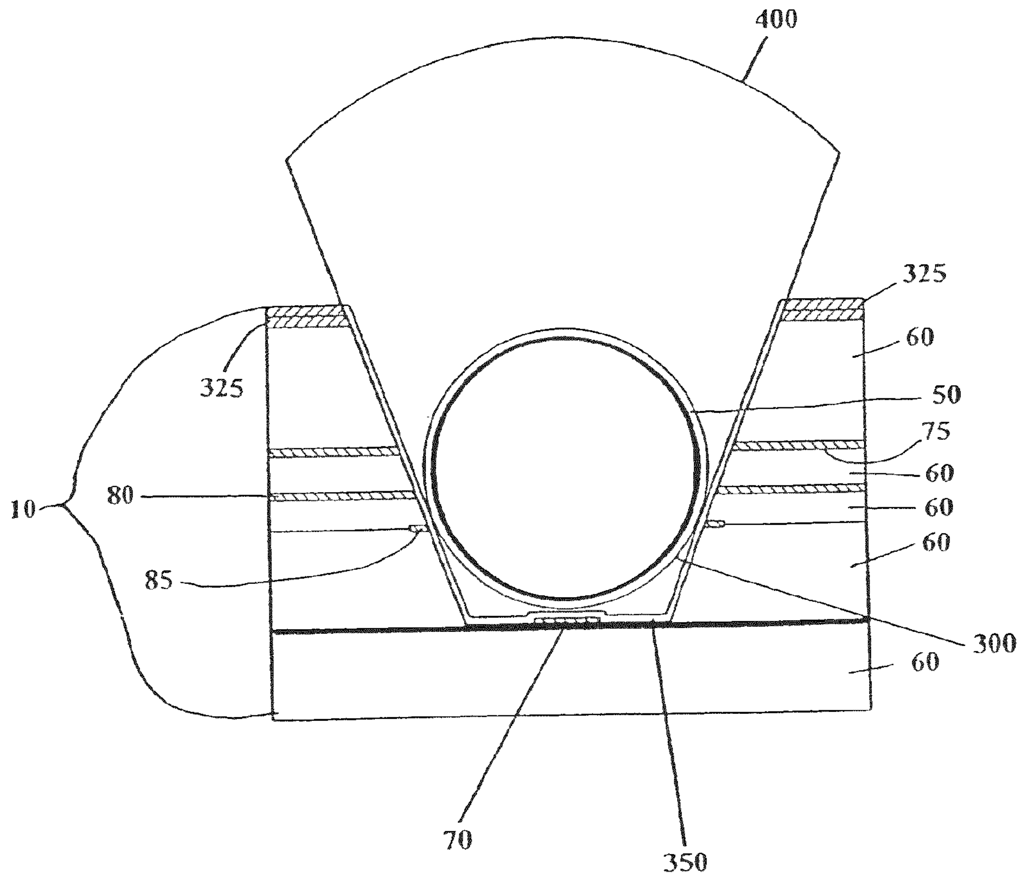


Fig. 5

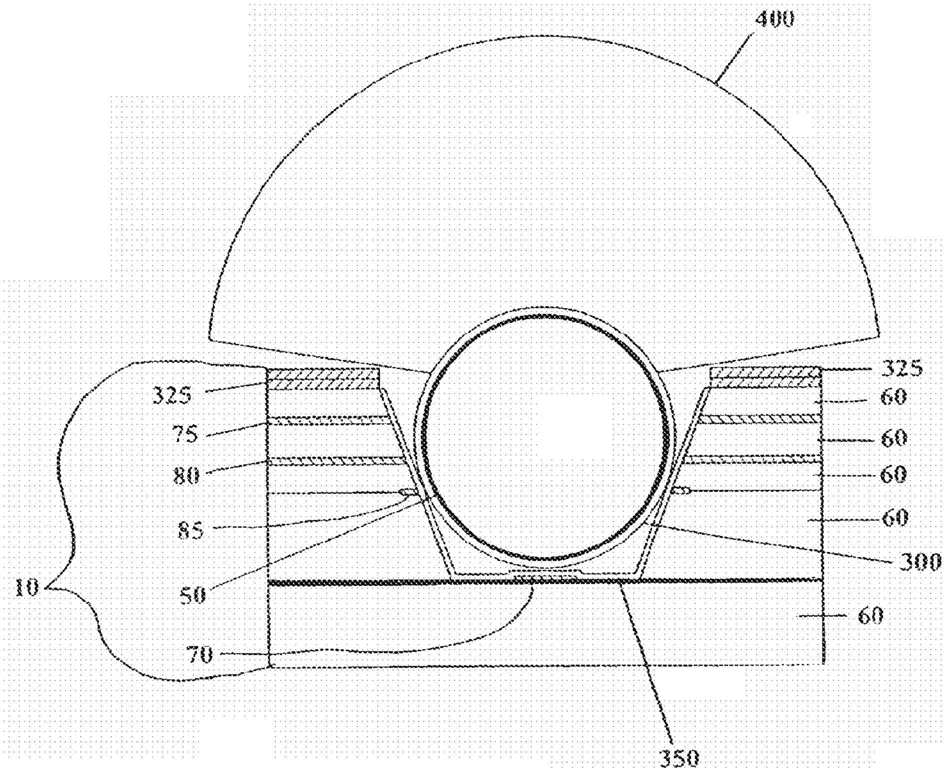


Fig. 6A

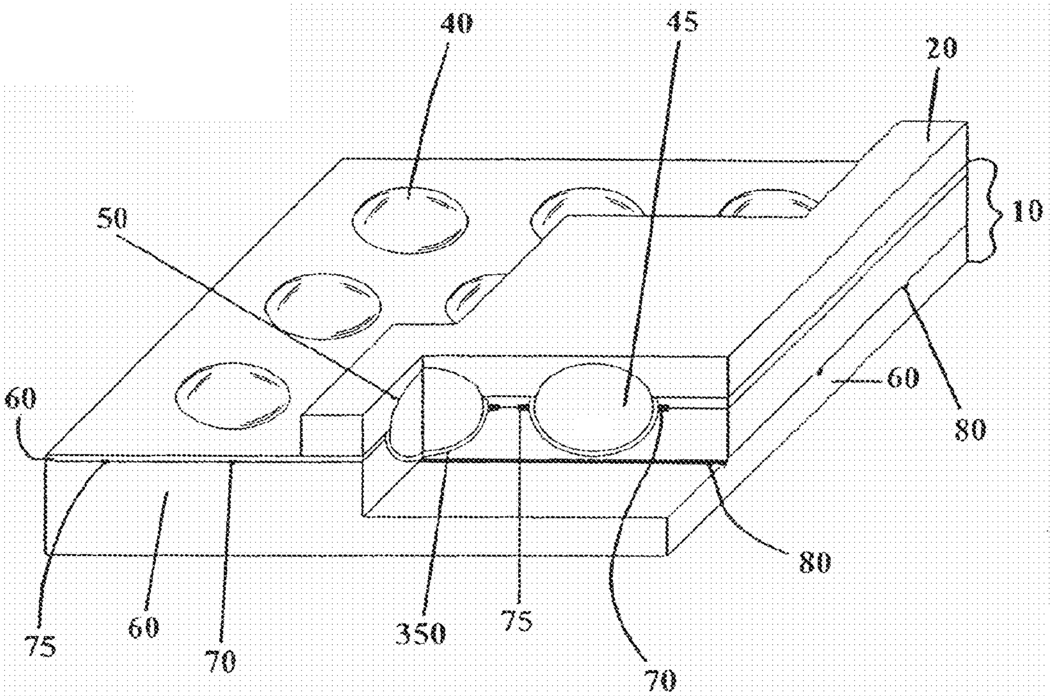


Fig. 6B

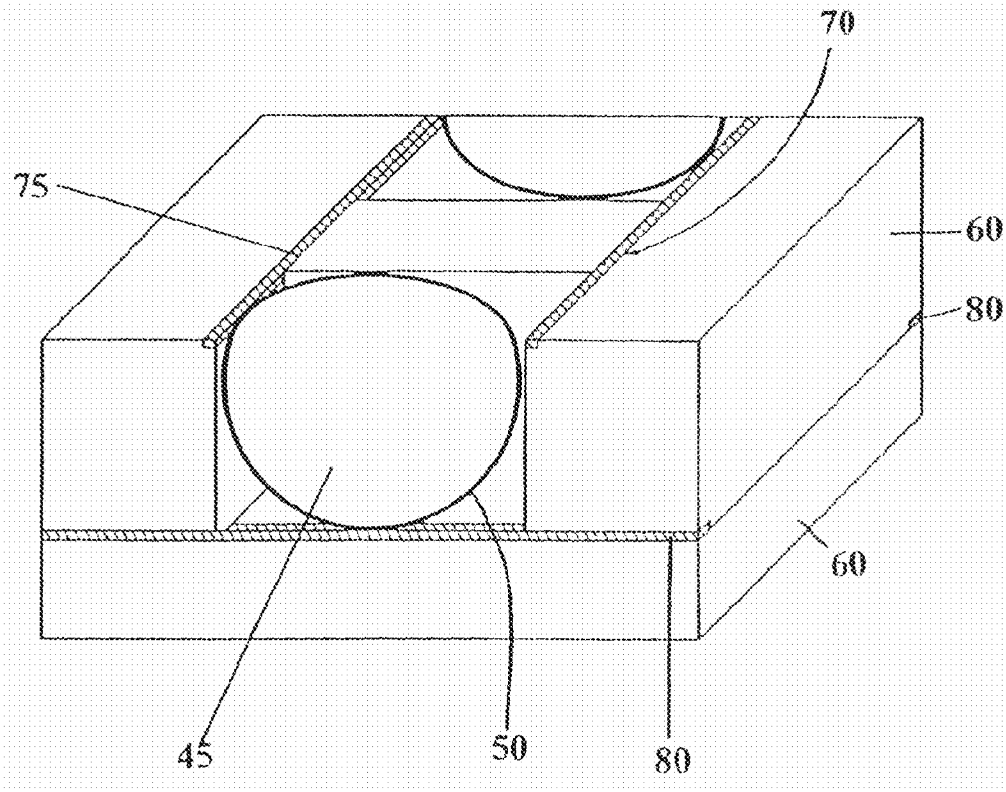


Fig. 7A

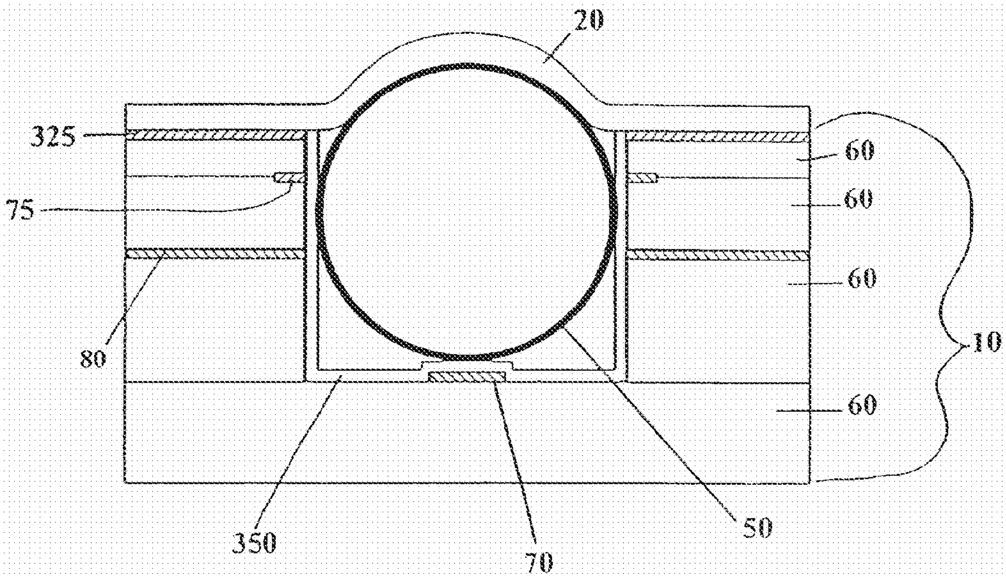


Fig. 7B

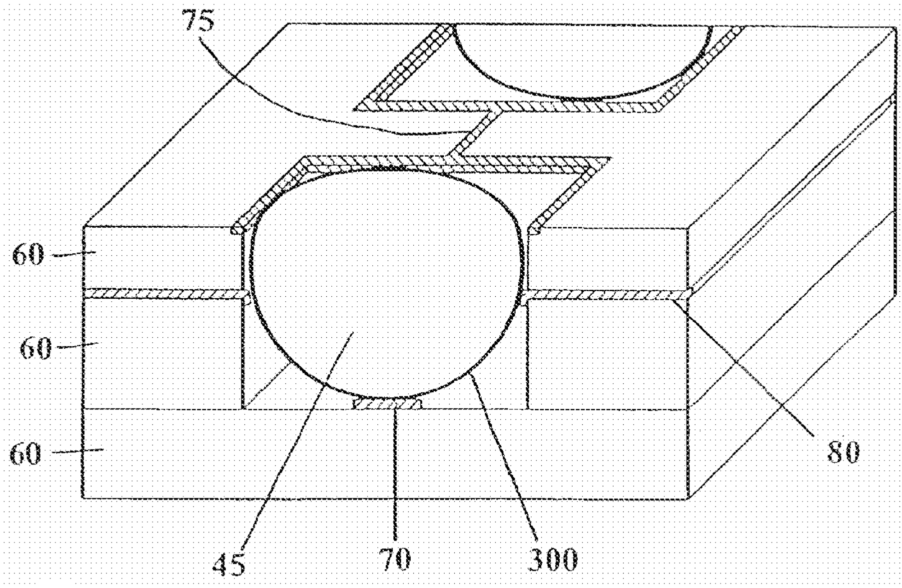


Fig. 8

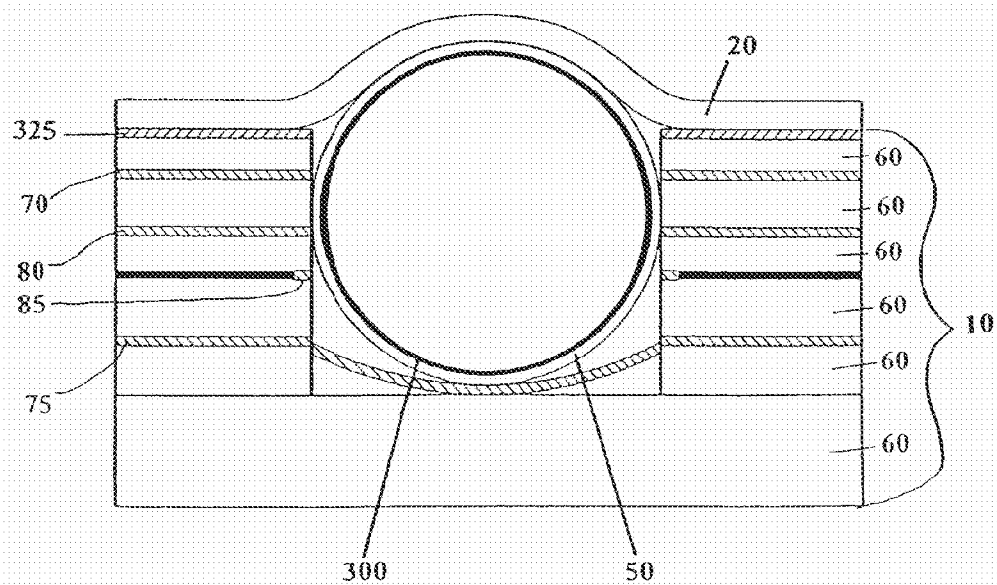


Fig. 9

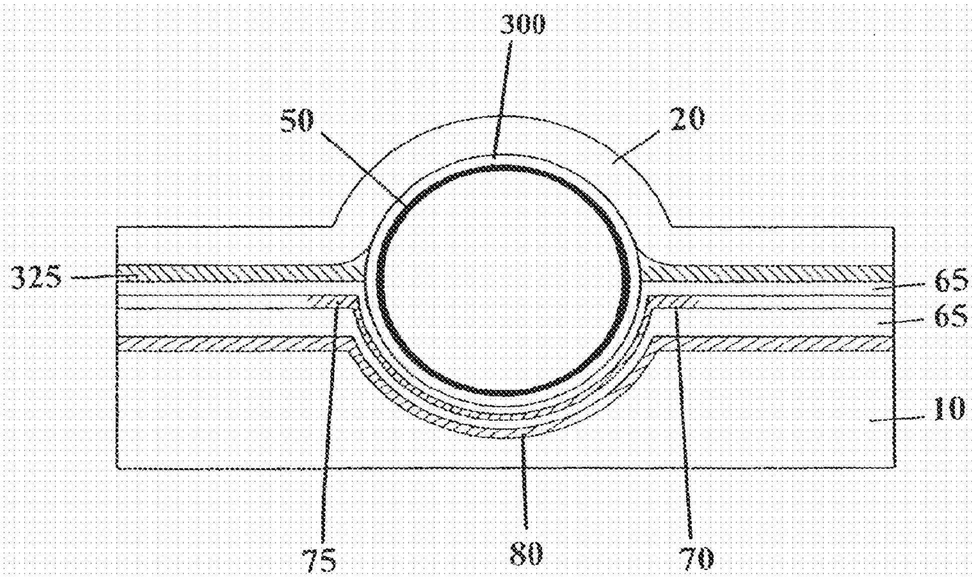


Fig. 10

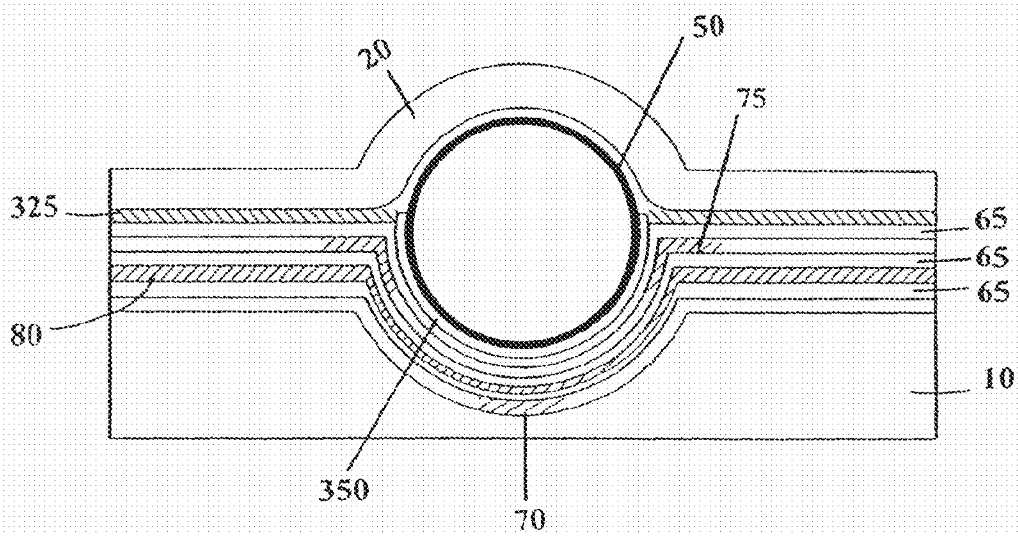
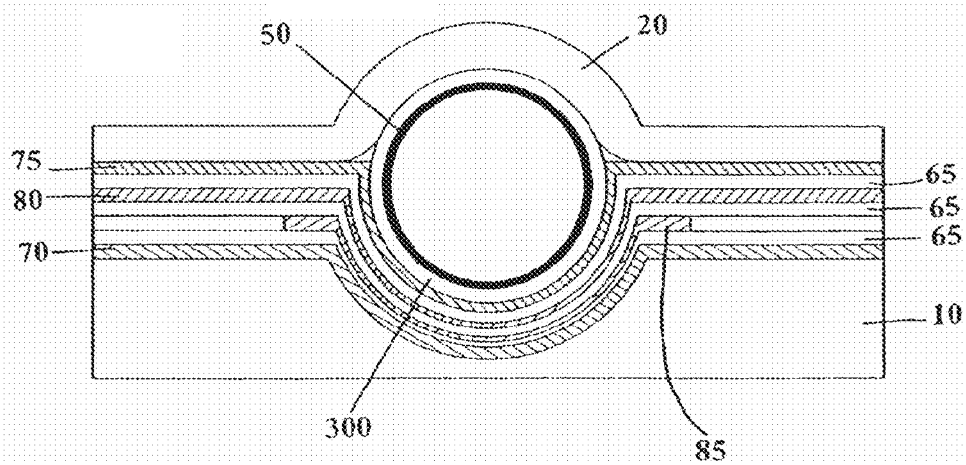
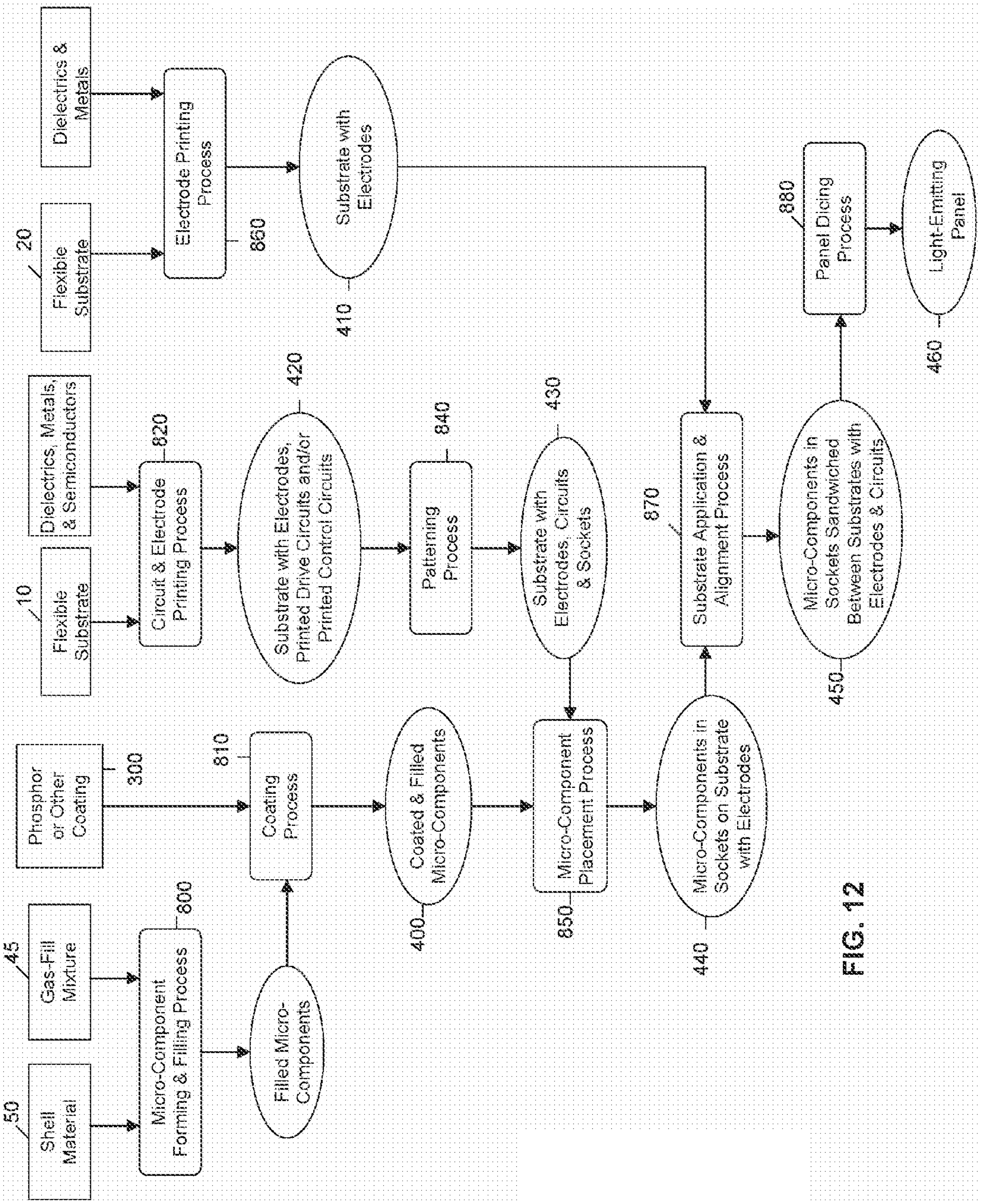


Fig. 11

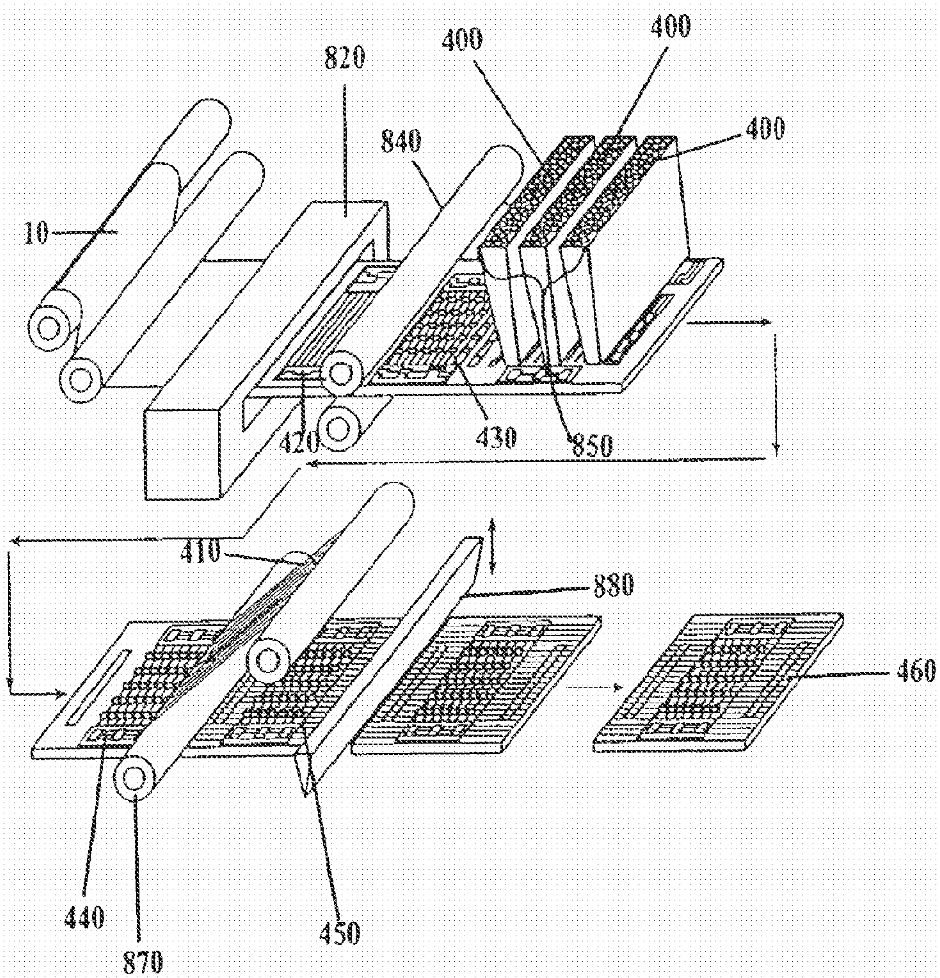




50
Shell Material
45
Gas-Fill Mixture
300
Phosphor or Other Coating
10
Flexible Substrate
Dielectrics, Metals, & Semiconductors
20
Flexible Substrate
Dielectrics & Metals
800
Micro-Component Forming & Filling Process
810
Coating Process
820
Circuit & Electrode Printing Process
860
Electrode Printing Process
Filled Micro-Components
400
Coated & Filled Micro-Components
420
Substrate with Electrodes, Printed Drive Circuits and/or Printed Control Circuits
410
Substrate with Electrodes
840
Patterning Process
850
Micro-Component Placement Process
430
Substrate with Electrodes, Circuits & Sockets
440
Micro-Components in Sockets on Substrate with Electrodes
870
Substrate Application & Alignment Process
450
Micro-Components in Sockets Sandwiched Between Substrates with Electrodes & Circuits
880
Panel Dicing Process
460
Light-Emitting Panel


FIG. 12

Fig. 13



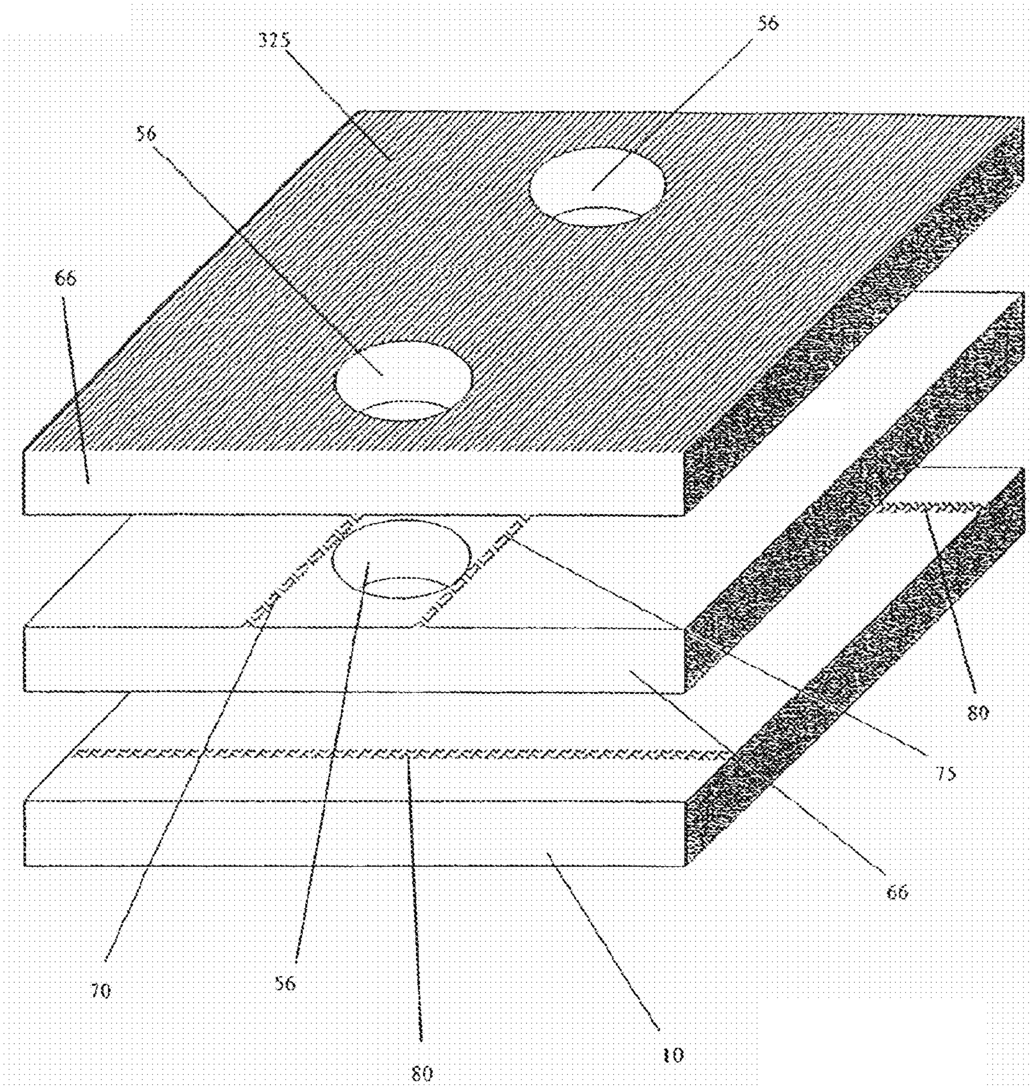



Fig. 14

Fig. 15

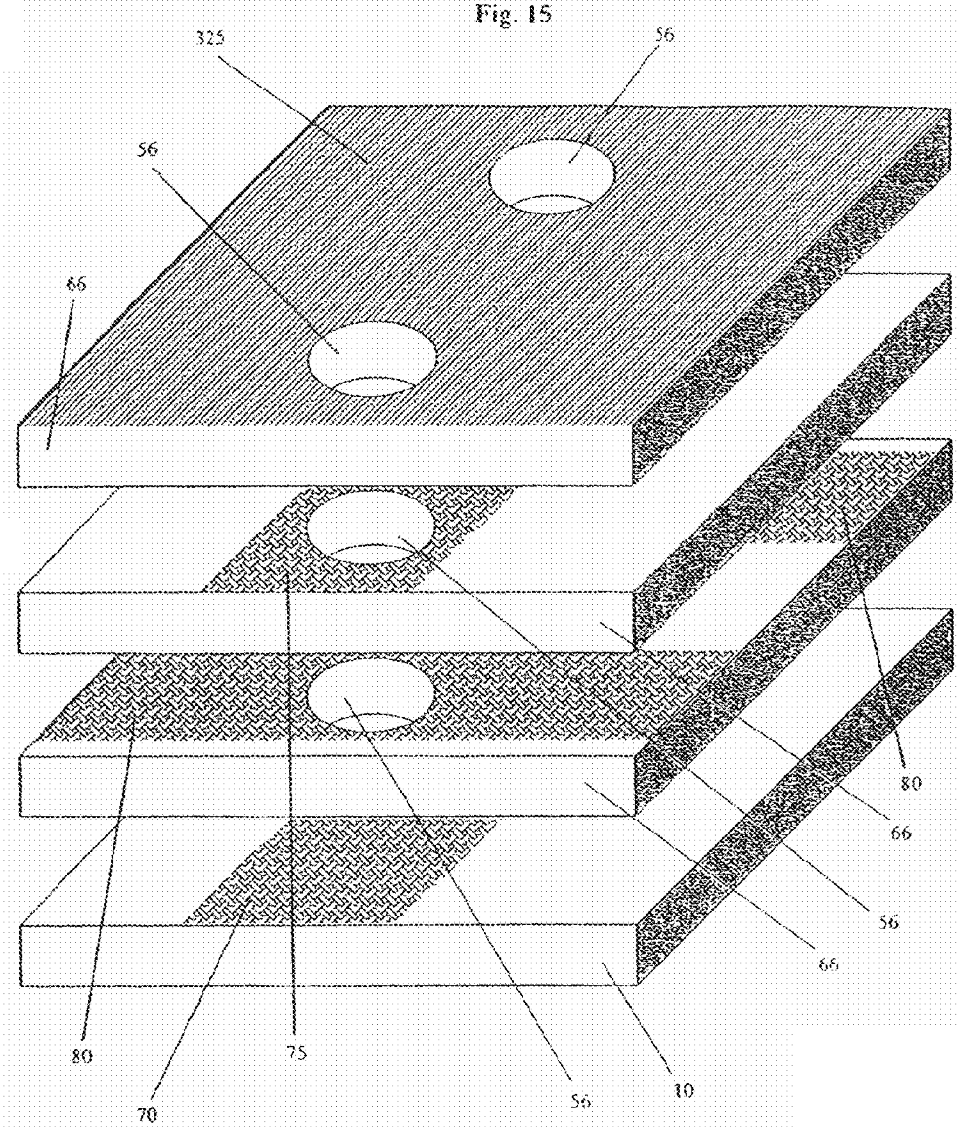
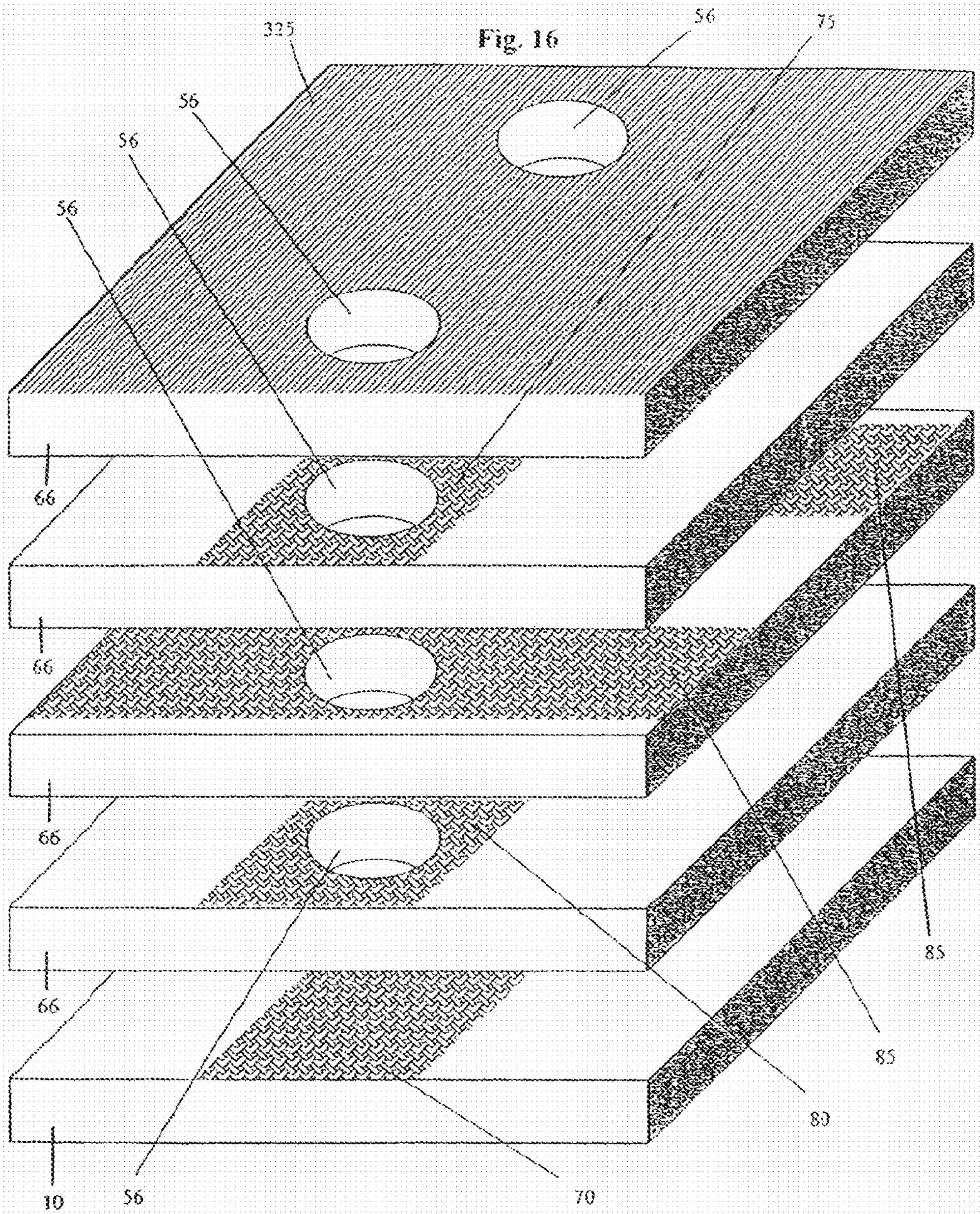


Fig. 16



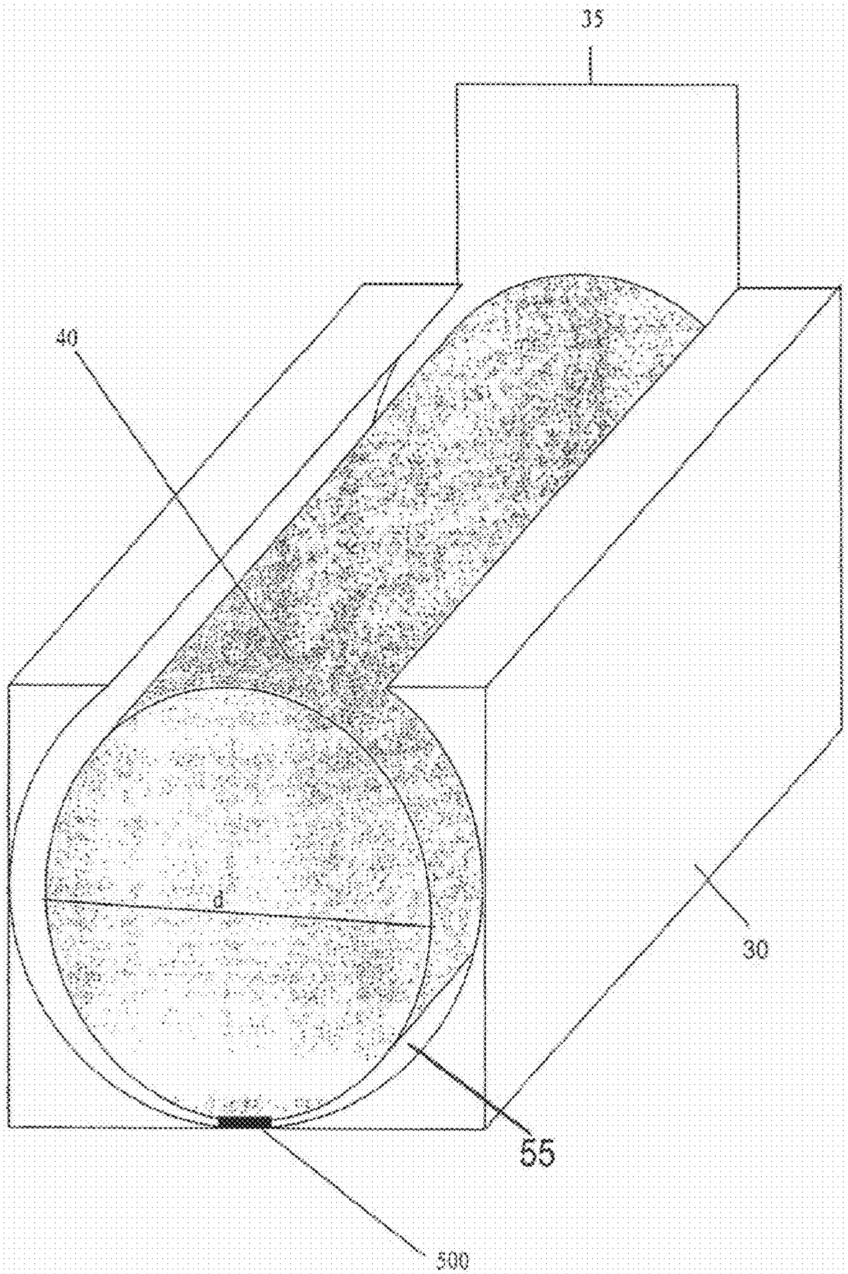



FIG. 17

Fig. 18

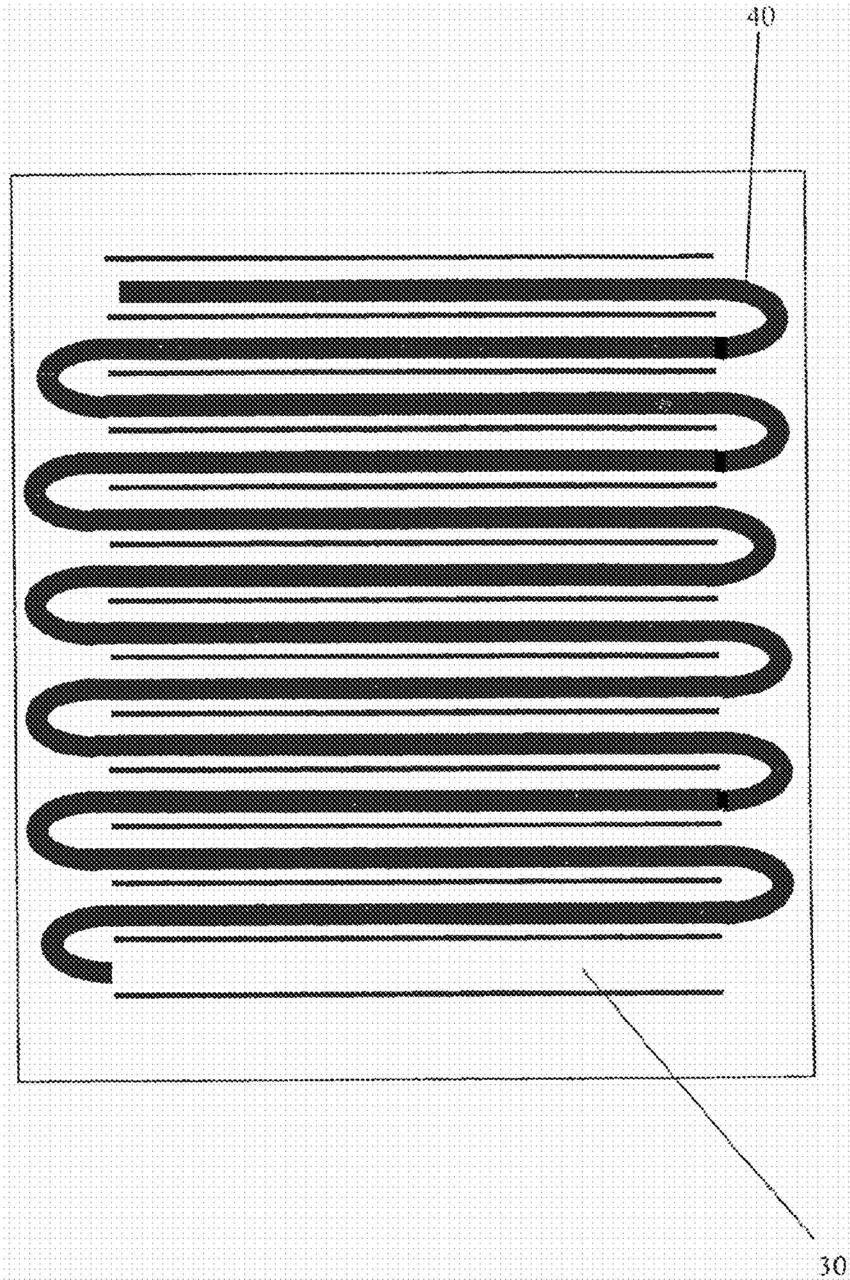
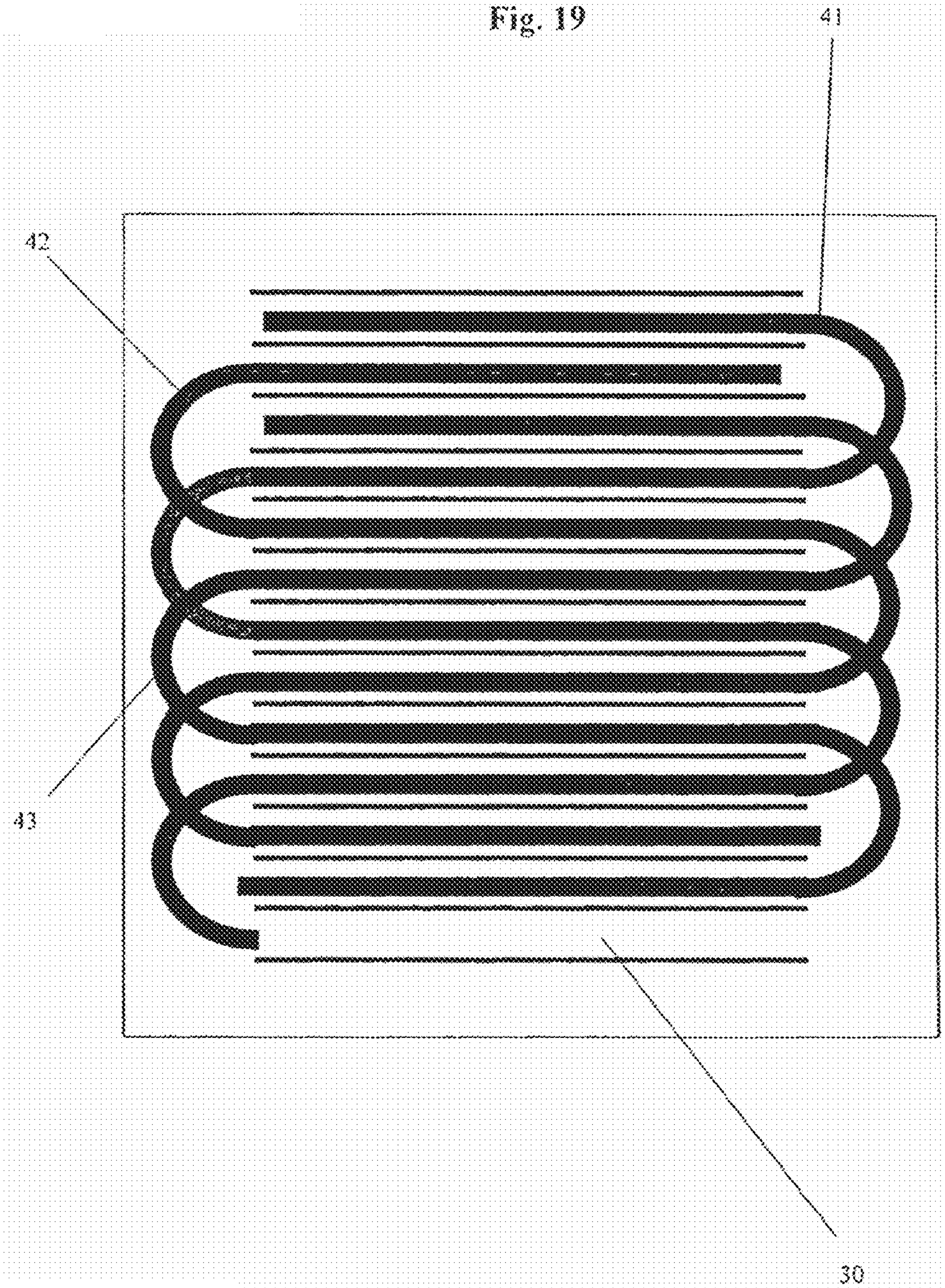


Fig. 19



# LIGHT-EMITTING PANEL AND A METHOD FOR MAKING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 11/527,415 entitled "A Light-Emitting Panel and a Method for Making," filed Sep. 27, 2006 now abandoned, which is a divisional application of application Ser. No. 10/614,049 entitled "A Light-Emitting Panel and a Method for Making," filed Jul. 8, 2003, now U.S. Pat. No. 7,125,305 which is a continuation of application Ser. No. 09/697,344, filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,762,566; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000, now U.S. Pat. No. 6,620,012; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,570,335; and U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use in a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,545,422.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s=V_w-V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In another embodiment of the present invention, at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, at least two electrodes are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In yet another embodiment, disposed in, or proximate to, each socket is at least one enhancement material.

Another preferred embodiment of the present invention is drawn to a web fabrication method for manufacturing light-emitting panels. In an embodiment, the web fabrication process includes providing a first substrate, disposing a plurality of micro-components on the first substrate, disposing a second substrate on the first substrate so the at the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrates to form individual light-emitting panels. In another embodiment, the web fabrication method includes the following process steps: a micro-component forming process; a micro-component coating process; a circuit and electrode printing process; a patterning process; a micro-component placement process; an electrode printing process; a second substrate application and alignment process; and a panel dicing process.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3**A-**3**J, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the first substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17**, and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

The invention claimed is:

**1**. A web fabrication process for manufacturing a plurality of light-emitting panels, comprising:

providing a first substrate comprising a plurality of channels approximately equally space one from another in parallel; and

weaving a first, second and third micro-component through the plurality of channels in an alternate fashion, the first, second and third micro-components each having a cylindrical shape, wherein the first, second and third micro-components are bent in a u-shape at multiple points so as to be woven through the plurality of channels in a continuous fashion; and

providing at least one electrode in contact with each of the first, second and third micro-components, such that each of the first, second and third micro-components is capable of emitting radiation of a different color when the at least one electrode is exposed to a trigger voltage.

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US008246409B2

(12) **United States Patent**
**Green et al.**

(10) **Patent No.: US 8,246,409 B2**
(45) **Date of Patent: Aug. 21, 2012**

(54) **LIGHT-EMITTING PANEL AND A METHOD FOR MAKING**

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( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/212,334**

(22) Filed: **Aug. 18, 2011**

(65) **Prior Publication Data**

US 2011/0300769 A1 Dec. 8, 2011

**Related U.S. Application Data**

(60) Continuation of application No. 12/465,160, filed on May 13, 2009, now Pat. No. 8,043,137, which is a continuation of application No. 11/527,415, filed on Sep. 27, 2006, now abandoned, which is a division of application No. 10/614,049, filed on Jul. 8, 2003, now Pat. No. 7,125,305, which is a continuation of application No. 09/697,344, filed on Oct. 27, 2000, now Pat. No. 6,612,889.

(51) **Int. Cl.**
*H01J 9/00* (2006.01)

(52) **U.S. Cl.** ........................................ **445/24**; 445/25

(58) **Field of Classification Search** ............... 445/24–25
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 1,923,148 | A | 8/1933 | Hotchner | 49/7 |
| 1,961,735 | A | 6/1934 | Braun | 40/130 |
| 2,036,616 | A | 4/1936 | Asch | 176/14 |
| 2,095,291 | A | 10/1937 | Schneider | 40/130 |
| 3,395,301 | A | 7/1968 | Iannelli | 313/25 |
| 3,453,478 | A | 7/1969 | Shoulders et al. | 313/309 |
| 3,559,190 | A | 1/1971 | Blitzer et al. | 340/173 |
| 3,646,384 | A | 2/1972 | Lay | 313/109.5 |
| 3,684,468 | A | 8/1972 | Bode et al. | 65/4 |
| 3,704,052 | A | 11/1972 | Coleman | 316/17 |
| 3,704,386 | A | 11/1972 | Cola | 313/108 R |
| 3,755,027 | A | 8/1973 | Gilsing | 156/67 |
| 3,755,704 | A | 8/1973 | Spindt et al. | 313/309 |
| 3,848,248 | A | 11/1974 | MacIntyre, Jr. | 340/324 M |

(Continued)

FOREIGN PATENT DOCUMENTS

JP 51-150272 12/1976

(Continued)

OTHER PUBLICATIONS

Preliminary Examination Report for Application No. PCT/US01/42805, dated Dec. 2004 (mailing date). Preliminary Examination Report for Application No. PCT/US03/22868, dated Sep. 27, 2004 (mailing date).

(Continued)

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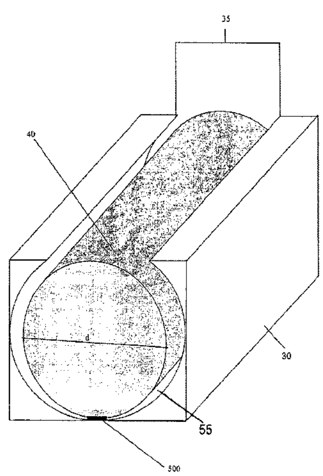
(57) **ABSTRACT**

An improved light-emitting panel having a plurality of micro-components sandwiched between two substrates is disclosed. Each micro-component contains a gas or gas-mixture capable of ionization when a sufficiently large voltage is supplied across the micro-component via at least two electrodes. An improved method of manufacturing a light-emitting panel is also disclosed, which uses a web fabrication process to manufacturing light-emitting displays as part of a high-speed, continuous inline process.

**5 Claims, 22 Drawing Sheets**



## U.S. PATENT DOCUMENTS


| | | | | |
|---|---|---|---|---|
| 3,935,494 | A | 1/1976 | Dick et al. | 313/587 |
| 3,969,651 | A | 7/1976 | Greeson, Jr. | 315/169 TV |
| 3,990,068 | A | 11/1976 | Mayer et al. | 340/324 M |
| 3,998,618 | A | 12/1976 | Kreick et al. | 65/105 |
| 4,027,246 | A | 5/1977 | Caccoma et al. | 235/151.1 |
| 4,035,690 | A | 7/1977 | Roeber | 315/169 TV |
| 4,303,433 | A | 12/1981 | Torobin | 65/21.4 |
| 4,379,301 | A | 4/1983 | Fischbeck | 346/1.1 |
| 4,386,358 | A | 5/1983 | Fischbeck | 346/1.1 |
| 4,393,326 | A | 7/1983 | Kamegaya et al. | 313/582 |
| 4,429,303 | A | 1/1984 | Aboelfotoh | 340/701 |
| 4,459,145 | A | 7/1984 | Elsholz | 65/21.3 |
| 4,534,743 | A | 8/1985 | D'Onofrio et al. | 445/24 |
| 4,554,537 | A | 11/1985 | Dick | 340/775 |
| 4,563,617 | A | 1/1986 | Davidson | 315/312 |
| 4,591,847 | A | 5/1986 | Criscimagna et al. | 340/776 |
| 4,654,561 | A | 3/1987 | Shelton | 315/111.71 |
| 4,658,269 | A | 4/1987 | Rezanka | 346/75 |
| 4,697,123 | A | 9/1987 | Shinoda et al. | 315/169.4 |
| 4,728,864 | A | 3/1988 | Dick | 315/169.3 |
| 4,833,463 | A | 5/1989 | Dick et al. | 340/775 |
| 4,843,281 | A | 6/1989 | Mendelsohn | 313/587 |
| 4,887,003 | A | 12/1989 | Parker | 313/634 |
| 4,890,383 | A | 1/1990 | Lumbard et al. | 438/27 |
| 4,912,364 | A | 3/1990 | Holló et al. | 313/623 |
| 5,019,807 | A | 5/1991 | Stapleton et al. | 340/718 |
| 5,030,888 | A | 7/1991 | Salavin et al. | 315/169.4 |
| 5,062,916 | A | 11/1991 | Aufderheide et al. | 156/269 |
| 5,068,916 | A | 11/1991 | Harrison et al. | 455/39 |
| 5,075,597 | A | 12/1991 | Salavin et al. | 315/169.4 |
| 5,126,632 | A | 6/1992 | Parker | 313/634 |
| 5,150,007 | A | 9/1992 | Andreadakis | 313/586 |
| 5,315,129 | A | 5/1994 | Forrest et al. | 257/21 |
| 5,396,149 | A | 3/1995 | Kwon | 313/486 |
| 5,482,486 | A | 1/1996 | Vaudaine et al. | 445/3 |
| 5,500,287 | A | 3/1996 | Henderson | 428/403 |
| 5,501,871 | A | 3/1996 | Henderson | 427/160 |
| 5,510,678 | A | 4/1996 | Sakai et al. | 315/58 |
| 5,514,934 | A | 5/1996 | Matsumoto et al. | 313/607 |
| 5,674,351 | A | 10/1997 | Lovoi | 156/629.1 |
| 5,675,212 | A | 10/1997 | Schmid et al. | 313/422 |
| 5,686,790 | A | 11/1997 | Curtin et al. | 313/493 |
| 5,703,436 | A | 12/1997 | Forrest et al. | 313/506 |
| 5,707,745 | A | 1/1998 | Forrest et al. | 428/432 |
| 5,721,160 | A | 2/1998 | Forrest et al. | 438/28 |
| 5,725,787 | A | 3/1998 | Curtin et al. | 216/25 |
| 5,746,635 | A | 5/1998 | Spindt et al. | 445/24 |
| 5,747,931 | A | 5/1998 | Riddle et al. | 313/581 |
| 5,755,944 | A | 5/1998 | Haven et al. | 204/486 |
| 5,757,026 | A | 5/1998 | Forrest et al. | 257/40 |
| 5,757,131 | A | 5/1998 | Tsuchiya | 375/582 |
| 5,757,139 | A | 5/1998 | Forrest et al. | 315/169.3 |
| 5,777,782 | A | 7/1998 | Sheridon | 359/296 |
| 5,788,814 | A | 8/1998 | Sun et al. | 204/297 R |
| 5,793,158 | A | 8/1998 | Wedding, Sr. | 313/493 |
| 5,798,604 | A | 8/1998 | Duboc, Jr. et al. | 313/495 |
| 5,808,403 | A | 9/1998 | Clerc | 313/336 |
| 5,811,833 | A | 9/1998 | Thompson | 257/40 |
| 5,815,306 | A | 9/1998 | Sheridon et al. | 359/296 |
| 5,825,451 | A | 10/1998 | Ma et al. | 349/187 |
| 5,837,221 | A | 11/1998 | Bernstein et al. | 424/9.52 |
| 5,844,363 | A | 12/1998 | Gu et al. | 313/506 |
| 5,853,446 | A | 12/1998 | Carre et al. | 65/17.3 |
| 5,862,054 | A | 1/1999 | Li | 364/468.28 |
| 5,865,657 | A | 2/1999 | Haven et al. | 445/24 |
| 5,897,414 | A | 4/1999 | Bergeron et al. | 445/3 |
| 5,898,266 | A | 4/1999 | Spindt et al. | 313/495 |
| 5,913,704 | A | 6/1999 | Spindt et al. | 445/24 |
| 5,914,150 | A | 6/1999 | Porter et al. | 427/77 |
| 5,917,646 | A | 6/1999 | Sheridon | 359/296 |
| 5,920,080 | A | 7/1999 | Jones | 257/40 |
| 5,939,826 | A | 8/1999 | Ohsawa et al. | 313/582 |
| 5,945,174 | A | 8/1999 | Shaw et al. | 427/509 |
| 5,953,587 | A | 9/1999 | Forrest et al. | 438/99 |
| 5,964,630 | A | 10/1999 | Slusarczuk et al. | 445/25 |
| 5,965,109 | A | 10/1999 | Lohrmann | 424/9.52 |
| 5,967,871 | A | 10/1999 | Kaake et al. | 445/24 |
| 5,969,472 | A | 10/1999 | Kisner | 313/484 |
| 5,975,683 | A | 11/1999 | Smith et al. | 347/55 |
| 5,984,747 | A | 11/1999 | Bhagavatula et al. | 445/24 |
| 5,985,460 | A | 11/1999 | Wang et al. | 428/426 |
| 5,986,409 | A | 11/1999 | Farnworth et al. | 315/169.4 |
| 5,990,614 | A | 11/1999 | Spindt | 313/495 |
| 5,990,620 | A | 11/1999 | Lepselter | 313/585 |
| 6,002,198 | A | 12/1999 | Spindt et al. | 313/292 |
| 6,013,538 | A | 1/2000 | Burrows et al. | 438/22 |
| 6,017,584 | A | 1/2000 | Albert et al. | 427/213.3 |
| 6,019,657 | A | 2/2000 | Chakvorty et al. | 445/24 |
| 6,022,652 | A | 2/2000 | Haven et al. | 430/26 |
| 6,023,259 | A | 2/2000 | Howard et al. | 345/76 |
| 6,025,097 | A | 2/2000 | Drumm | 430/7 |
| 6,030,269 | A | 2/2000 | Drumm | 445/52 |
| 6,030,715 | A | 2/2000 | Thompson et al. | 428/690 |
| 6,033,547 | A | 3/2000 | Trau et al. | 204/622 |
| 6,037,710 | A | 3/2000 | Poole et al. | 313/422 |
| 6,037,918 | A | 3/2000 | Hansen et al. | 345/74 |
| 6,038,002 | A | 3/2000 | Song | 349/43 |
| 6,039,619 | A | 3/2000 | Kang et al. | 445/24 |
| 6,045,930 | A | 4/2000 | Thompson et al. | 428/690 |
| 6,046,543 | A | 4/2000 | Bulovic et al. | 313/504 |
| 6,048,469 | A | 4/2000 | Xiang et al. | 252/301.6 R |
| 6,048,630 | A | 4/2000 | Burrows et al. | 428/690 |
| 6,049,366 | A | 4/2000 | Hakemi et al. | 349/86 |
| 6,069,443 | A | 5/2000 | Jones et al. | 313/504 |
| 6,072,276 | A | 6/2000 | Okajima | 313/581 |
| 6,079,814 | A | 6/2000 | Lean et al. | 347/55 |
| 6,080,606 | A | 6/2000 | Gleskova et al. | 438/151 |
| 6,087,196 | A | 7/2000 | Sturm et al. | 438/29 |
| 6,091,195 | A | 7/2000 | Forrest et al. | 313/504 |
| 6,091,380 | A | 7/2000 | Hashimoto et al. | 345/60 |
| 6,091,874 | A | 7/2000 | Higashi et al. | 385/130 |
| 6,097,147 | A | 8/2000 | Baldo et al. | 313/506 |
| 6,130,655 | A | 10/2000 | Lammers | 345/72 |
| 6,137,553 | A | 10/2000 | Izumi et al. | 349/49 |
| 6,201,518 | B1 | 3/2001 | Kane et al. | 345/60 |
| 6,255,777 | B1 | 7/2001 | Kim et al. | 313/582 |
| 6,262,706 | B1 | 7/2001 | Albert et al. | 345/107 |
| 6,265,826 | B1 | 7/2001 | Miyazaki | 313/586 |
| 6,281,863 | B1 | 8/2001 | Sasaki et al. | 345/60 |
| 6,285,129 | B1 | 9/2001 | Park et al. | 313/586 |
| 6,285,434 | B1 | 9/2001 | Ma et al. | 349/189 |
| 6,288,488 | B1 | 9/2001 | Amemiya | 313/582 |
| 6,288,693 | B1 | 9/2001 | Song et al. | 345/68 |
| 6,291,925 | B1 | 9/2001 | Jacobson | 310/319 |
| 6,292,159 | B1 | 9/2001 | Someya et al. | 345/60 |
| 6,292,160 | B1 | 9/2001 | Mikoshiba et al. | 345/60 |
| 6,295,040 | B1 | 9/2001 | Nhan et al. | 345/60 |
| 6,296,539 | B1 | 10/2001 | Awaji et al. | 445/24 |
| 6,297,590 | B1 | 10/2001 | Nanto et al. | 313/586 |
| 6,300,152 | B1 | 10/2001 | Kim | 438/30 |
| 6,300,932 | B1 | 10/2001 | Albert | 345/107 |
| 6,304,031 | B1 | 10/2001 | Wani et al. | 313/582 |
| 6,304,032 | B1 | 10/2001 | Asano | 313/582 |
| 6,304,238 | B1 | 10/2001 | Tsuchida | 345/87 |
| 6,307,319 | B1 | 10/2001 | Lee | 313/590 |
| 6,312,304 | B1 | 11/2001 | Duthaler et al. | 445/24 |
| 6,312,971 | B1 | 11/2001 | Amundson et al. | 438/99 |
| 6,319,325 | B1 | 11/2001 | Hiratsuka et al. | 118/718 |
| 6,322,010 | B1 | 11/2001 | Sasaki et al. | 239/568 |
| 6,527,964 | B1 | 3/2003 | Smith et al. | 216/19 |
| 6,545,422 | B1 | 4/2003 | George et al. | 315/169.3 |
| 6,570,335 | B1 | 5/2003 | George et al. | 315/169.3 |
| 6,612,889 | B1 | 9/2003 | Green et al. | 445/24 |
| 6,762,566 | B1 | 7/2004 | George et al. | 315/169.3 |
| 6,822,626 | B2 | 11/2004 | George et al. | 345/60 |
| 6,864,631 | B1 | 3/2005 | Wedding | 313/587 |
| 7,137,857 | B2 | 11/2006 | George et al. | 445/24 |
| 7,140,941 | B2 | 11/2006 | Green et al. | 445/24 |
| 2001/0008825 | A1 | 7/2001 | Toyoda et al. | 445/24 |
| 2001/0033256 | A1 | 10/2001 | Moore | 345/60 |
| 2001/0053570 | A1 | 12/2001 | Kido | 438/149 |
| 2002/0008470 | A1 | 1/2002 | Uegaki et al. | 313/567 |
| 2002/0009536 | A1 | 1/2002 | Iguchi et al. | 427/10 |
| 2002/0016075 | A1 | 2/2002 | Peng et al. | 438/700 |
| 2002/0017864 | A1 | 2/2002 | Watanabe et al. | 313/586 |
| 2002/0022565 | A1 | 2/2002 | Sreeram et al. | 501/16 |
| 2002/0024295 | A1 | 2/2002 | Miyashita et al. | 313/495 |

| | | | | |
|---|---|---|---|---|
| 2002/0195936 | A1 | 12/2002 | Kato et al. | 313/582 |
| 2003/0073372 | A1 | 4/2003 | Nakatake et al. | 445/25 |
| 2003/0094891 | A1 | 5/2003 | Green et al. | 313/495 |
| 2003/0164684 | A1 | 9/2003 | Green et al. | 313/582 |
| 2004/0175854 | A1 | 9/2004 | George et al. | 438/30 |
| 2005/0095944 | A1 | 5/2005 | George et al. | 445/3 |
| 2006/0205311 | A1 | 9/2006 | Green et al. | 445/24 |
| 2007/0015431 | A1 | 1/2007 | Green et al. | 445/24 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| JP | 53-063972 | 6/1978 |
| JP | 4-287397 | 10/1992 |
| JP | 10-3869 | 1/1998 |
| JP | 11-162358 | 6/1999 |
| KR | 1998-077351 | 11/1998 |
| WO | WO 00/36465 | 6/2000 |
| WO | WO 02/35510 | 5/2002 |

OTHER PUBLICATIONS

International Search Report for Application No. PCT/US03/22868, dated Jun. 1, 2004 (mailing date).
Written Opinion for Application No. PCT/US01/42805, dated Apr. 2, 2004 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42803, dated Sep. 2003 (mailing date).
Preliminary Examination Report for Application No. PCT/US01/42782, dated Jun. 4, 2003 (mailing date).
International Search Report for Application No. PCT/US01/42805, dated Apr. 3, 2003 (mailing date).
Written Opinion for Application No. PCT/US01/42782, dated Dec. 31, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42803, dated Dec. 9, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
Preliminary Examination Report for U.S. Application No. PCT/US01/42807, dated Dec. 8, 2002 (mailing date).
Jacobson, et al., "The Last Book" [online], *IBM Systems Journal*, vol. 36, No. 3, 1997 [retrieved on Dec. 4, 2002], 6 pp., Retrieved from the Internet: http://www.research.ibm.com/journal/sj/363/Jacobson.html.
Peterson, "Rethinking Ink" [online], *Science News*, vol. 153, No. 25, Jun. 20, 1998 [retrieved on Dec. 4, 2002], 7 pp., Retrieved from the Internet: http://www.sciencenews.org/sn_arc98/6_20_98/bob2.htm.
Franjione, et al., "The Art and Science of Microencapsulation" [online] *Technology Today*, Summer, 1995 [retrieved on Dec. 4, 2002], 10 pp., Retrieved from the Internet: http://www.swri.edu/3pubs/ttoday/summer95/microeng.htm.
International Search Report for Application No. PCT/US01/51439, dated Sep. 23, 2002 (mailing date).
Written Opinion for Application No. PCT/US01/42807, dated Sep. 17, 2002 (mailing date).
International Search Report for Application No. PCT/US01/42807, dated May 20, 2002 (mailing date).
Sheats, James, "Introduction to Organic Light-Emitting Diodes (OLEDs)" [online], [retrieved on May 9, 2002], 8 pp., Retrieved from the Internet: http://www.rolltronics.com/intro_oled.htm.
Sauvante, Michael, "Roll-to-Roll Manufacturing" [online], [retrieved on May 9, 2002], 4 pp., Retrieved from the Internet: http://www.rolltronics.com/roll2roll.htm.
International Search Report for Application No. PCT/US01/42782, dated Apr. 11, 2002 (mailing date).
Veronis, Georgios and Inan, Umran S., "Optimization of the Luminous Efficiency of Plasma Display Panels Using Numerical Modeling" [online], [retrieved on Mar. 13, 2002], 8 pp., Retrieved from the Internet: http://www-star.stanford.edu/~vlf/plasma_display/index.htm.
"Runco PlasmaWall Systems with Vivex Processing" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/Default.htm.
"Runco PlasmaWall PL-42cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL42cx.htm.
"Runco PlasmaWall Pl-50c" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL50c.htm.
"Runco PlasmaWall™ PL-61cx" [online], Copyright 2001 [retrieved on Jan. 17, 2002], 2 pp., Retrieved from the Internet: http://www.runco.com/Products/Plasma/PL61.htm.
"Electronics & Telecommunications" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lg.co.kr/English/company/electronic/index.jsp?code=A3.
"New Product" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 1 p., Retrieved from the Internet: http://www.lge.com.
"Monitor" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.lgeus.com/Product/Monitor/newmonitors.asp.
"LG Electronics Introduces 42-Inch Digital PDP TV" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.as?nSeqno=22.
"LG PDP Now Available at World Renowned Harrods Department Store" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqno21.
"LG Electronics—To the Top in PDP Business" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=16&type=&word=.
"LG Electronics Becomes First in Korea to Export PDP Module" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=19&type=&word=.
"LG Electronics Becomes the First in Korea to Export PDP" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=14&type=&word=.
"LG Electronics Held the Ceremony for the Completion of the PDP Factory" [online], LG Electronics, Copyright 2001 [retrieved on Nov. 7, 2001], 2 pp., Retrieved from the Internet: http://www.pdpdisplay.com/eng/news/e_read.asp?nSeqNo=13&type=&word.
Smilgys, Russell, et al., "Progress Toward Roll Processing of Solar Reflective Material," *Proceedings of Solar Forum 2001 Solar Energy: The Power to Choose*, Washington, DC, 8 pp., Apr. 21-25, 2001.
Srinivasan, Uthara, et al., "Microstructure to Substrate Self-Assembly Using Capillary Forces," *Nournal of Microelectromechanical Systems*, vol. 10, No. 1, Mar. 2001, pp. 17-17-24.
Chutinan, Alongkarn and Noda, Susumu, "Waveguides and Waveguide Bends in Two-Dimensional Photonic Crystal Slabs," *The American Physical Society*, vol. 62, No. 7, 5 pp., Aug. 15, 2000.
"Rolltronics" [online], Feb. 20, 2000 [retrieved on Mar. 12, 2000], 13 pp., Retrieved from the Internet: http://www.rolltronics.com.
Alien Technology Corporation's Technology Overview, Copyright © 2000, Alien Technology™, http://www.alientechnology.com/d/technology/overview.html.
Anonymous, "Alien Technology Corporation White Paper—Fluidic Self Assembly," Alien Technology Corp., Oct. 1999, pp. 1-7.
Kurihara, M., Makabe, T., "Two-Dimensional Modeling of a Micro-Cell Plasma in Xe Driven by High Frequency," *IEEE Transactions on Plasma Science*, vol. 27, No. 5, Oct. 1999, pp. 1372-1378.
Rauf, S., Kushner, M. J., "Operation of a Coplanar-Electrode Plasma Display Panel Cell," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 10-11.
Shin, Y. K., Lee, J. K., Shon, C. H., "Two-Dimensional Breakdown Characteristics of PDP Cells for Varying Geometry," *IEEE Transactions on Plasma Science*, vol. 27, No. 1, Feb. 1999, pp. 14-15.
"Transparent Conductive Coatings," Copyright 1998, 4 pp.
Lin, Yi-Zhen, et al., "A New Method of Analyzing the Light Transmission in Leaky and Absorbing Planar Waveguides," *IEEE Photonics Technology Letters*, vol. 9, No. 9, Sep. 1997, pp. 1241-.
Stearns, Thomas H., "Flexible Printed Circuitry," 6 pp., 1996.
"Flat Panel Displays in Perspective," 44 pp., Sep. 1995.

Fig. 1

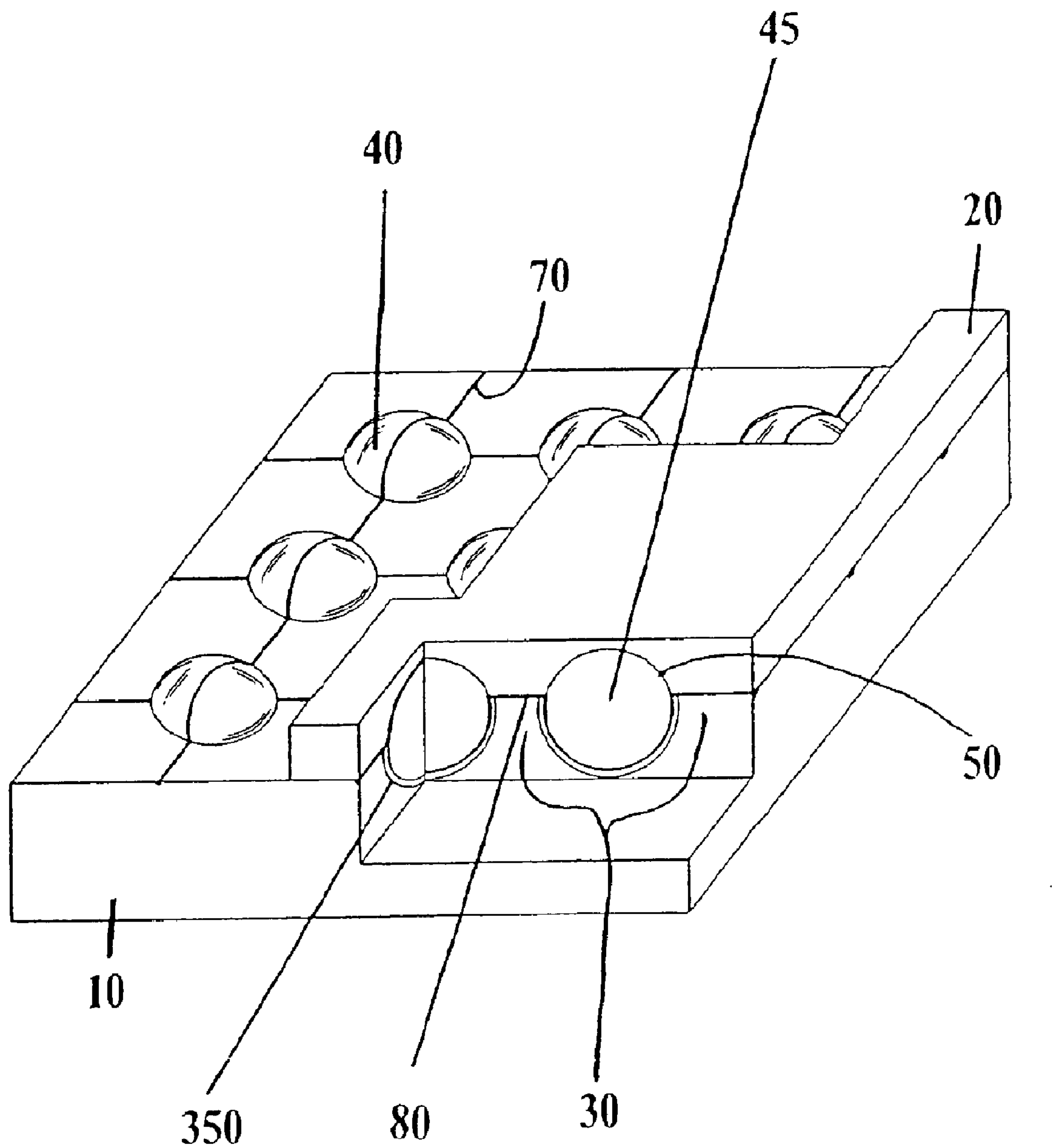
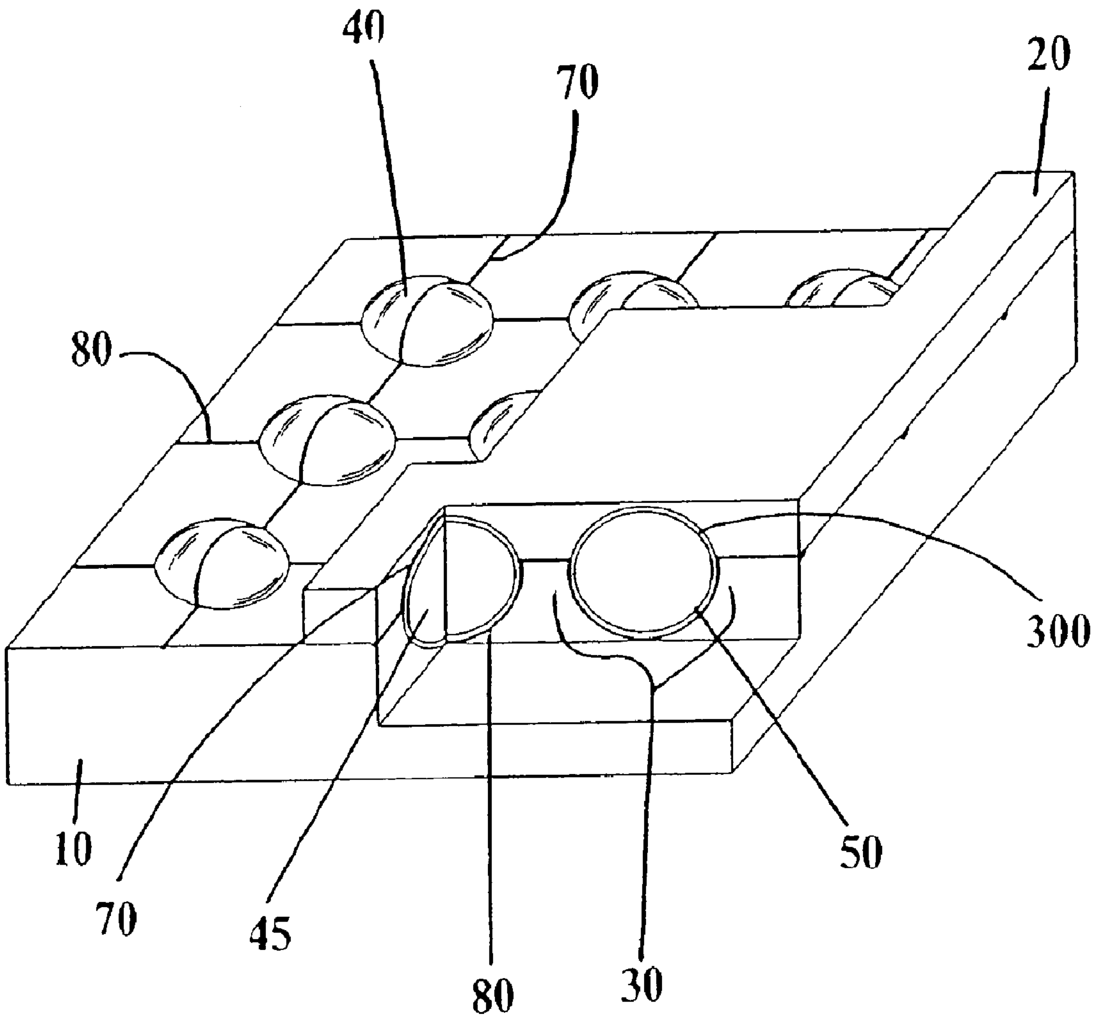


Fig. 2



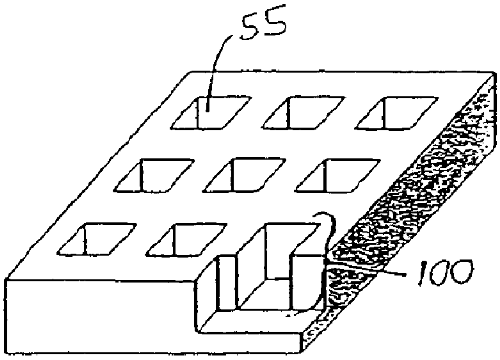



Fig. 3 A

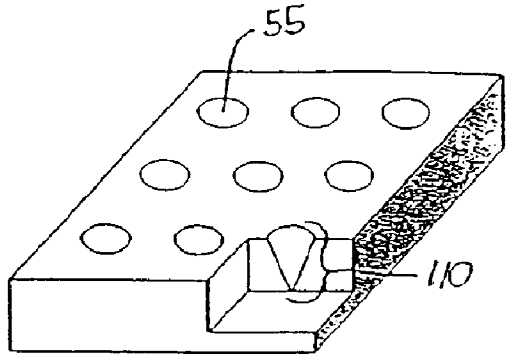



Fig. 3 B

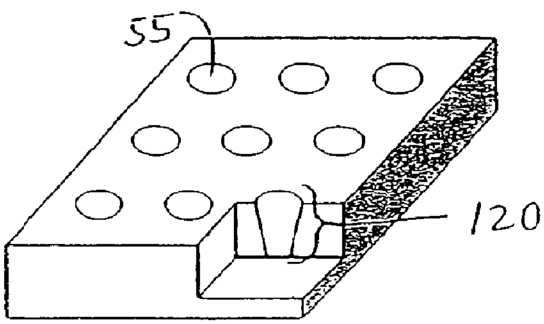



Fig. 3C

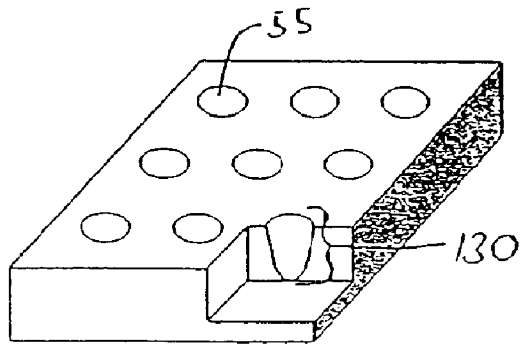



Fig 3D

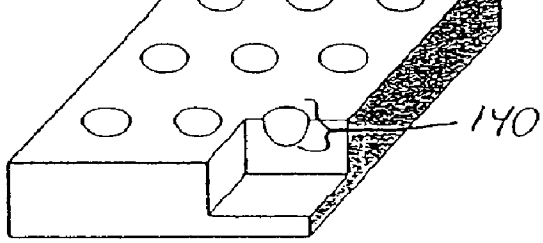



Fig 3E

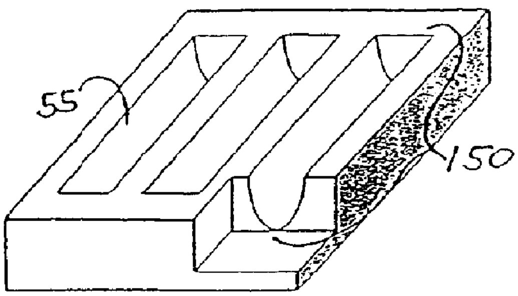



Fig. 3F

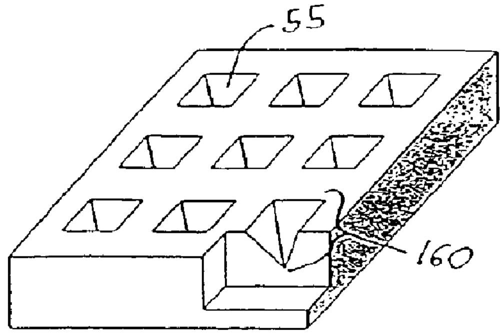



Fig. 3G

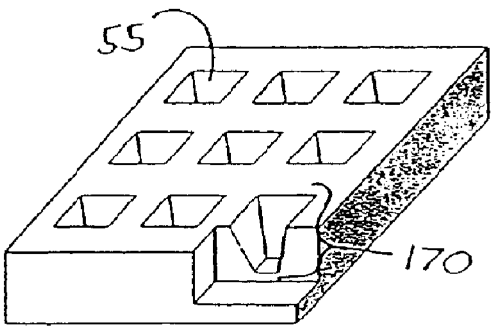



Fig. 3H

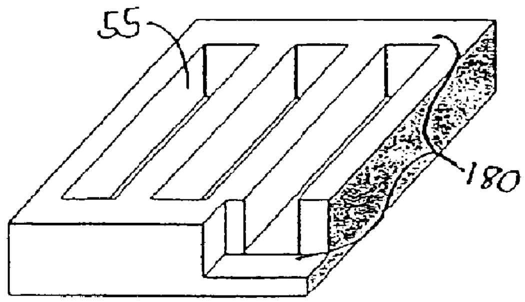



Fig. 3I

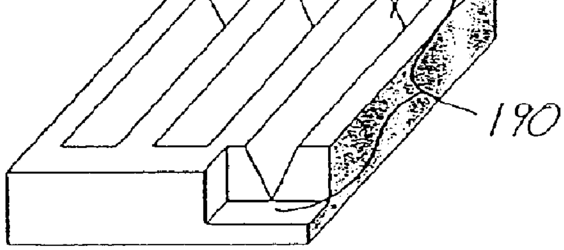



Fig. 3J

Fig. 4

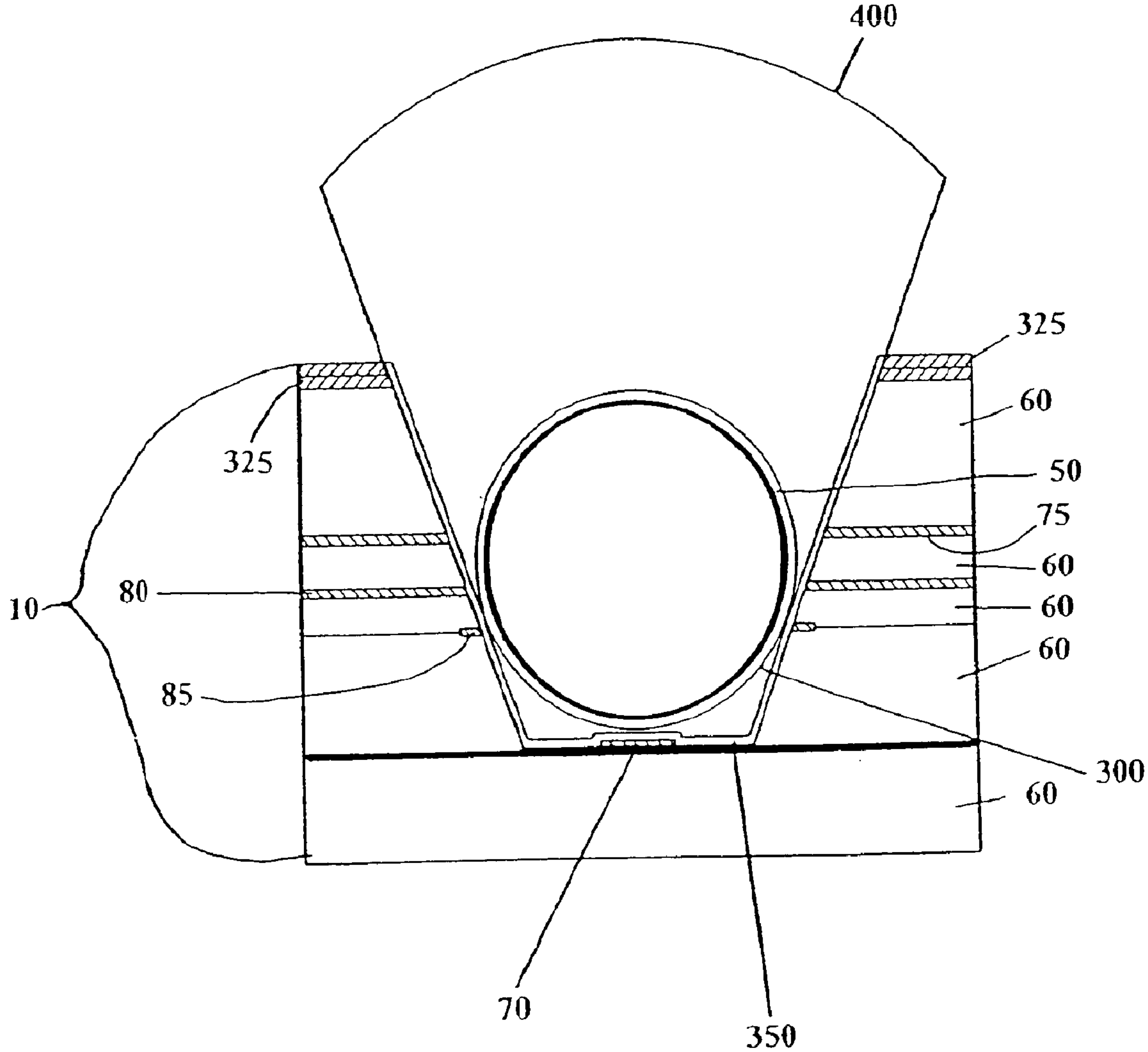


Fig. 5

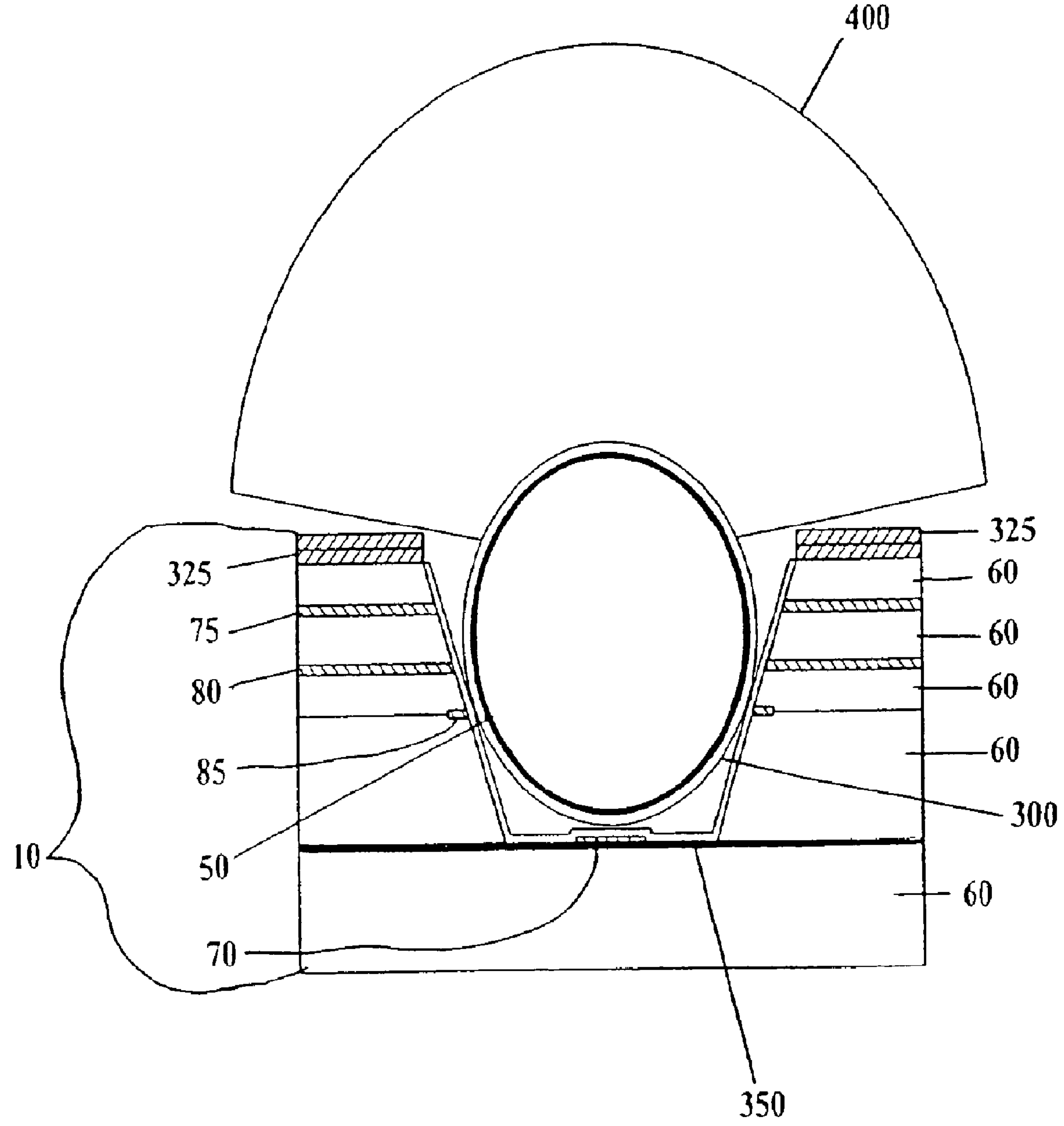


Fig. 6A

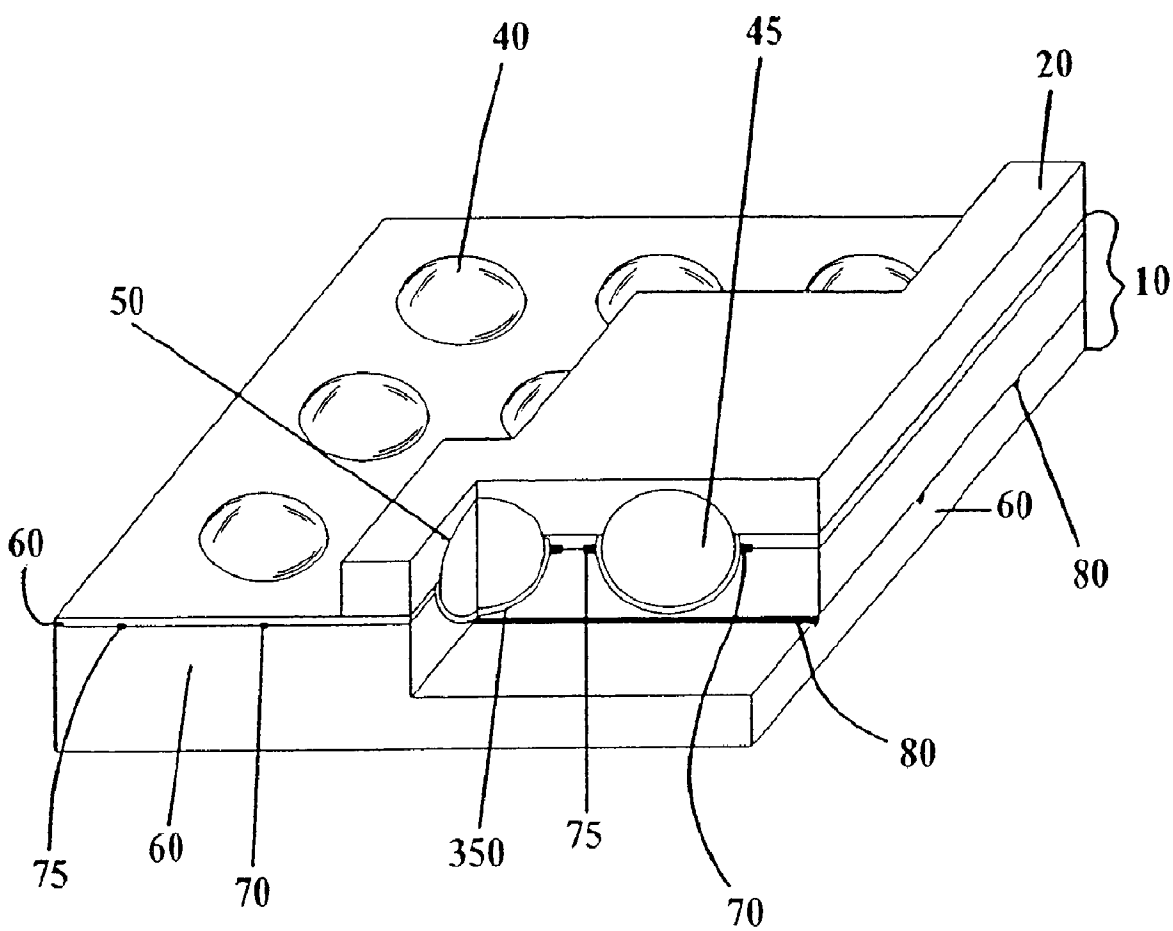


Fig. 6B

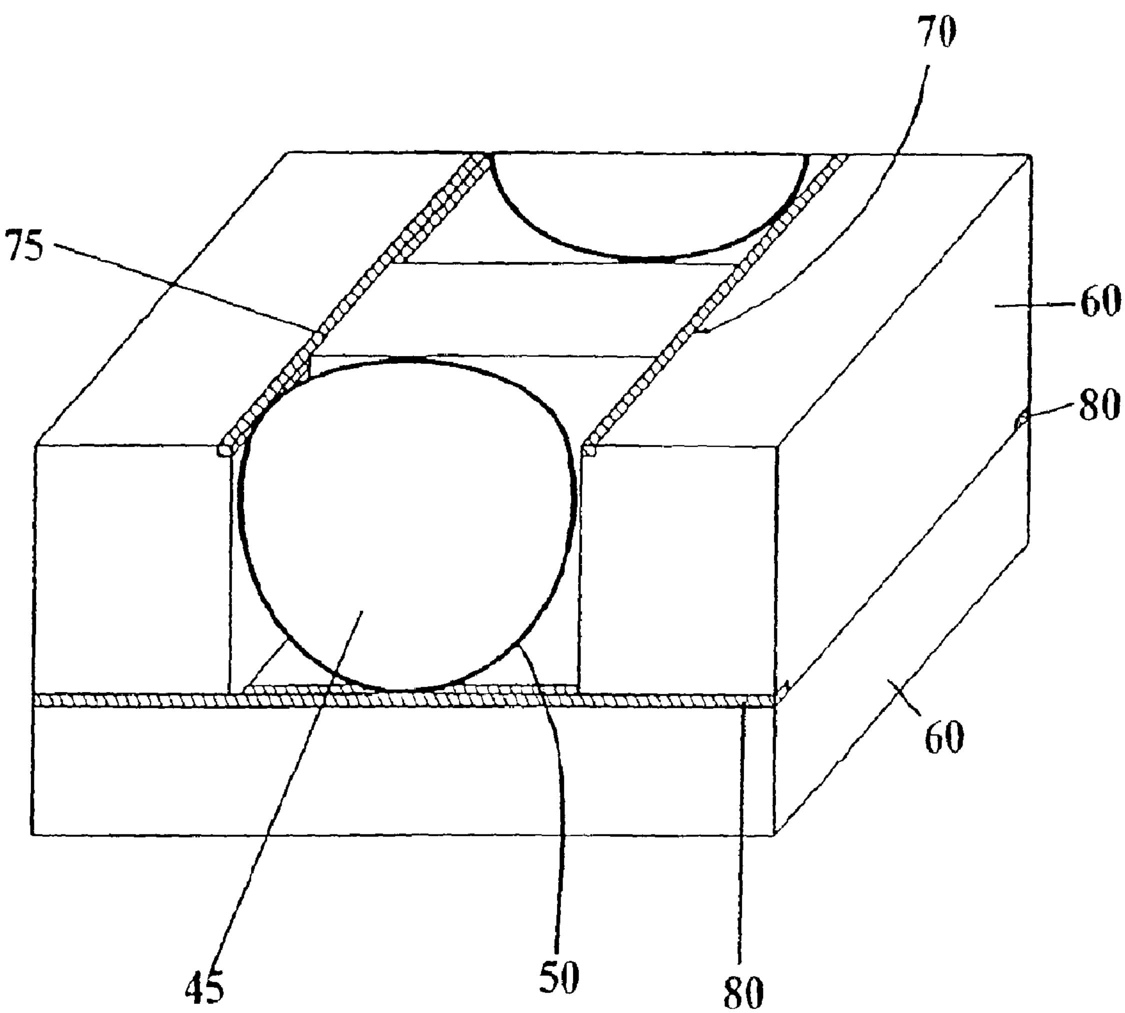


Fig. 7A

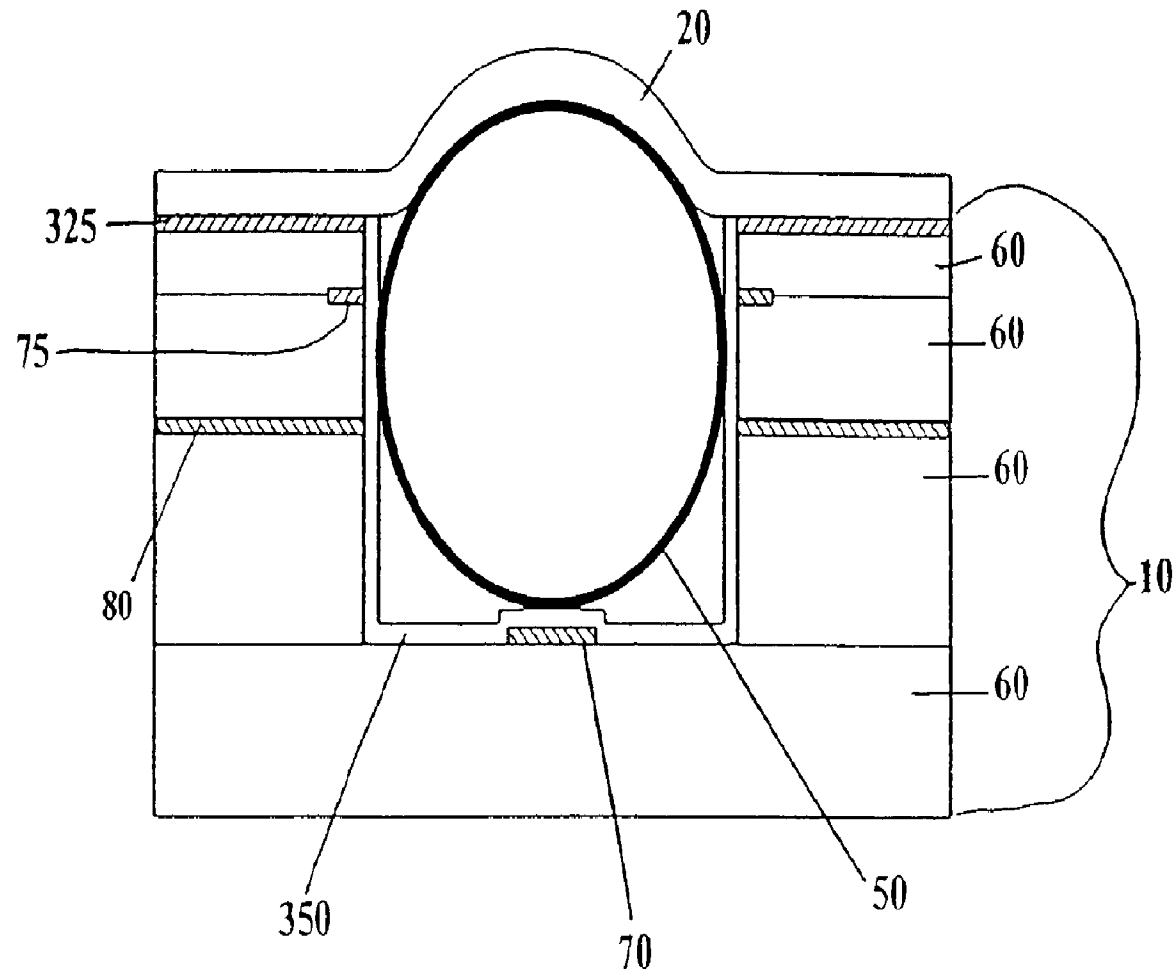


Fig. 7B

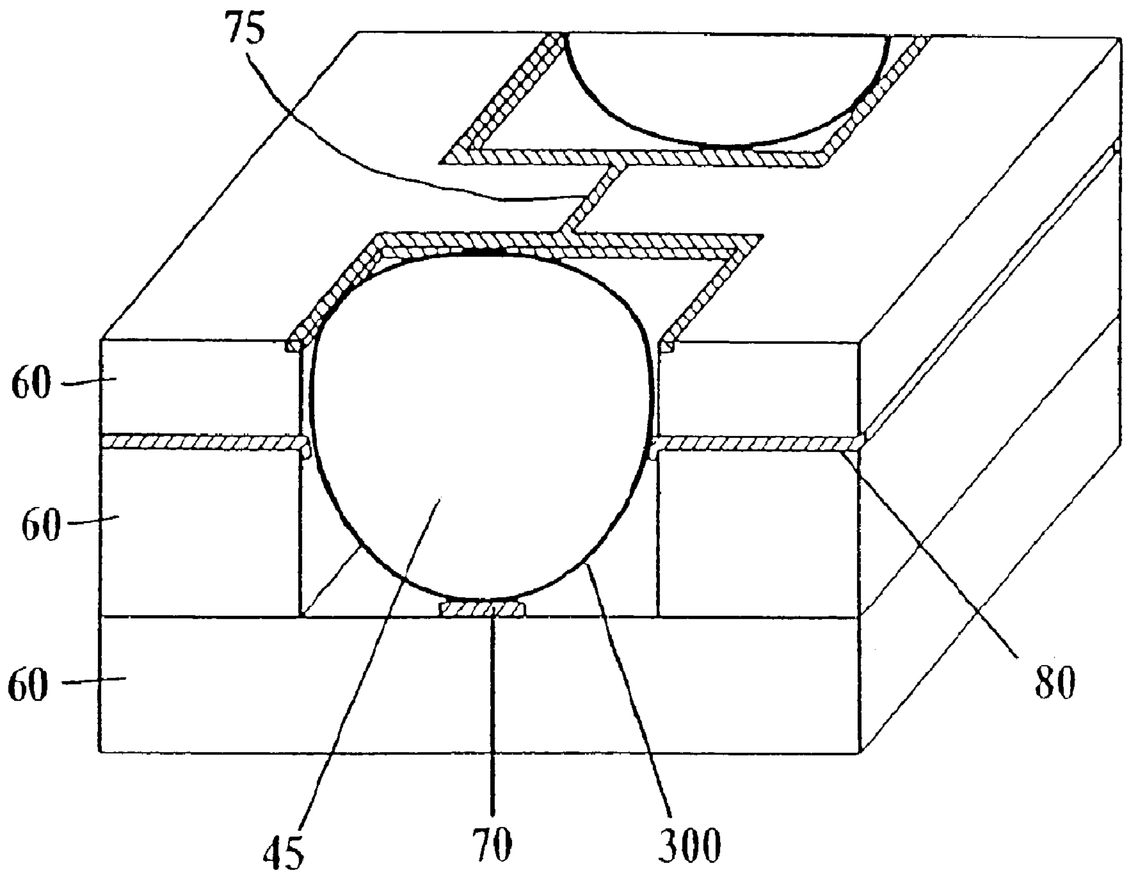


Fig. 8

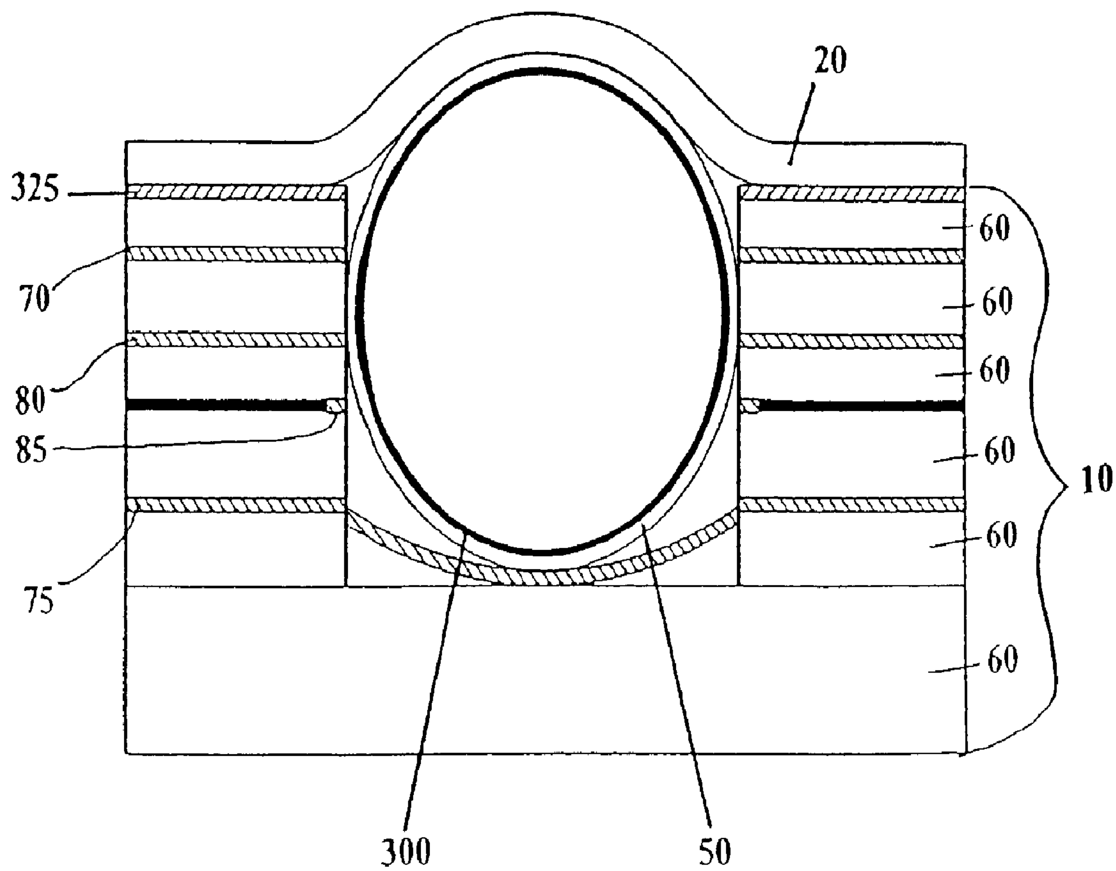


Fig. 9

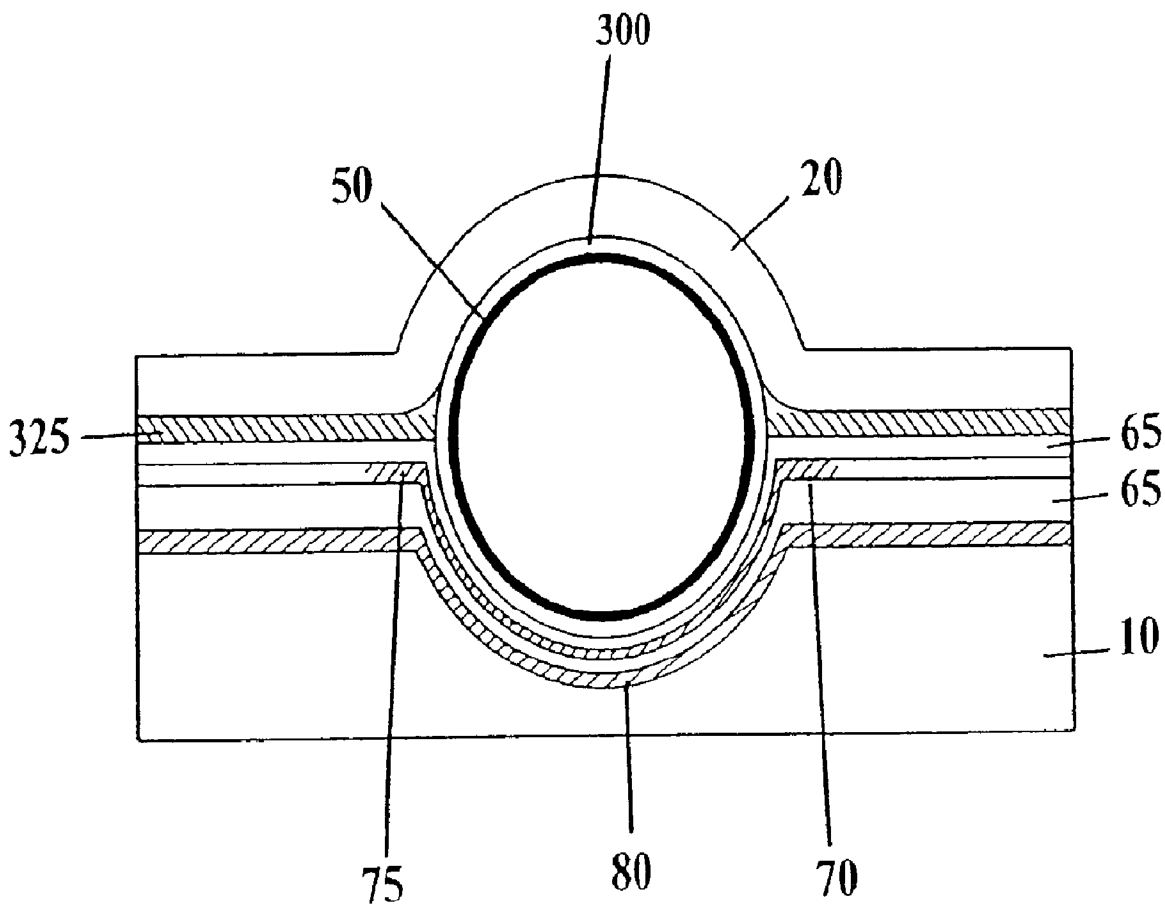


Fig. 10

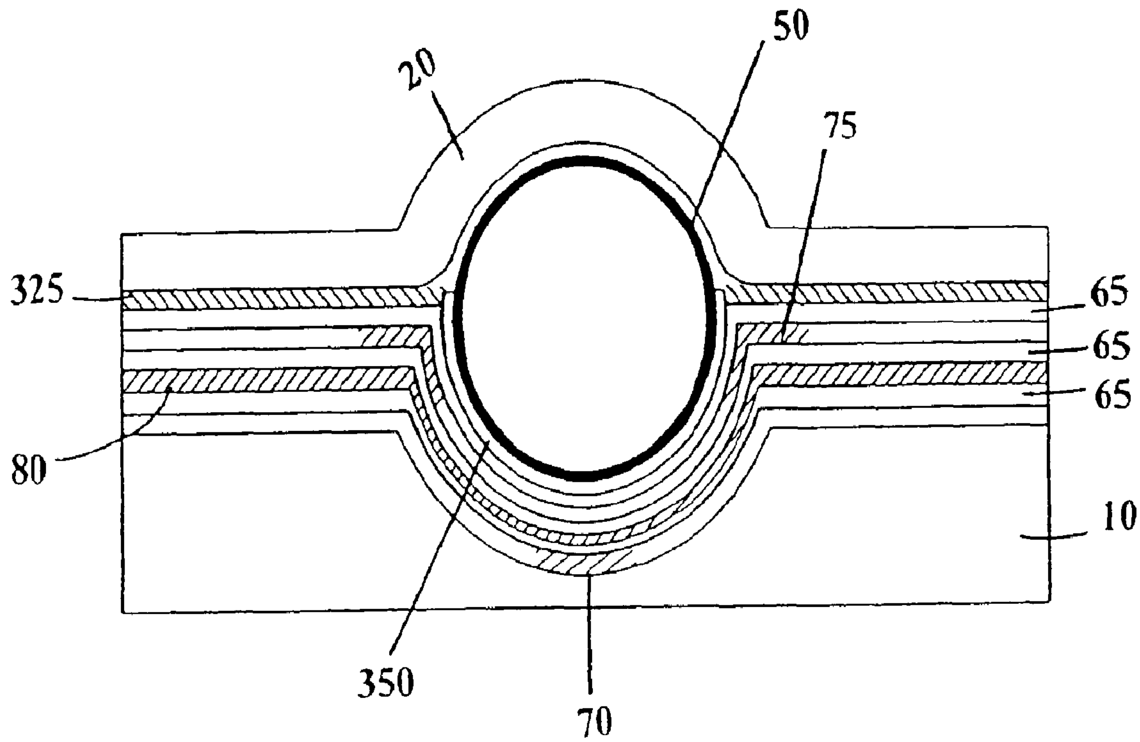
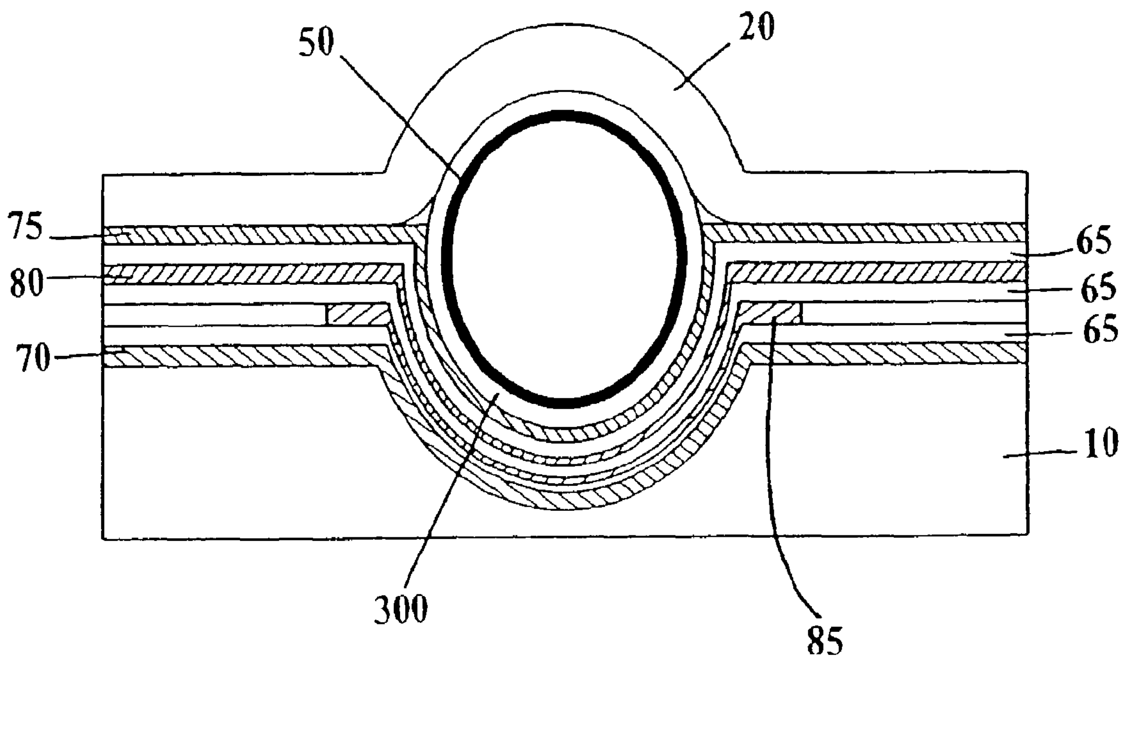


Fig. 11



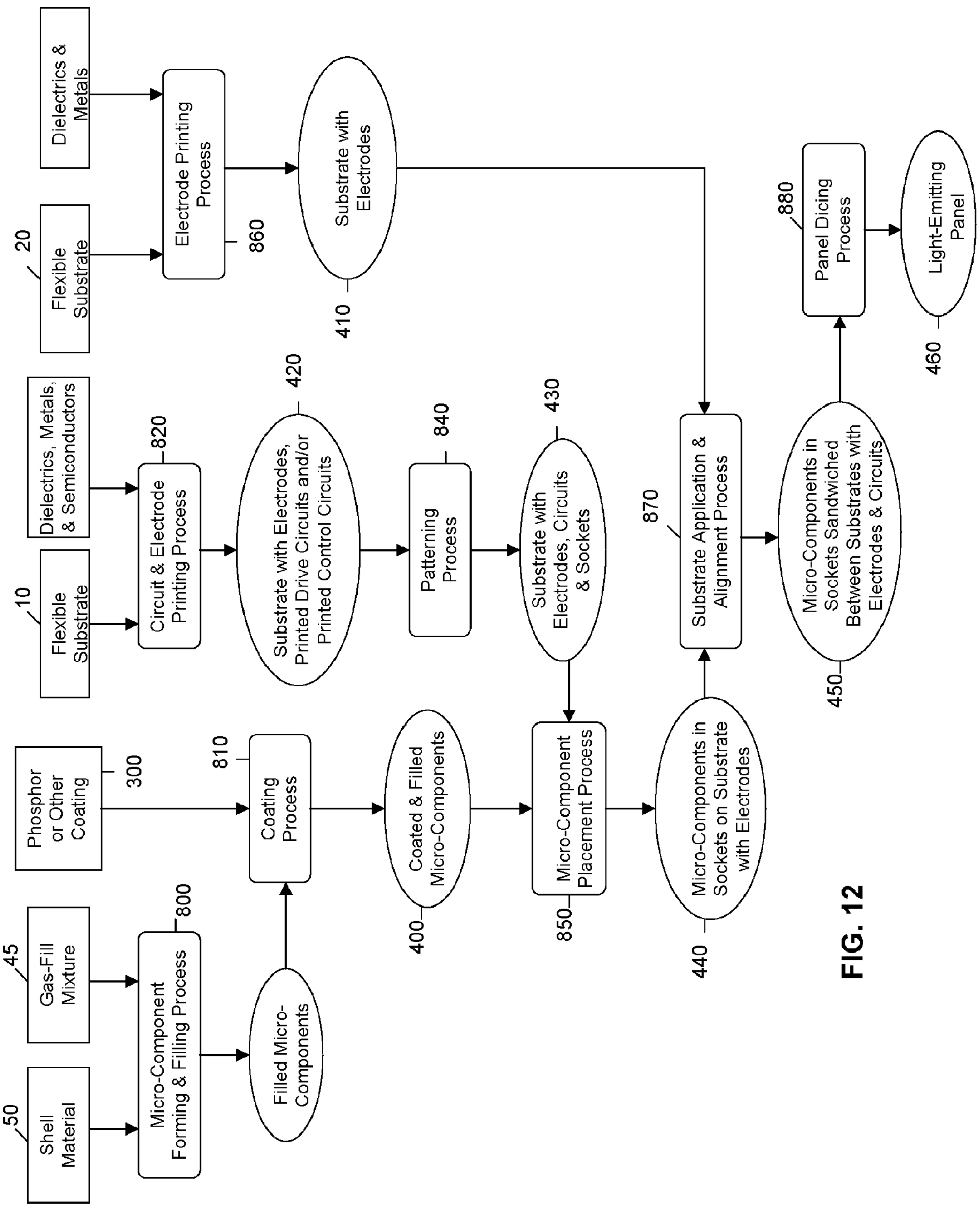
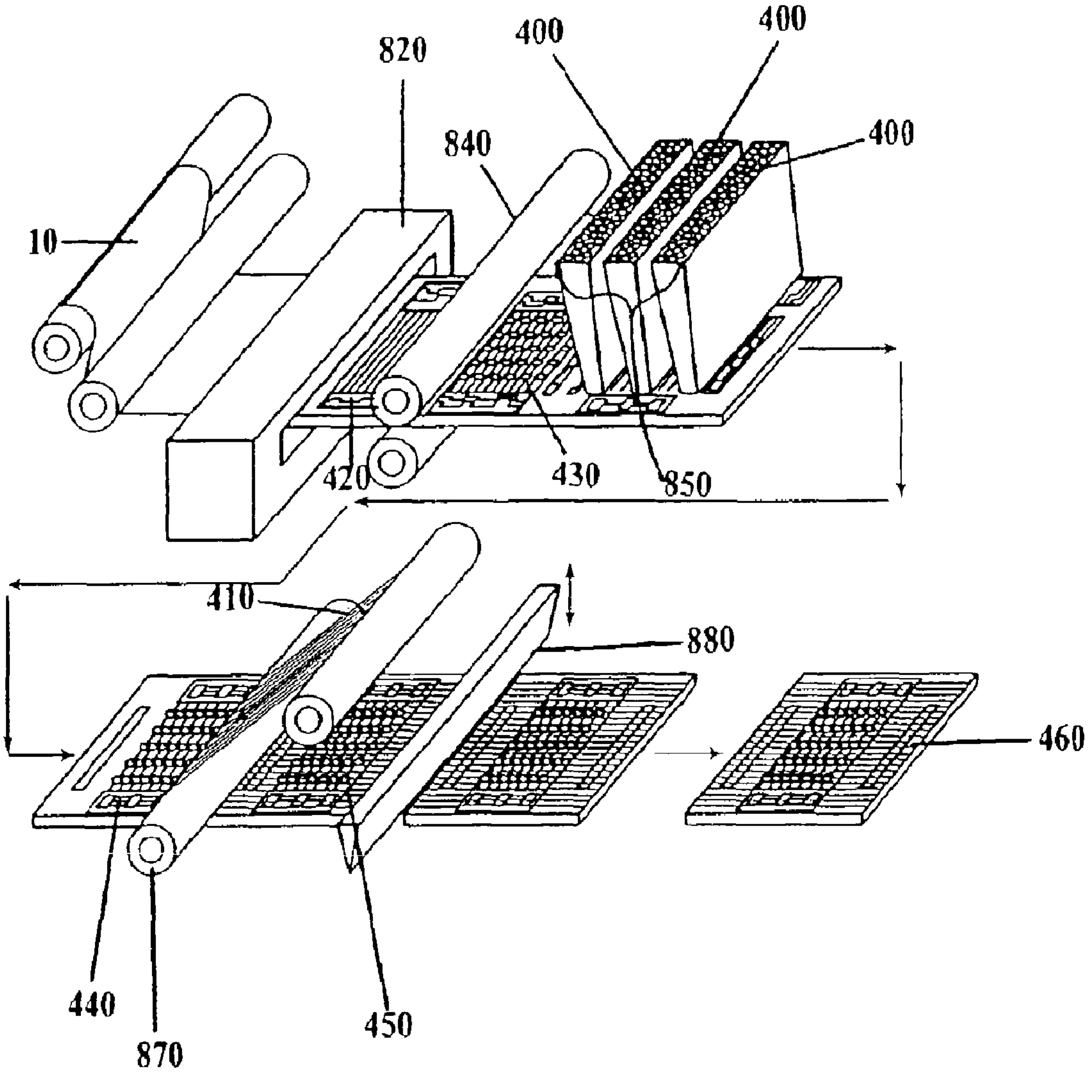

Shell Material
50
Gas-Fill Mixture
45
Micro-Component Forming & Filling Process
800
Filled Micro-Components
Phosphor or Other Coating
300
Coating Process
810
Coated & Filled Micro-Components
400
Micro-Component Placement Process
850
Micro-Components in Sockets on Substrate with Electrodes
440
Flexible Substrate
10
Dielectrics, Metals, & Semiconductors
Circuit & Electrode Printing Process
820
Substrate with Electrodes, Printed Drive Circuits and/or Printed Control Circuits
420
Patterning Process
840
Substrate with Electrodes, Circuits & Sockets
430
Substrate Application & Alignment Process
870
Micro-Components in Sockets Sandwiched Between Substrates with Electrodes & Circuits
450
Flexible Substrate
20
Dielectrics & Metals
Electrode Printing Process
860
Substrate with Electrodes
410
Panel Dicing Process
880
Light-Emitting Panel
460

FIG. 12

Fig. 13



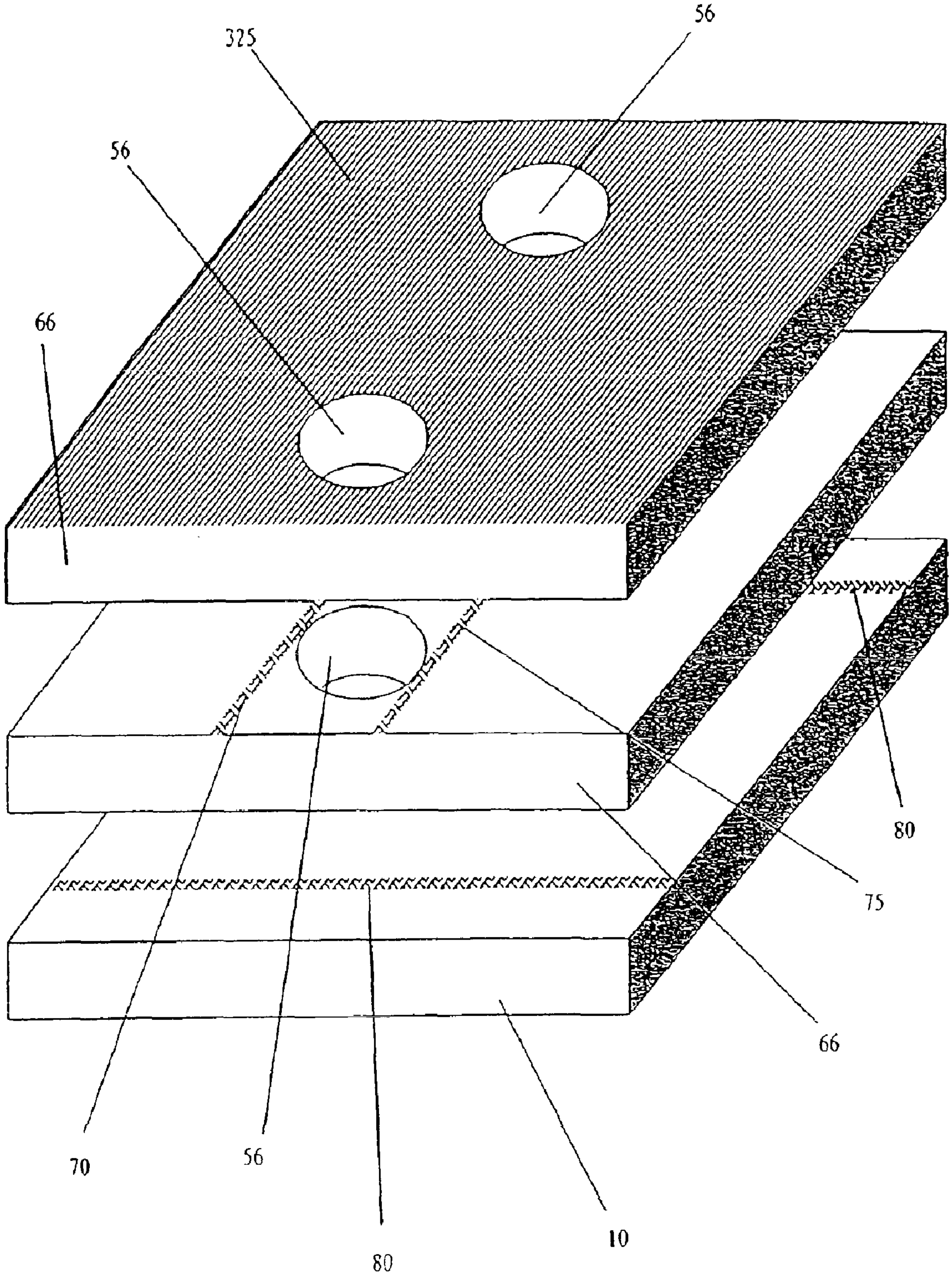



Fig. 14

Fig. 15

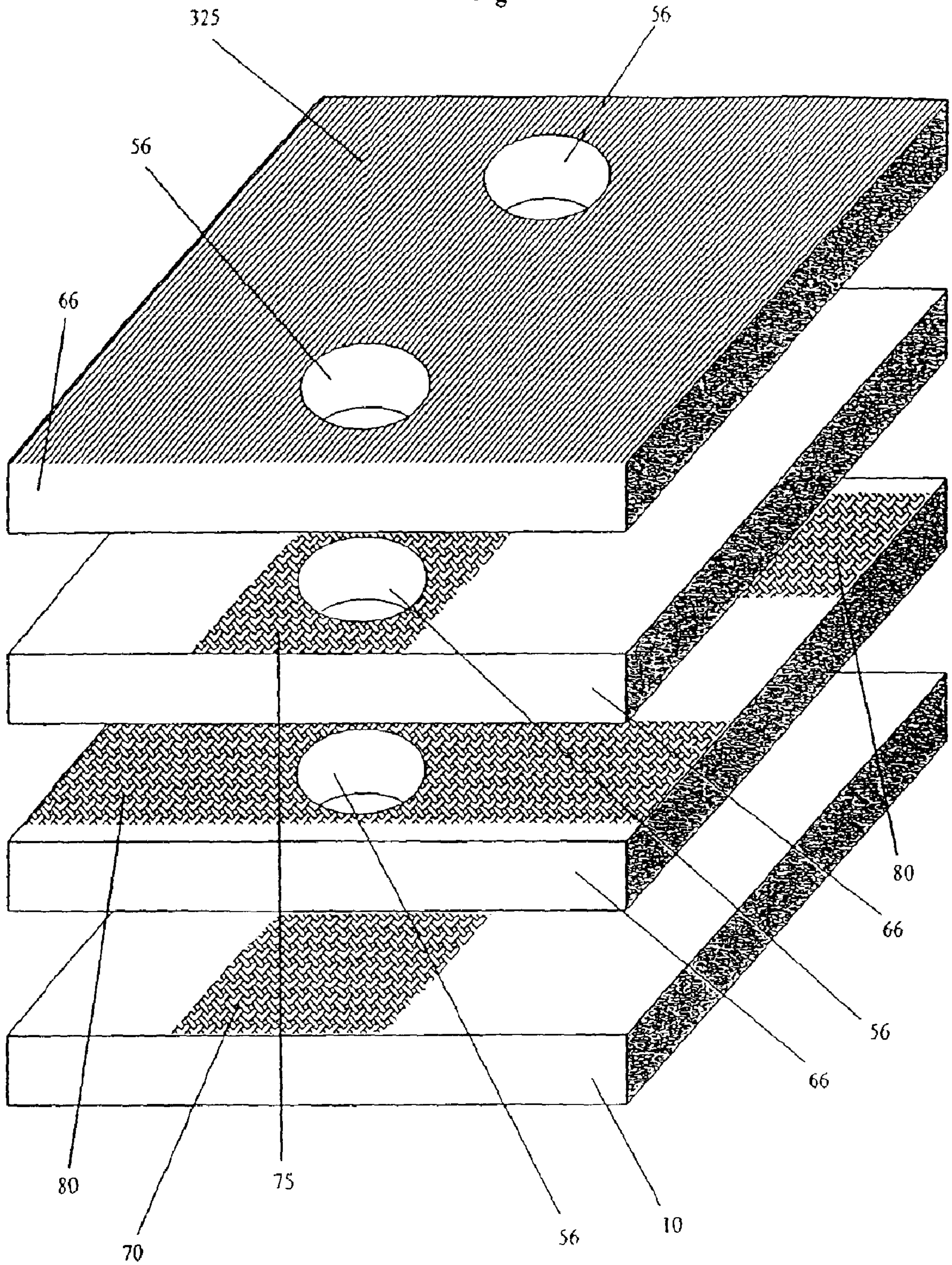
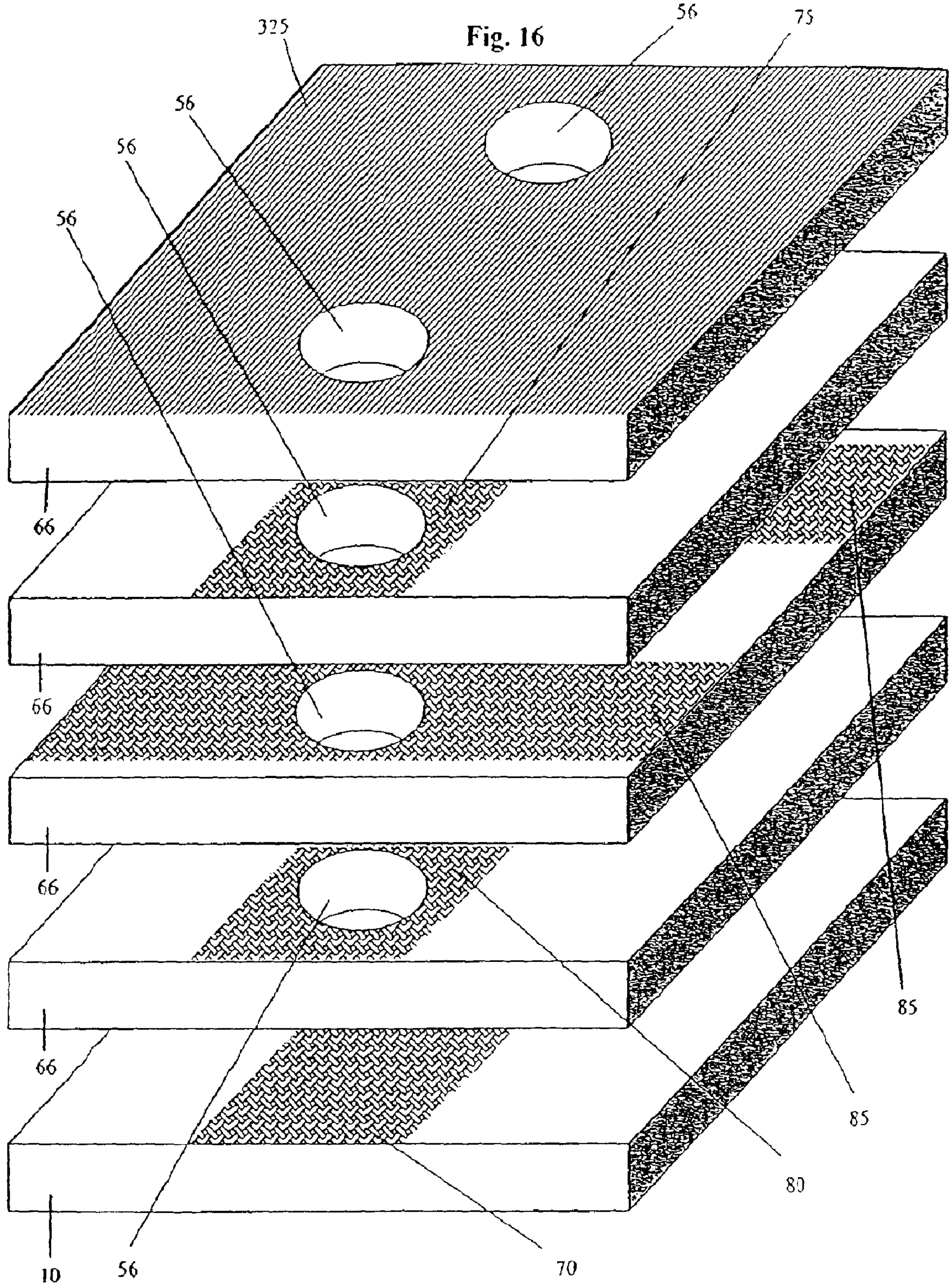


Fig. 16



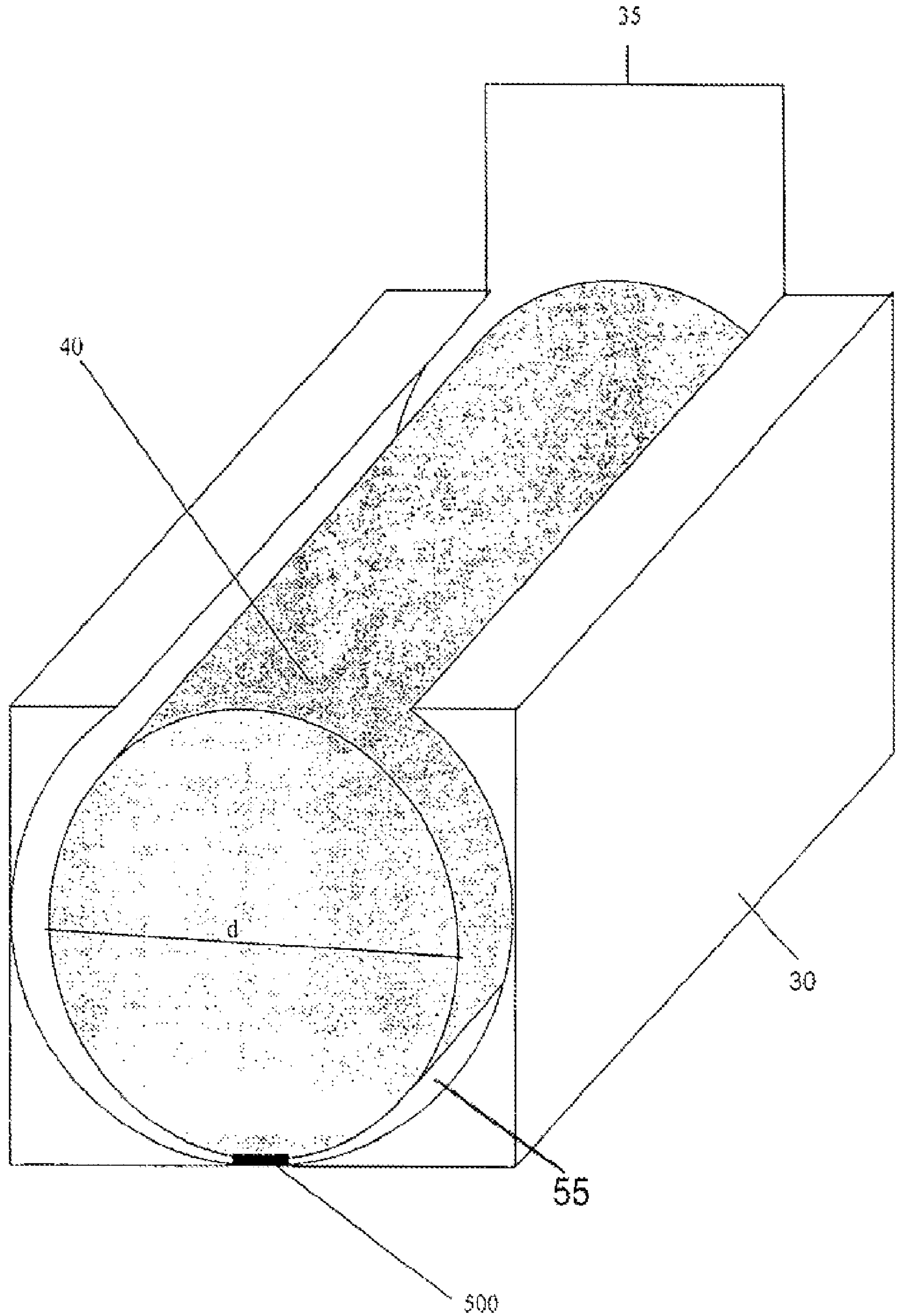



FIG. 17

Fig. 18

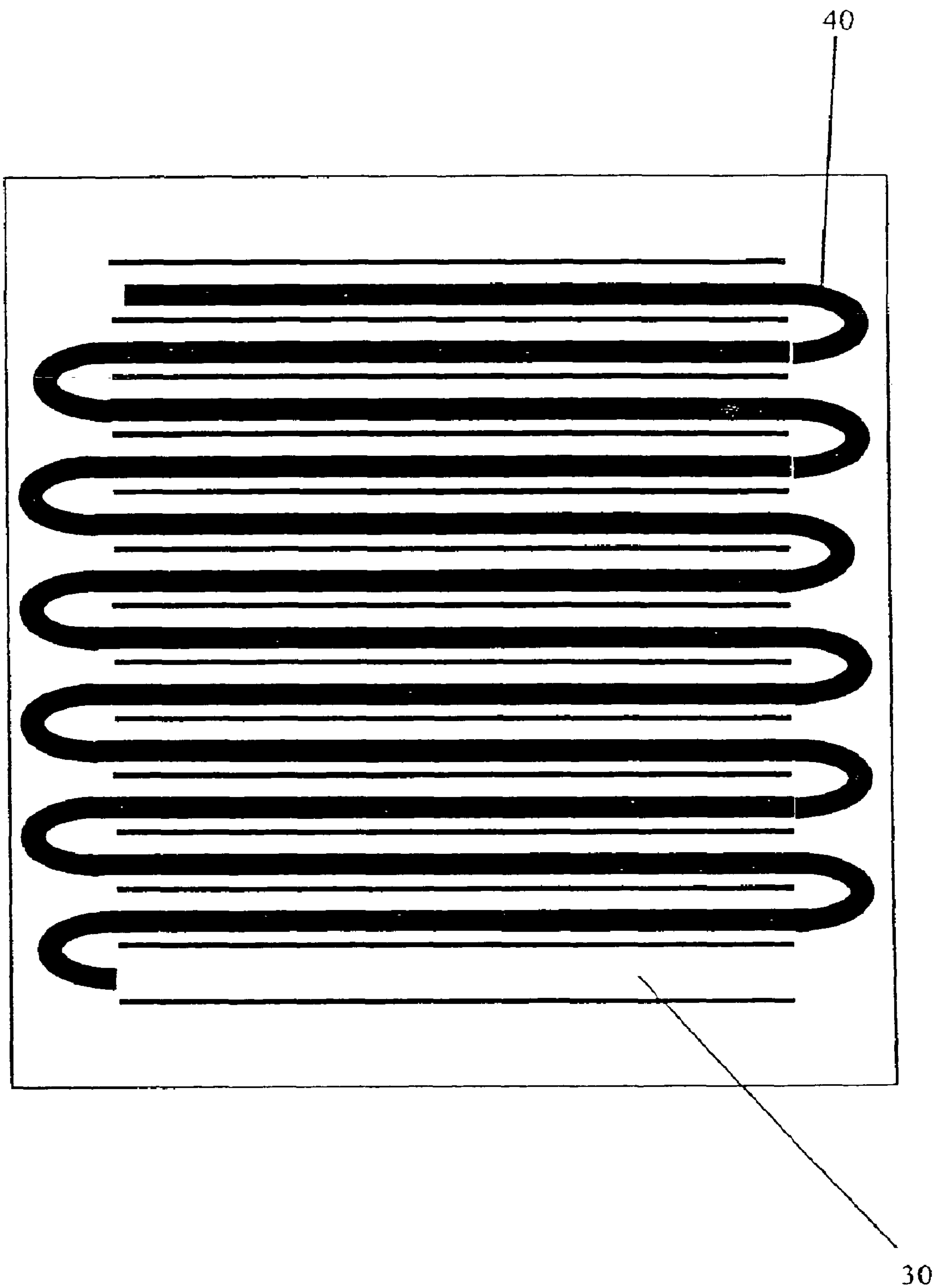
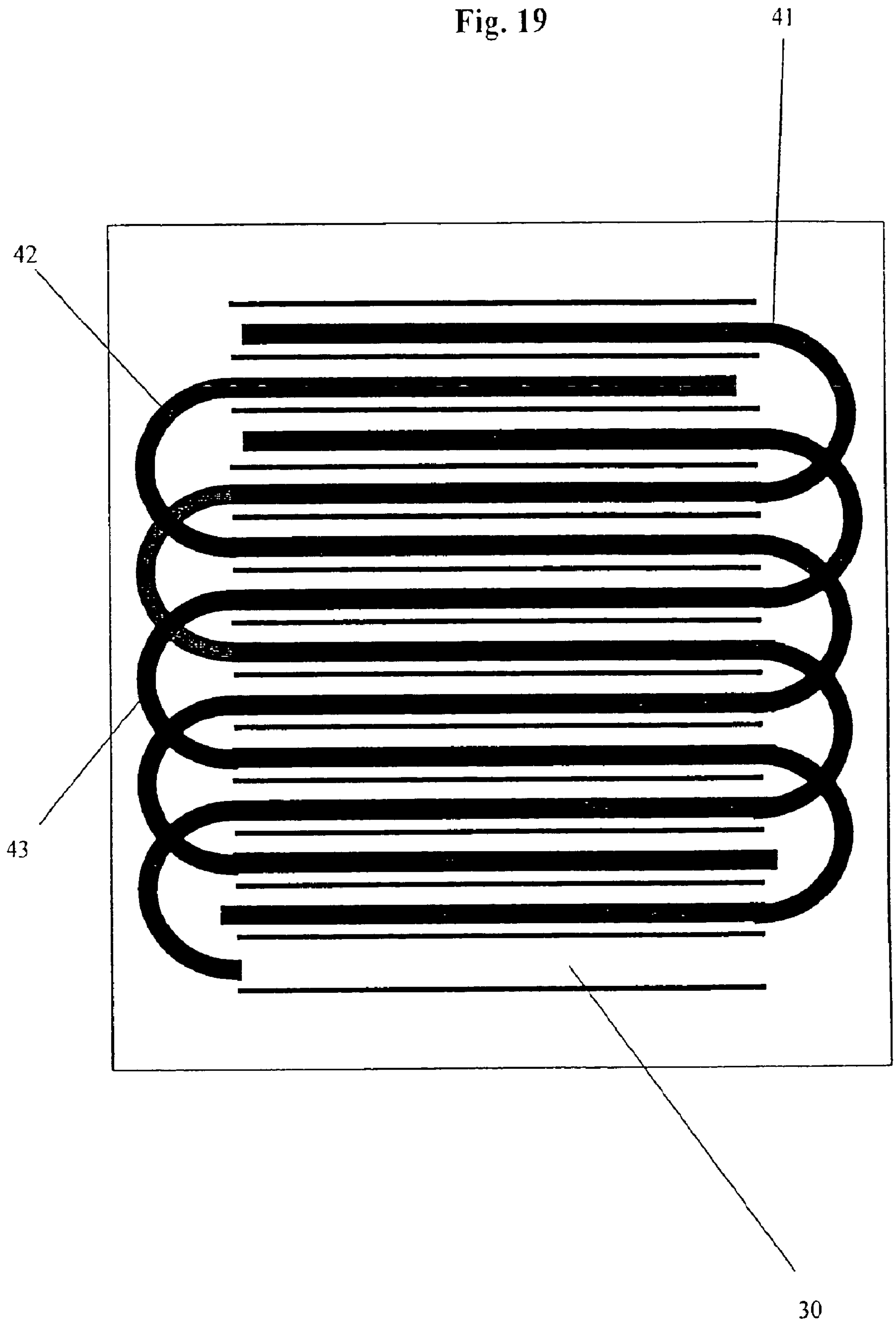


Fig. 19



# LIGHT-EMITTING PANEL AND A METHOD FOR MAKING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 12/465,160 entitled "Light-Emitting Panel and a Method For Making," filed May 13, 2009, now U.S. Pat. No. 8,043,137, which is a continuation of application Ser. No. 11/527,415 entitled "A Light-Emitting Panel and a Method for Making," filed Sep. 27, 2006, now abandoned, which is a divisional application of application Ser. No. 10/614,049 entitled "A Light-Emitting Panel and a Method for Making," filed Jul. 8, 2003, now U.S. Pat. No. 7,125,305, which is a continuation of application Ser. No. 09/697,344, filed Oct. 27, 2000, now U.S. Pat. No. 6,612,889. Also referenced hereby are the following applications which are incorporated herein by reference in their entireties: U.S. patent application Ser. No. 09/697,358 entitled A Micro-Component for Use in a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,762,566; U.S. patent application Ser. No. 09/697,498 entitled A Method for Testing a Light-Emitting Panel and the Components Therein filed Oct. 27, 2000, now U.S. Pat. No. 6,620,012; U.S. patent application Ser. No. 09/697,345 entitled A Method and System for Energizing a Micro-Component In a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,570,335; and U.S. patent application Ser. No. 09/697,346 entitled A Socket for Use in a Light-Emitting Panel filed Oct. 27, 2000, now U.S. Pat. No. 6,545,422.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is relates to a light-emitting panel and methods of fabricating the same. The present invention further relates to a web fabrication process for manufacturing a light-emitting panel.

2. Description of Related Art

In a typical plasma display, a gas or mixture of gases is enclosed between orthogonally crossed and spaced conductors. The crossed conductors define a matrix of cross over points, arranged as an array of miniature picture elements (pixels), which provide light. At any given pixel, the orthogonally crossed and spaced conductors function as opposed plates of a capacitor, with the enclosed gas serving as a dielectric. When a sufficiently large voltage is applied, the gas at the pixel breaks down creating free electrons that are drawn to the positive conductor and positively charged gas ions that are drawn to the negatively charged conductor. These free electrons and positively charged gas ions collide with other gas atoms causing an avalanche effect creating still more free electrons and positively charged ions, thereby creating plasma. The voltage level at which this ionization occurs is called the write voltage.

Upon application of a write voltage, the gas at the pixel ionizes and emits light only briefly as free charges formed by the ionization migrate to the insulating dielectric walls of the cell where these charges produce an opposing voltage to the applied voltage and thereby extinguish the ionization. Once a pixel has been written, a continuous sequence of light emissions can be produced by an alternating sustain voltage. The amplitude of the sustain waveform can be less than the amplitude of the write voltage, because the wall charges that remain from the preceding write or sustain operation produce a voltage that adds to the voltage of the succeeding sustain waveform applied in the reverse polarity to produce the ionizing voltage. Mathematically, the idea can be set out as $V_s = V_w - V_{wall}$, where $V_s$ is the sustain voltage, $V_w$ is the write voltage, and $V_{wall}$ is the wall voltage. Accordingly, a previously unwritten (or erased) pixel cannot be ionized by the sustain waveform alone. An erase operation can be thought of as a write operation that proceeds only far enough to allow the previously charged cell walls to discharge; it is similar to the write operation except for timing and amplitude.

Typically, there are two different arrangements of conductors that are used to perform the write, erase, and sustain operations. The one common element throughout the arrangements is that the sustain and the address electrodes are spaced apart with the plasma-forming gas in between. Thus, at least one of the address or sustain electrodes is located within the path the radiation travels, when the plasma-forming gas ionizes, as it exits the plasma display. Consequently, transparent or semi-transparent conductive materials must be used, such as indium tin oxide (ITO), so that the electrodes do not interfere with the displayed image from the plasma display. Using ITO, however, has several disadvantages, for example, ITO is expensive and adds significant cost to the manufacturing process and ultimately the final plasma display.

The first arrangement uses two orthogonally crossed conductors, one addressing conductor and one sustaining conductor. In a gas panel of this type, the sustain waveform is applied across all the addressing conductors and sustain conductors so that the gas panel maintains a previously written pattern of light emitting pixels. For a conventional write operation, a suitable write voltage pulse is added to the sustain voltage waveform so that the combination of the write pulse and the sustain pulse produces ionization. In order to write an individual pixel independently, each of the addressing and sustain conductors has an individual selection circuit. Thus, applying a sustain waveform across all the addressing and sustain conductors, but applying a write pulse across only one addressing and one sustain conductor will produce a write operation in only the one pixel at the intersection of the selected addressing and sustain conductors.

The second arrangement uses three conductors. In panels of this type, called coplanar sustaining panels, each pixel is formed at the intersection of three conductors, one addressing conductor and two parallel sustaining conductors. In this arrangement, the addressing conductor orthogonally crosses the two parallel sustaining conductors. With this type of panel, the sustain function is performed between the two parallel sustaining conductors and the addressing is done by the generation of discharges between the addressing conductor and one of the two parallel sustaining conductors.

The sustaining conductors are of two types, addressing-sustaining conductors and solely sustaining conductors. The function of the addressing-sustaining conductors is twofold: to achieve a sustaining discharge in cooperation with the solely sustaining conductors; and to fulfill an addressing role. Consequently, the addressing-sustaining conductors are individually selectable so that an addressing waveform may be applied to any one or more addressing-sustaining conductors. The solely sustaining conductors, on the other hand, are typically connected in such a way that a sustaining waveform can be simultaneously applied to all of the solely sustaining conductors so that they can be carried to the same potential in the same instant.

Numerous types of plasma panel display devices have been constructed with a variety of methods for enclosing a plasma forming gas between sets of electrodes. In one type of plasma display panel, parallel plates of glass with wire electrodes on the surfaces thereof are spaced uniformly apart and sealed together at the outer edges with the plasma forming gas filling the cavity formed between the parallel plates. Although widely used, this type of open display structure has various disadvantages. The sealing of the outer edges of the parallel plates and the introduction of the plasma forming gas are both expensive and time-consuming processes, resulting in a costly end product. In addition, it is particularly difficult to achieve a good seal at the sites where the electrodes are fed through the ends of the parallel plates. This can result in gas leakage and a shortened product lifecycle. Another disadvantage is that individual pixels are not segregated within the parallel plates. As a result, gas ionization activity in a selected pixel during a write operation may spill over to adjacent pixels, thereby raising the undesirable prospect of possibly igniting adjacent pixels. Even if adjacent pixels are not ignited, the ionization activity can change the turn-on and turn-off characteristics of the nearby pixels.

In another type of known plasma display, individual pixels are mechanically isolated either by forming trenches in one of the parallel plates or by adding a perforated insulating layer sandwiched between the parallel plates. These mechanically isolated pixels, however, are not completely enclosed or isolated from one another because there is a need for the free passage of the plasma forming gas between the pixels to assure uniform gas pressure throughout the panel. While this type of display structure decreases spill over, spill over is still possible because the pixels are not in total electrical isolation from one another. In addition, in this type of display panel it is difficult to properly align the electrodes and the gas chambers, which may cause pixels to misfire. As with the open display structure, it is also difficult to get a good seal at the plate edges. Furthermore, it is expensive and time consuming to introduce the plasma producing gas and seal the outer edges of the parallel plates.

In yet another type of known plasma display, individual pixels are also mechanically isolated between parallel plates. In this type of display, the plasma forming gas is contained in transparent spheres formed of a closed transparent shell. Various methods have been used to contain the gas filled spheres between the parallel plates. In one method, spheres of varying sizes are tightly bunched and randomly distributed throughout a single layer, and sandwiched between the parallel plates. In a second method, spheres are embedded in a sheet of transparent dielectric material and that material is then sandwiched between the parallel plates. In a third method, a perforated sheet of electrically nonconductive material is sandwiched between the parallel plates with the gas filled spheres distributed in the perforations.

While each of the types of displays discussed above are based on different design concepts, the manufacturing approach used in their fabrication is generally the same. Conventionally, a batch fabrication process is used to manufacture these types of plasma panels. As is well known in the art, in a batch process individual component parts are fabricated separately, often in different facilities and by different manufacturers, and then brought together for final assembly where individual plasma panels are created one at a time. Batch processing has numerous shortcomings, such as, for example, the length of time necessary to produce a finished product. Long cycle times increase product cost and are undesirable for numerous additional reasons known in the art. For example, a sizeable quantity of substandard, defective, or useless fully or partially completed plasma panels may be produced during the period between detection of a defect or failure in one of the components and an effective correction of the defect or failure.

This is especially true of the first two types of displays discussed above; the first having no mechanical isolation of individual pixels, and the second with individual pixels mechanically isolated either by trenches formed in one parallel plate or by a perforated insulating layer sandwiched between two parallel plates. Due to the fact that plasma-forming gas is not isolated at the individual pixel/subpixel level, the fabrication process precludes the majority of individual component parts from being tested until the final display is assembled. Consequently, the display can only be tested after the two parallel plates are sealed together and the plasma-forming gas is filled inside the cavity between the two plates. If post production testing shows that any number of potential problems have occurred, (e.g. poor luminescence or no luminescence at specific pixels/subpixels) the entire display is discarded.

## BRIEF SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a light-emitting panel that may be used as a large-area radiation source, for energy modulation, for particle detection and as a flat-panel display. Gas-plasma panels are preferred for these applications due to their unique characteristics.

In one form, the light-emitting panel may be used as a large area radiation source. By configuring the light-emitting panel to emit ultraviolet (UV) light, the panel has application for curing, painting, and sterilization. With the addition of a white phosphor coating to convert the UV light to visible white light, the panel also has application as an illumination source.

In addition, the light-emitting panel may be used as a plasma-switched phase array by configuring the panel in at least one embodiment in a microwave transmission mode. The panel is configured in such a way that during ionization the plasma-forming gas creates a localized index of refraction change for the microwaves (although other wavelengths of light would work). The microwave beam from the panel can then be steered or directed in any desirable pattern by introducing at a localized area a phase shift and/or directing the microwaves out of a specific aperture in the panel.

Additionally, the light-emitting panel may be used for particle/photon detection. In this embodiment, the light-emitting panel is subjected to a potential that is just slightly below the write voltage required for ionization. When the device is subjected to outside energy at a specific position or location in the panel, that additional energy causes the plasma forming gas in the specific area to ionize, thereby providing a means of detecting outside energy.

Further, the light-emitting panel may be used in flat-panel displays. These displays can be manufactured very thin and lightweight, when compared to similar sized cathode ray tube (CRTs), making them ideally suited for home, office, theaters and billboards. In addition, these displays can be manufactured in large sizes and with sufficient resolution to accommodate high-definition television (HDTV). Gas-plasma panels do not suffer from electromagnetic distortions and are, therefore, suitable for applications strongly affected by magnetic fields, such as military applications, radar systems, railway stations and other underground systems.

According to one general embodiment of the present invention, a light-emitting panel is made from two substrates, wherein one of the substrates includes a plurality of sockets and wherein at least two electrodes are disposed. At least partially disposed in each socket is a micro-component, although more than one micro-component may be disposed therein. Each micro-component includes a shell at least partially filled with a gas or gas mixture capable of ionization. When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation.

In another embodiment of the present invention, at least two electrodes are adhered to the first substrate, the second substrate or any combination thereof.

In another embodiment, at least two electrodes are arranged so that voltage supplied to the electrodes causes at least one micro-component to emit radiation throughout the field of view of the light-emitting panel without the radiation crossing the electrodes.

In yet another embodiment, disposed in, or proximate to, each socket is at least one enhancement material.

Another preferred embodiment of the present invention is drawn to a web fabrication method for manufacturing light-emitting panels. In an embodiment, the web fabrication process includes providing a first substrate, disposing a plurality of micro-components on the first substrate, disposing a second substrate on the first substrate so the at the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrates to form individual light-emitting panels. In another embodiment, the web fabrication method includes the following process steps: a micro-component forming process; a micro-component coating process; a circuit and electrode printing process; a patterning process; a micro-component placement process; an electrode printing process; a second substrate application and alignment process; and a panel dicing process.

Other features, advantages, and embodiments of the invention are set forth in part in the description that follows, and in part, will be obvious from this description, or may be learned from the practice of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of this invention will become more apparent by reference to the following detailed description of the invention taken in conjunction with the accompanying drawings.

FIG. **1** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in an embodiment of the present invention.

FIG. **2** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate, as disclosed in another embodiment of the present invention.

FIG. **3**A shows an example of a cavity that has a cube shape.

FIG. **3**B shows an example of a cavity that has a cone shape.

FIG. **3**C shows an example of a cavity that has a conical frustum shape.

FIG. **3**D shows an example of a cavity that has a paraboloid shape.

FIG. **3**E shows an example of a cavity that has a spherical shape.

FIG. **3**F shows an example of a cavity that has a cylindrical shape.

FIG. **3**G shows an example of a cavity that has a pyramid shape.

FIG. **3**H shows an example of a cavity that has a pyramidal frustum shape.

FIG. **3**I shows an example of a cavity that has a parallelepiped shape.

FIG. **3**J shows an example of a cavity that has a prism shape.

FIG. **4** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a narrower field of view.

FIG. **5** shows the socket structure from a light-emitting panel of an embodiment of the present invention with a wider field of view.

FIG. **6**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a co-planar configuration.

FIG. **6**B is a cut-away of FIG. **6**A showing in more detail the co-planar sustaining electrodes.

FIG. **7**A depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having a mid-plane configuration.

FIG. **7**B is a cut-away of FIG. **7**A showing in more detail the uppermost sustain electrode.

FIG. **8** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from disposing a plurality of material layers and then selectively removing a portion of the material layers with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **9** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a co-planar configuration.

FIG. **10** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having a mid-plane configuration.

FIG. **11** depicts a portion of a light-emitting panel showing the basic socket structure of a socket formed from patterning a substrate and then disposing a plurality of material layers on the substrate so that the material layers conform to the shape of the cavity with the electrodes having an configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **12** is a flowchart describing a web fabrication method for manufacturing light-emitting displays as described in an embodiment of the present invention.

FIG. **13** is a graphical representation of a web fabrication method for manufacturing light-emitting panels as described in an embodiment of the present invention.

FIG. **14** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a co-planar configuration.

FIG. **15** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with the electrodes having a mid-plane configuration.

FIG. **16** shows an exploded view of a portion of a light-emitting panel showing the basic socket structure of a socket formed by disposing a plurality of material layers with aligned apertures on a substrate with electrodes having a configuration with two sustain and two address electrodes, where the address electrodes are between the two sustain electrodes.

FIG. **17** shows a portion of a socket of an embodiment of the present invention where the micro-component and the cavity are formed as a type of male-female connector.

FIG. **18** shows a top down view of a portion of a light-emitting panel showing a method for making a light-emitting panel by weaving a single micro-component through the entire light-emitting panel.

FIG. **19** shows a top down view of a portion of a color light-emitting panel showing a method for making a color light-emitting panel by weaving multiple micro-components through the entire light-emitting panel.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

As embodied and broadly described herein, the preferred embodiments of the present invention are directed to a novel light-emitting panel. In particular, preferred embodiments are directed to light-emitting panels and to a web fabrication process for manufacturing light-emitting panels.

FIGS. **1** and **2** show two embodiments of the present invention wherein a light-emitting panel includes a first substrate **10** and a second substrate **20**. The first substrate **10** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. Similarly, second substrate **20** may be made from silicates, polypropylene, quartz, glass, any polymeric-based material or any material or combination of materials known to one skilled in the art. First substrate **10** and second substrate **20** may both be made from the same material or each of a different material. Additionally, the first and second substrate may be made of a material that dissipates heat from the light-emitting panel. In a preferred embodiment, each substrate is made from a material that is mechanically flexible.

The first substrate **10** includes a plurality of sockets **30**. The sockets **30** may be disposed in any pattern, having uniform or non-uniform spacing between adjacent sockets. Patterns may include, but are not limited to, alphanumeric characters, symbols, icons, or pictures. Preferably, the sockets **30** are disposed in the first substrate **10** so that the distance between adjacent sockets **30** is approximately equal. Sockets **30** may also be disposed in groups such that the distance between one group of sockets and another group of sockets is approximately equal. This latter approach may be particularly relevant in color light-emitting panels, where each socket in each group of sockets may represent red, green and blue, respectively.

At least partially disposed in each socket **30** is at least one micro-component **40**. Multiple micro-components may be disposed in a socket to provide increased luminosity and enhanced radiation transport efficiency. In a color light-emitting panel according to one embodiment of the present invention, a single socket supports three micro-components configured to emit red, green, and blue light, respectively. The micro-components **40** may be of any shape, including, but not limited to, spherical, cylindrical, and aspherical. In addition, it is contemplated that a micro-component **40** includes a micro-component placed or formed inside another structure, such as placing a spherical micro-component inside a cylindrical-shaped structure. In a color light-emitting panel according to an embodiment of the present invention, each cylindrical-shaped structure holds micro-components configured to emit a single color of visible light or multiple colors arranged red, green, blue, or in some other suitable color arrangement.

In another embodiment of the present invention, an adhesive or bonding agent is applied to each micro-component to assist in placing/holding a micro-component **40** or plurality of micro-components in a socket **30**. In an alternative embodiment, an electrostatic charge is placed on each micro-component and an electrostatic field is applied to each micro-component to assist in the placement of a micro-component **40** or plurality of micro-components in a socket **30**. Applying an electrostatic charge to the micro-components also helps avoid agglomeration among the plurality of micro-components. In one embodiment of the present invention, an electron gun is used to place an electrostatic charge on each micro-component and one electrode disposed proximate to each socket **30** is energized to provide the needed electrostatic field required to attract the electrostatically charged micro-component.

Alternatively, in order to assist placing/holding a micro-component **40** or plurality of micro-components in a socket **30**, a socket **30** may contain a bonding agent or an adhesive. The bonding agent or adhesive may be applied to the inside of the socket **30** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside of the socket **30** may be used.

In its most basic form, each micro-component **40** includes a shell **50** filled with a plasma-forming gas or gas mixture **45**. Any suitable gas or gas mixture **45** capable of ionization may be used as the plasma-forming gas, including, but not limited to, krypton, xenon, argon, neon, oxygen, helium, mercury, and mixtures thereof. In fact, any noble gas could be used as the plasma-forming gas, including, but not limited to, noble gases mixed with cesium or mercury. One skilled in the art would recognize other gasses or gas mixtures that could also be used. In a color display, according to another embodiment, the plasma-forming gas or gas mixture **45** is chosen so that during ionization the gas will irradiate a specific wavelength of light corresponding to a desired color. For example, neon-argon emits red light, xenon-oxygen emits green light, and krypton-neon emits blue light. While a plasma-forming gas or gas mixture **45** is used in a preferred embodiment, any other material capable of providing luminescence is also contemplated, such as an electro-luminescent material, organic light-emitting diodes (OLEDs), or an electro-phoretic material.

The shell **50** may be made from a wide assortment of materials, including, but not limited to, silicates, polypropylene, glass, any polymeric-based material, magnesium oxide and quartz and may be of any suitable size. The shell **50** may have a diameter ranging from micrometers to centimeters as measured across its minor axis, with virtually no limitation as to its size as measured across its major axis. For example, a cylindrical-shaped micro-component may be only 100 microns in diameter across its minor axis, but may be hundreds of meters long across its major axis. In a preferred embodiment, the outside diameter of the shell, as measured across its minor axis, is from 100 microns to 300 microns. In addition, the shell thickness may range from micrometers to millimeters, with a preferred thickness from 1 micron to 10 microns.

When a sufficiently large voltage is applied across the micro-component the gas or gas mixture ionizes forming plasma and emitting radiation. The potential required to initially ionize the gas or gas mixture inside the shell **50** is governed by Paschen's Law and is closely related to the pressure of the gas inside the shell. In the present invention, the gas pressure inside the shell **50** ranges from tens of torrs to several atmospheres. In a preferred embodiment, the gas pressure ranges from 100 torr to 700 torr. The size and shape of a micro-component **40** and the type and pressure of the plasma-forming gas contained therein, influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation.

There are a variety of coatings **300** and dopants that may be added to a micro-component **40** that also influence the performance and characteristics of the light-emitting panel. The coatings **300** may be applied to the outside or inside of the shell **50**, and may either partially or fully coat the shell **50**. Types of outside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used as reflecting filters, and coatings used as band-gap filters. Types of inside coatings include, but are not limited to, coatings used to convert UV light to visible light (e.g. phosphor), coatings used to enhance secondary emissions and coatings used to prevent erosion. One skilled in the art will recognize that other coatings may also be used. The coatings **300** may be applied to the shell **50** by differential stripping, lithographic process, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One skilled in the art will realize that other methods of coating the inside and/or outside of the shell **50** may be used. Types of dopants include, but are not limited to, dopants used to convert UV light to visible light (e.g. phosphor), dopants used to enhance secondary emissions and dopants used to provide a conductive path through the shell **50**. The dopants are added to the shell **50** by any suitable technique known to one skilled in the art, including ion implantation. It is contemplated that any combination of coatings and dopants may be added to a micro-component **40**. Alternatively, or in combination with the coatings and dopants that may be added to a micro-component **40**, a variety of coatings **350** may be coated on the inside of a socket **30**. These coatings **350** include, but are not limited to, coatings used to convert UV light to visible light, coatings used as reflecting filters, and coatings used as band-gap filters.

In an embodiment of the present invention, when a micro-component is configured to emit UV light, the UV light is converted to visible light by at least partially coating the inside the shell **50** with phosphor, at least partially coating the outside of the shell **50** with phosphor, doping the shell **50** with phosphor and/or coating the inside of a socket **30** with phosphor. In a color panel, according to an embodiment of the present invention, colored phosphor is chosen so the visible light emitted from alternating micro-components is colored red, green and blue, respectively. By combining these primary colors at varying intensities, all colors can be formed. It is contemplated that other color combinations and arrangements may be used. In another embodiment for a color light-emitting panel, the UV light is converted to visible light by disposing a single colored phosphor on the micro-component **40** and/or on the inside of the socket **30**. Colored filters may then be alternatingly applied over each socket **30** to convert the visible light to colored light of any suitable arrangement, for example red, green and blue. By coating all the micro-components with a single colored phosphor and then converting the visible light to colored light by using at least one filter applied over the top of each socket, micro-component placement is made less complicated and the light-emitting panel is more easily configurable.

To obtain an increase in luminosity and radiation transport efficiency, in an embodiment of the present invention, the shell **50** of each micro-component **40** is at least partially coated with a secondary emission enhancement material. Any low affinity material may be used including, but not limited to, magnesium oxide and thulium oxide. One skilled in the art would recognize that other materials will also provide secondary emission enhancement. In another embodiment of the present invention, the shell **50** is doped with a secondary emission enhancement material. It is contemplated that the doping of shell **50** with a secondary emission enhancement material may be in addition to coating the shell **50** with a secondary emission enhancement material. In this case, the secondary emission enhancement material used to coat the shell **50** and dope the shell **50** may be different.

In addition to, or in place of, doping the shell **50** with a secondary emission enhancement material, according to an embodiment of the present invention, the shell **50** is doped with a conductive material. Possible conductive materials include, but are not limited to silver, gold, platinum, and aluminum. Doping the shell **50** with a conductive material provides a direct conductive path to the gas or gas mixture contained in the shell and provides one possible means of achieving a DC light-emitting panel.

In another embodiment of the present invention, the shell **50** of the micro-component **40** is coated with a reflective material. An index matching material that matches the index of refraction of the reflective material is disposed so as to be in contact with at least a portion of the reflective material. The reflective coating and index matching material may be separate from, or in conjunction with, the phosphor coating and secondary emission enhancement coating of previous embodiments. The reflective coating is applied to the shell **50** in order to enhance radiation transport. By also disposing an index-matching material so as to be in contact with at least a portion of the reflective coating, a predetermined wavelength range of radiation is allowed to escape through the reflective coating at the interface between the reflective coating and the index-matching material. By forcing the radiation out of a micro-component through the interface area between the reflective coating and the index-matching material greater micro-component efficiency is achieved with an increase in luminosity. In an embodiment, the index matching material is coated directly over at least a portion of the reflective coating. In another embodiment, the index matching material is disposed on a material layer, or the like, that is brought in contact with the micro-component such that the index matching material is in contact with at least a portion of the reflective coating. In another embodiment, the size of the interface is selected to achieve a specific field of view for the light-emitting panel.

A cavity **55** formed within and/or on the first substrate **10** provides the basic socket **30** structure. The cavity **55** may be any shape and size. As depicted in FIGS. **3**A-**3**J, the shape of the cavity **55** may include, but is not limited to, a cube **100**, a cone **110**, a conical frustum **120**, a paraboloid **130**, spherical **140**, cylindrical **150**, a pyramid **160**, a pyramidal frustum **170**, a parallelepiped **180**, or a prism **190**.

The size and shape of the socket **30** influence the performance and characteristics of the light-emitting panel and are selected to optimize the panel's efficiency of operation. In addition, socket geometry may be selected based on the shape and size of the micro-component to optimize the surface contact between the micro-component and the socket and/or to ensure connectivity of the micro-component and any electrodes disposed within the socket. Further, the size and shape of the sockets **30** may be chosen to optimize photon generation and provide increased luminosity and radiation transport efficiency. As shown by example in FIGS. **4** and **5**, the size and shape may be chosen to provide a field of view **400** with a specific angle θ, such that a micro-component **40** disposed in a deep socket **30** may provide more collimated light and hence a narrower viewing angle θ (FIG. **4**), while a micro-component **40** disposed in a shallow socket **30** may provide a wider viewing angle θ (FIG. **5**). That is to say, the cavity may be sized, for example, so that its depth subsumes a micro-component deposited in a socket, or it may be made shallow so that a micro-component is only partially disposed within a socket. Alternatively, in another embodiment of the present invention, the field of view **400** may be set to a specific angle θ by disposing on the second substrate at least one optical lens. The lens may cover the entire second substrate or, in the case of multiple optical lenses, arranged so as to be in register with each socket. In another embodiment, the optical lens or optical lenses are configurable to adjust the field of view of the light-emitting panel.

In an embodiment for a method of making a light-emitting panel including a plurality of sockets, a cavity **55** is formed, or patterned, in a substrate **10** to create a basic socket shape. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. Disposed proximate to, and/or in, each socket may be a variety of enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **60** to form a first substrate **10**, disposing at least one electrode either directly on the first substrate **10**, within the material layers or any combination thereof, and selectively removing a portion of the material layers **60** to create a cavity. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate. The cavity **55** may be formed in the material layers **60** by a variety of methods including, but not limited to, wet or dry etching, photolithography, laser heat treatment, thermal form, mechanical punch, embossing, stamping-out, drilling, electroforming or by dimpling.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by patterning a cavity **55** in a first substrate **10**, disposing a plurality of material layers **65** on the first substrate **10** so that the material layers **65** conform to the cavity **55**, and disposing at least one electrode on the first substrate **10**, within the material layers **65**, or any combination thereof. The cavity may be formed in any suitable shape and size by any combination of physically, mechanically, thermally, electrically, optically, or chemically deforming the substrate. The material layers **60** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **60** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In another embodiment of the present invention for a method of making a light-emitting panel including a plurality of sockets, a socket **30** is formed by disposing a plurality of material layers **66** on a first substrate **10** and disposing at least one electrode on the first substrate **10**, within the material layers **66**, or any combination thereof. Each of the material layers includes a preformed aperture **56** that extends through the entire material layer. The apertures may be of the same size or may be of different sizes. The plurality of material layers **66** are disposed on the first substrate with the apertures in alignment thereby forming a cavity **55**. The material layers **66** include any combination, in whole or in part, of dielectric materials, metals, and enhancement materials **325**. The enhancement materials **325** include, but are not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, diodes, control electronics, drive electronics, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. The placement of the material layers **66** may be accomplished by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, or deposition using ink jet technology. One of general skill in the art will recognize other appropriate methods of disposing a plurality of material layers on a substrate.

In the above embodiments describing four different methods of making a socket in a light-emitting panel, disposed in, or proximate to, each socket may be at least one enhancement material. As stated above the enhancement material **325** may include, but is not limited to, anti-glare coatings, touch sensitive surfaces, contrast enhancement coatings, protective coatings, transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits. In a preferred embodiment of the present invention the enhancement materials may be disposed in, or proximate to each socket by any transfer process, photolithography, sputtering, laser deposition, chemical deposition, vapor deposition, deposition using ink jet technology, or mechanical means. In another embodiment of the present invention, a method for making a light-emitting panel includes disposing at least one electrical enhancement (e.g. the transistors, integrated-circuits, semiconductor devices, inductors, capacitors, resistors, control electronics, drive electronics, diodes, pulse-forming networks, pulse compressors, pulse transformers, and tuned-circuits), in, or proximate to, each socket by suspending the at least one electrical enhancement in a liquid and flowing the liquid across the first substrate. As the liquid flows across the substrate the at least one electrical enhancement will settle in each socket. It is contemplated that other substances or means may be use to move the electrical enhancements across the substrate. One such means may include, but is not limited to, using air to move the electrical enhancements across the substrate. In another embodiment of the present invention the socket is of a corresponding shape to the at least one electrical enhancement such that the at least one electrical enhancement self-aligns with the socket.

The electrical enhancements may be used in a light-emitting panel for a number of purposes including, but not limited to, lowering the voltage necessary to ionize the plasma-forming gas in a micro-component, lowering the voltage required to sustain/erase the ionization charge in a micro-component, increasing the luminosity and/or radiation transport efficiency of a micro-component, and augmenting the frequency at which a micro-component is lit. In addition, the electrical enhancements may be used in conjunction with the light-emitting panel driving circuitry to alter the power requirements necessary to drive the light-emitting panel. For example, a tuned-circuit may be used in conjunction with the driving circuitry to allow a DC power source to power an AC-type light-emitting panel. In an embodiment of the present invention, a controller is provided that is connected to the electrical enhancements and capable of controlling their operation. Having the ability to individual control the electrical enhancements at each pixel/subpixel provides a means by which the characteristics of individual micro-components may be altered/corrected after fabrication of the light-emitting panel. These characteristics include, but are not limited to, luminosity and the frequency at which a micro-component is lit. One skilled in the art will recognize other uses for electrical enhancements disposed in, or proximate to, each socket in a light-emitting panel.

The electrical potential necessary to energize a micro-component **40** is supplied via at least two electrodes. In a general embodiment of the present invention, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are adhered to only the first substrate, only the second substrate or at least one electrode is adhered to each of the first substrate and the second substrate and wherein the electrodes are arranged so that voltage applied to the electrodes causes one or more micro-components to emit radiation. In another general embodiment, a light-emitting panel includes a plurality of electrodes, wherein at least two electrodes are arranged so that voltage supplied to the electrodes cause one or more micro-components to emit radiation throughout the field of view of the light-emitting panel without crossing either of the electrodes.

In an embodiment where the sockets **30** are patterned on the first substrate **10** so that the sockets are formed in the first substrate, at least two electrodes may be disposed on the first substrate **10**, the second substrate **20**, or any combination thereof. In exemplary embodiments as shown in FIGS. **1** and **2**, a sustain electrode **70** is adhered on the second substrate **20** and an address electrode **80** is adhered on the first substrate **10**. In a preferred embodiment, at least one electrode adhered to the first substrate **10** is at least partly disposed within the socket (FIGS. **1** and **2**).

In an embodiment where the first substrate **10** includes a plurality of material layers **60** and the sockets **30** are formed within the material layers, at least two electrodes may be disposed on the first substrate **10**, disposed within the material layers **60**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **6**A, a first address electrode **80** is disposed within the material layers **60**, a first sustain electrode **70** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. FIG. **6**B is a cut-away of FIG. **6**A showing the arrangement of the co-planar sustain electrodes **70** and **75**. In another embodiment, as shown in FIG. **7**A, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. FIG. **7**B is a cut-away of FIG. **7**A showing the first sustain electrode **70**. As seen in FIG. **8**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed within the material layers **60**, a first address electrode **80** is disposed within the material layers **60**, a second address electrode **85** is disposed within the material layers **60**, and a second sustain electrode **75** is disposed within the material layers **60**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a cavity **55** is patterned on the first substrate **10** and a plurality of material layers **65** are disposed on the first substrate **10** so that the material layers conform to the cavity **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **9**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **10**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **11**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **65**, a second address electrode **85** is disposed within the material layers **65**, and a second sustain electrode **75** is disposed within the material layers **65**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

In an embodiment where a plurality of material layers **66** with aligned apertures **56** are disposed on a first substrate **10** thereby creating the cavities **55**, at least two electrodes may be disposed on the first substrate **10**, at least partially disposed within the material layers **65**, disposed on the second substrate **20**, or any combination thereof. In one embodiment, as shown in FIG. **14**, a first address electrode **80** is disposed on the first substrate **10**, a first sustain electrode **70** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first sustain electrode and the second sustain electrode are in a co-planar configuration. In another embodiment, as shown in FIG. **15**, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode is located between the first sustain electrode and the second sustain electrode in a mid-plane configuration. As seen in FIG. **16**, in a preferred embodiment of the present invention, a first sustain electrode **70** is disposed on the first substrate **10**, a first address electrode **80** is disposed within the material layers **66**, a second address electrode **85** is disposed within the material layers **66**, and a second sustain electrode **75** is disposed within the material layers **66**, such that the first address electrode and the second address electrode are located between the first sustain electrode and the second sustain electrode.

The specification, above, has described, among other things, various components of a light-emitting panel and methodologies to make those components and to make a light-emitting panel. In an embodiment of the present invention, it is contemplated that those components may be manufactured and those methods for making may be accomplished as part of web fabrication process for manufacturing light-emitting panels. In another embodiment of the present invention, a web fabrication process for manufacturing light-emitting panels includes the steps of providing a first substrate, disposing micro-components on the first substrate, disposing a second substrate on the first substrate so that the micro-components are sandwiched between the first and second substrates, and dicing the first and second substrate "sandwich" to form individual light-emitting panels. In another embodiment, the first and second substrates are provided as rolls of material. A plurality of sockets may either be preformed on the first substrate or may be formed in and/or on the first substrate as part of the web fabrication process. Likewise, the first and second substrates may be preformed so that the first substrate, the second substrate or both substrates include a plurality of electrodes. Alternatively, a plurality of electrodes may be disposed on or within the first substrate, on or within the second substrate, or on and within both the first substrate and second substrate as part of the web fabrication process. It should be noted that where suitable, fabrication steps may be performed in any order. It should also be noted that the micro-components may be preformed or may be formed as part of the web fabrication process. In another embodiment, the web fabrication process is performed as a continuous high-speed inline process with the ability to manufacture light-emitting panels at a rate faster than light-emitting panels manufactured as part of batch process.

As shown in FIGS. **12** and **13**, in an embodiment of the present invention, the web fabrication process includes the following process steps: a micro-component forming process **800** for forming the micro-component shells and filling the micro-components with plasma-forming gas; a micro-component coating process **810** for coating the micro-components with phosphor or any other suitable coatings and producing a plurality of coated and filled micro-components **400**; a circuit and electrode printing process **820** for printing at least one electrode and any needed driving and control circuitry on a first substrate **420**; a patterning process **840** for patterning a plurality of cavities on a first substrate to form a plurality of sockets **430**; a micro-component placement process **850** for properly placing at least one micro-component in each socket **430**; an electrode printing process **860** for printing, if required, at least one electrode on a second substrate **410**; a second substrate application and alignment process **870** for aligning the second substrate over the first substrate **440** so that the micro-components are sandwiched between the first substrate and the second substrate **450**; and a panel dicing process **880** for dicing the first and second substrates **450** to form individual light-emitting panels **460**.

In another embodiment of the present invention as shown in FIG. **17**, the socket **30** may be formed as a type of male-female connector with a male micro-component **40** and a female cavity **55**. The male micro-component **40** and female cavity **55** are formed to have complimentary shapes. As shown in FIG. **12**, as an example, both the cavity and micro-component have complimentary cylindrical shapes. The opening **35** of the female cavity is formed such that the opening is smaller than the diameter d of the male micro-component. The larger diameter male micro-component can be forced through the smaller opening of the female cavity **55** so that the male micro-component **40** is locked/held in the cavity and automatically aligned in the socket with respect to at least one electrode **500** disposed therein. This arrangement provides an added degree of flexibility for micro-component placement. In another embodiment, this socket structure provides a means by which cylindrical micro-components may be fed through the sockets on a row-by-row basis or in the case of a single long cylindrical micro-component (although other shapes would work equally well) fed/woven throughout the entire light-emitting panel.

In another embodiment of the present invention, as shown in FIG. **18**, a method for making a light-emitting panel includes weaving a single micro-component **40** through each socket **30** for the entire length of the light-emitting panel. Any socket **30** formed in the shape of a channel will work equally well in this embodiment. In a preferred embodiment, however, the socket illustrates in FIG. **17**, and described above, is used. As the single micro-component **40** is being woven/fed through the socket channels and as the single micro-component reaches the end of a channel, it is contemplated in an embodiment that the micro-component **40** will be heat treated so as to allow the micro-component **40** to bend around the end of the socket channel. In another embodiment, as shown in FIG. **19**, a method for making a color light-emitting panel includes weaving a plurality of micro-components **40**, each configured to emit a specific color of visible light, alternatingly through the entire light-emitting panel. For example, as shown in FIG. **19**, a red micro-component **41**, a green micro-component **42** and a blue micro-component **43** are woven/fed through the socket channels. Alternatively, a color light-emitting panel may be made by alternatingly coating the inside of each socket channel with a specific color phosphor or other UV conversion material, and then weaving/feeding a plurality of micro-components through the socket channels for the entire length of the light-emitting panel.

Other embodiments and uses of the present invention will be apparent to those skilled in the art from consideration of this application and practice of the invention disclosed herein. The present description and examples should be considered exemplary only, with the true scope and spirit of the invention being indicated by the following claims. As will be understood by those of ordinary skill in the art, variations and modifications of each of the disclosed embodiments, including combinations thereof, can be made within the scope of this invention as defined by the following claims.

The invention claimed is:

**1**. A web fabrication process for manufacturing a plurality of light-emitting panels, comprising:

forming a first substrate comprising a plurality of channels within the first substrate and at least one side surface including a plurality of substantially semi-circle openings to the plurality of channels; and

force-feeding a single micro-component through the plurality of channels via one of the plurality of substantially semi-circle openings of the side surface of the first substrate, the micro-component having a cylindrical shape, being not more than 300 microns in diameter across its minor axis, and emitting radiation when exposed to a trigger voltage.

**2**. The process of claim **1**, wherein each of the plurality of channels comprises at least one end at the side surface of the first substrate, and the process further comprises heating the micro-component to allow the micro-component to bend around the end of each channel.

**3**. The process of claim **1**, wherein the force-feeding comprises force-feeding a plurality of micro-components, each micro-component emitting a specific color of visible light when exposed to the trigger voltage.

**4**. The process of claim **1**, further comprising coating each channel with a specific color phosphor.

**5**. A web fabrication process for manufacturing a plurality of light-emitting panels, comprising:

forming a first substrate comprising a plurality of channels within the first substrate approximately equally spaced from one another in parallel and at least one side surface including a plurality of substantially semi-circle openings to the plurality of channels; and

force-feeding a single micro-component through the plurality of channels via one of the plurality of substantially semi-circle openings of the side surface of the first substrate, the micro-component having a cylindrical shape, the single micro-component being bent in a u-shape at multiple points so as to be woven through the plurality of channels in a continuous fashion; and

forming at least one electrode in contact with the single micro-component such that the single micro-component is capable of emitting radiation when the at least one electrode is exposed to a trigger voltage.

* * * * *

US009651813B2

(12) **United States Patent**
**Morris et al.**

(10) **Patent No.: US 9,651,813 B2**
(45) **Date of Patent: May 16, 2017**

(54) **LIQUID CRYSTAL PAPER**

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(73) Assignee: **Kent Displays Inc.**, Kent, OH (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1038 days.

(21) Appl. No.: **13/621,367**

(22) Filed: **Sep. 17, 2012**

(65) **Prior Publication Data**

US 2013/0070184 A1 Mar. 21, 2013

**Related U.S. Application Data**

(60) Provisional application No. 61/535,536, filed on Sep. 16, 2011.

(51) **Int. Cl.**

***G02F 1/1333*** (2006.01)
***G02F 1/137*** (2006.01)
*G02F 1/13* (2006.01)

(52) **U.S. Cl.**

CPC ...... ***G02F 1/13338*** (2013.01); ***G02F 1/13718*** (2013.01); *G02F 1/132* (2013.01); *G02F 1/1313* (2013.01); *G02F 1/133305* (2013.01)

(58) **Field of Classification Search**

CPC .... G02F 1/13338; G02F 1/1313; G02F 1/132; G02F 1/133305; G02F 1/13718; G02F 1/13452; G09F 9/301
USPC ...................... 349/12, 58, 158; 345/173, 174
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,685,771 A 8/1987 West et al.
5,347,811 A 9/1994 Hasegawa et al.
5,453,863 A 9/1995 West et al.
5,493,430 A 2/1996 Lu et al.
5,644,330 A 7/1997 Catchpole et al.
(Continued)

FOREIGN PATENT DOCUMENTS

WO 2005081779 9/2005

OTHER PUBLICATIONS

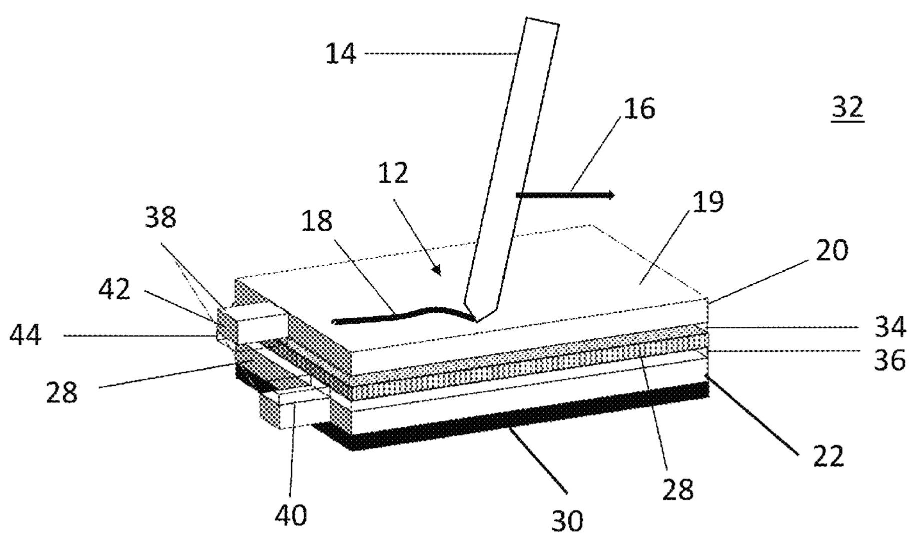
J.William Doane and Asad Khan, Cholesteric Liquid Crystals for Flexible Displays, Flexible Flat Panel Displays, 331-354, 2005, John Wiley & Sons, Ltd.
(Continued)

*Primary Examiner* — Edward Glick
*Assistant Examiner* — David Chung
(74) *Attorney, Agent, or Firm* — Abel Law Group, LLP

(57) **ABSTRACT**

Disclosed is liquid crystal paper and an erasing device that is not permanently connected to the liquid crystal paper. A sheet of liquid crystal paper includes flexible polymeric substrates. A polymer network or a spacer network, in which bistable cholesteric reflective liquid crystal material is dispersed, is disposed between two of the substrates. Optional alignment layers or optional electrically conductive layers sandwich the liquid crystal material therebetween. An optional layer of light absorbing material is disposed near one of the substrates. Application of pressure to an upper substrate changes a focal conic nonreflective texture of the liquid crystal material to a reflective planar texture. The erasing device applies a voltage or heat for erasing the paper by changing the reflective planar texture to the focal conic nonreflective texture.

**29 Claims, 5 Drawing Sheets**



(56) **References Cited**

U.S. PATENT DOCUMENTS

| | | | | |
|---|---|---|---|---|
| 5,691,795 | A | 11/1997 | Doane et al. | |
| 5,748,277 | A | 5/1998 | Huang et al. | |
| 5,831,816 | A * | 11/1998 | Johns | F16M 11/10 349/60 |
| 5,933,203 | A | 8/1999 | Wu et al. | |
| 6,104,448 | A | 8/2000 | Doane et al. | |
| 6,133,895 | A | 10/2000 | Huang | |
| 6,154,190 | A | 11/2000 | Yang et al. | |
| 6,268,839 | B1 | 7/2001 | Yang et al. | |
| 6,269,225 | B1 * | 7/2001 | Sato | G02F 1/133348 349/1 |
| 6,359,673 | B1 | 3/2002 | Stephenson | |
| 6,377,321 | B1 | 4/2002 | Khan et al. | |
| 6,476,885 | B1 * | 11/2002 | Murray | G02F 1/13452 349/150 |
| 6,654,080 | B1 | 11/2003 | Khan et al. | |
| 6,752,430 | B2 | 6/2004 | Holt et al. | |
| 6,788,362 | B2 | 9/2004 | Stephenson et al. | |
| 6,788,363 | B2 | 9/2004 | Liu et al. | |
| 6,816,138 | B2 | 11/2004 | Huang et al. | |
| 6,833,885 | B2 | 12/2004 | Hisamitsu et al. | |
| 6,934,792 | B1 | 8/2005 | Nakazawa | |
| 7,061,559 | B2 | 6/2006 | Khan et al. | |
| 7,075,593 | B2 | 7/2006 | Vidal et al. | |
| 7,142,190 | B2 | 11/2006 | Martinez | |
| 7,170,481 | B2 | 1/2007 | Doane et al. | |
| 7,188,996 | B2 | 3/2007 | Parker | |
| 7,236,151 | B2 | 6/2007 | Doane et al. | |
| 7,351,506 | B2 | 4/2008 | Schneider et al. | |
| 7,362,485 | B2 * | 4/2008 | Yamaguchi | G02F 1/1345 349/139 |
| 7,479,940 | B2 | 1/2009 | Marhefka | |
| 7,755,610 | B2 * | 7/2010 | Capurso | G09F 9/30 345/173 |
| 8,310,630 | B2 | 11/2012 | Marhefka et al. | |
| 2002/0109802 | A1 * | 8/2002 | Cheng | H04M 1/0266 349/58 |
| 2003/0160741 | A1 | 8/2003 | Martinez | |
| 2005/0078245 | A1 * | 4/2005 | Sasaki | G02B 5/3016 349/117 |
| 2005/0259197 | A1 * | 11/2005 | Hirai | G02F 1/134309 349/113 |
| 2007/0085837 | A1 * | 4/2007 | Ricks | G02F 1/13338 345/173 |
| 2007/0126674 | A1 | 6/2007 | Doane et al. | |
| 2007/0152928 | A1 | 7/2007 | Doane et al. | |
| 2007/0277659 | A1 * | 12/2007 | Schneider | B23K 26/40 83/73 |
| 2008/0074383 | A1 | 3/2008 | Dean | |
| 2009/0033811 | A1 | 2/2009 | Schneider | |
| 2009/0096942 | A1 | 4/2009 | Schneider et al. | |
| 2009/0284691 | A1 * | 11/2009 | Marhefka | G02F 1/1347 349/86 |
| 2010/0216635 | A1 | 8/2010 | Kazmaier et al. | |
| 2010/0256802 | A1 * | 10/2010 | Garica | G01R 31/01 700/218 |
| 2012/0099030 | A1 | 4/2012 | Pishnyak | |
| 2013/0342432 | A1 * | 12/2013 | Schneider | G09G 3/3493 345/89 |
| 2015/0054775 | A1 * | 2/2015 | Montbach | G02F 1/13718 345/174 |

OTHER PUBLICATIONS

J.Y. Nahm, et al. Amorphous Silicon Thin-Film Transistor Active-Matrix Reflective Cholesteric Liquid Crystal Display, Asia Display 98: 979-982.

Brochure of a Skin Flik™ electronic skin product published in the U.S. after May 22, 2011.

Description of a Skin Flik™ electronic skin product sold in the U.S. after May 22, 2011.

E. Montbach, et al., Flexible Electronic Skin Display, SID Symposium Digest of Technical Papers, 2009, vol. 40, p. 16.

U.S. Appl. No. 12/729,678, filed Mar. 23, 2010, entitled Display With Overlayed Electronic Skin , Inventor Asad Khan.

* cited by examiner

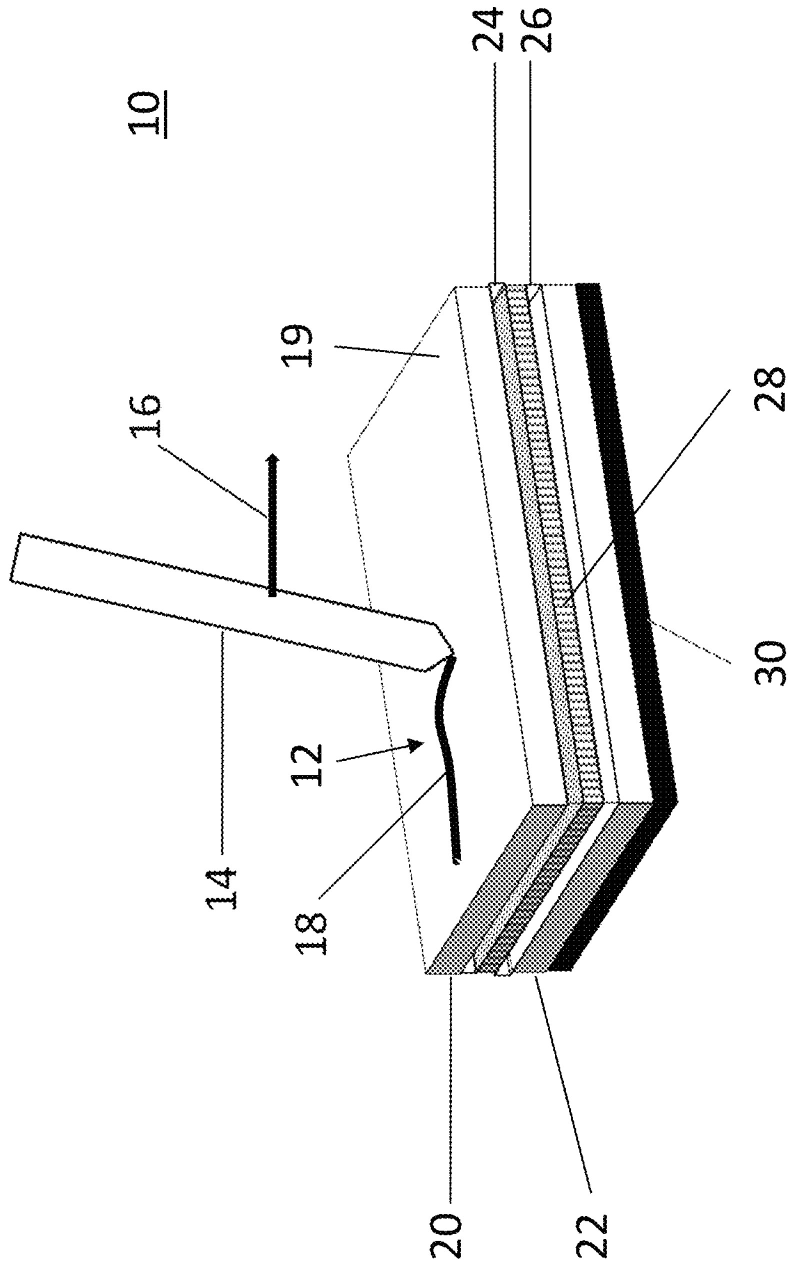



Figure 1

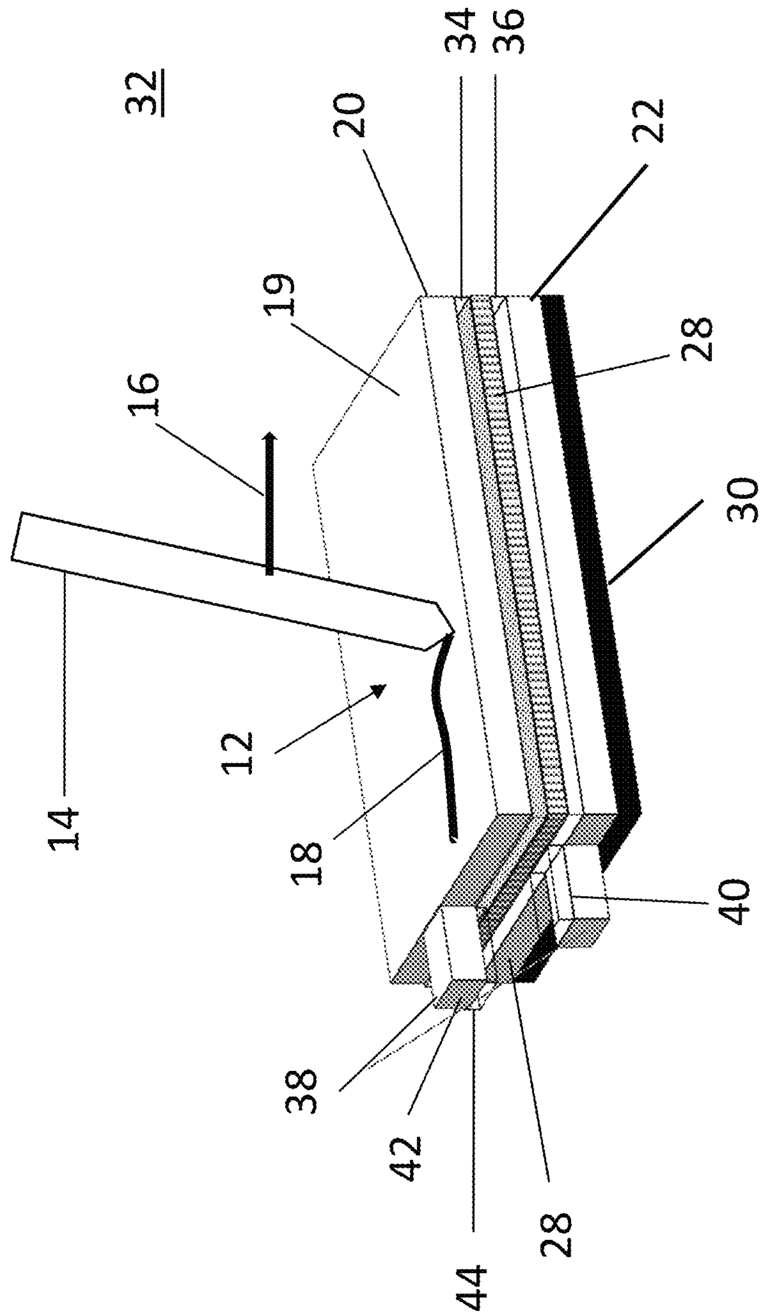



Figure 2

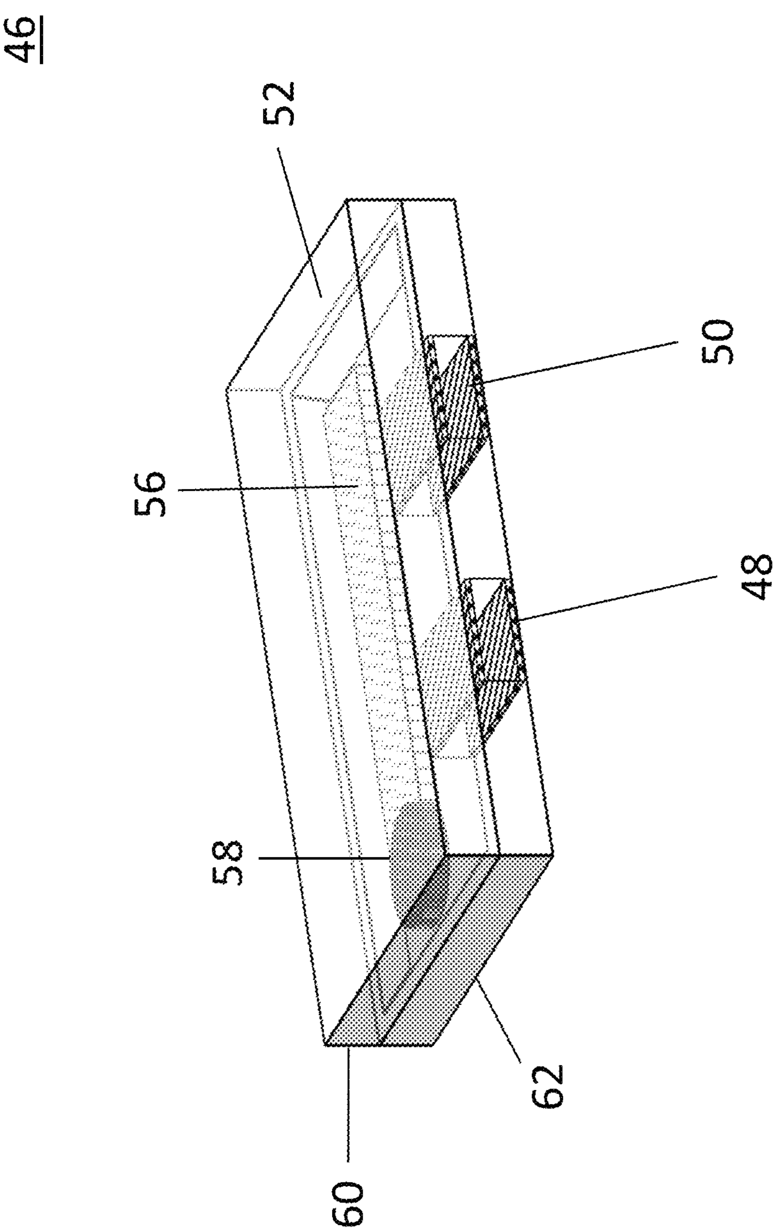



Figure 3

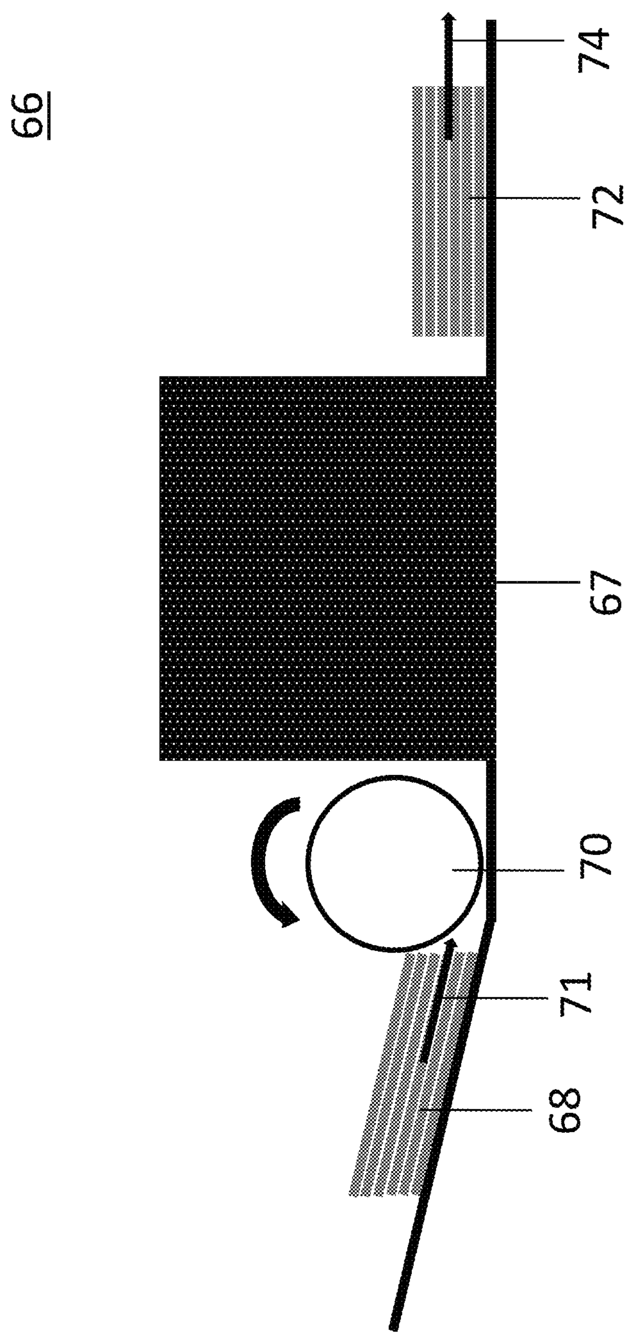



Figure 4

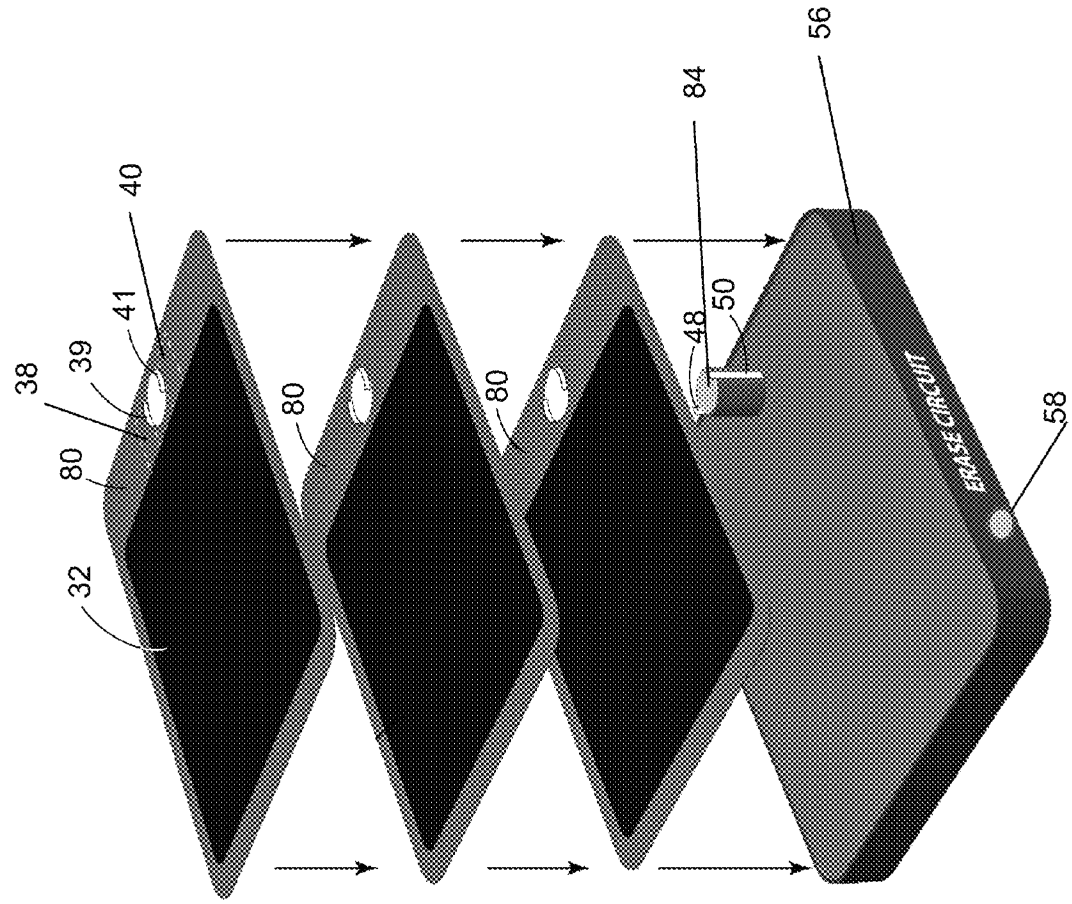



Figure 5

# LIQUID CRYSTAL PAPER

## TECHNICAL FIELD

This disclosure features liquid crystal paper in combination with an erasing device for erasing the liquid crystal paper that is not permanently attached to the liquid crystal paper.

## BACKGROUND

We are accustomed to reading and writing or drawing on paper. Paper is convenient and is readily available but it can only be used once; after use, it is promptly discarded. Discarding paper is a huge problem world-wide at a significant cost and impact on the environment. Recycling it has been a growing business. Using more modern technology, brought on by computers with touch screens and powerful software, we can write on computer screens and the image can be saved or discarded without waste. An example is the iPad® of Apple Inc. However, we have not had the privilege of something that truly imitates paper but does not need to be discarded after use.

Photochromic paper has been disclosed for paper replacement that can be erased and reused; see for example, U.S. Patent Application Publication 2010/0216635 by Xerox. A problem with photochromic paper, however, is that the image is transient, being erased by ambient and sun light. It also requires a special optical stylus or masked light to create an image.

U.S. Pat. No. 6,104,448 discloses a thin film of cholesteric liquid crystal material sandwiched between two thin sheets of plastic used as a writing surface. The light pressure of a pointed stylus such as a pencil can be used to write or draw an image on the tablet. A unique feature of the tablet is that the image remains indefinitely under sun and ambient light and even elevated temperatures which can exceed 50° C. With transparent electrodes on the plastic substrates and attached drive electronics, the image traced on the writing pad can be written and electrically erased and rewritten with a different image. A writing pad including a cholesteric liquid crystal layer sandwiched between substrates and in contact with electrodes, which is erased by attached drive electronics, has been recently commercialized under the name Boogie Board™ by Kent Displays, Inc.

More recently, full-color writing tablets have been proposed (see U.S. Patent Application Publications 2009/0033811 and 2009/0096942), which are incorporated herein by reference in their entireties. The patent applications disclose, among other things, writing pads in which two or more cholesteric liquid crystal layers that reflect different primary colors are stacked on top of one another. With a stylus one can draw or write in a different primary color. Colors are changed using attached drive electronics. The primary colors can be mixed depending upon the pressure of the pen to create many different colors. This provides the user of a writing pad to create artwork in full color.

As disclosed in U.S. Pat. No. 6,104,448 polymer networks can be incorporated into the cholesteric liquid crystal layer. U.S. Patent Application Publication 2009/0033811 further discloses how the polymer networks can be used to control the pressure sensitivity of the stylus in tracing an image. Published U.S. patent application Pub No. 2012/0099030, which is incorporated herein by reference in its entirety,



discloses the use of a spacer network where the density and placement of the spacers control the pressure sensitivity.

## BRIEF DESCRIPTION OF THE INVENTION

A liquid crystal paper of this disclosure has similar properties as normal writing paper but, unlike paper, does not need to be discarded after use; it can be cleared and reused many times over. To imitate actual wood pulp-based paper (normal writing paper) the liquid crystal paper must by thin, flexible, light weight, devoid of electronics and software and able to be written on with an untethered stylus. Like normal writing paper, liquid crystal paper is a thin, flexible sheet that has no electronic circuitry permanently attached. One uses liquid crystal paper in the same way normal writing paper is used for hand writing or drawing pictures. An untethered, pointed stylus is used to write on the liquid crystal paper but with the advantage that it does not have to be a pencil or pen but only a pointed object which could even be ones finger nail. Like normal writing paper, liquid crystal paper is placed on a hard surface for writing. The paper can also be designed to go into a mechanical printer that uses raised type to type documents from the paper. Another advantage over normal writing paper is that water does not damage the liquid crystal paper. It is more rugged and not so easily wrinkled or torn.

After use, the liquid crystal paper can be cleared or erased for reuse. This can be accomplished by several different mechanisms:

A liquid crystal material that can be cleared by application of heat is used in the liquid crystal paper. Using an optional liquid crystal alignment layer on the surface of the substrate the paper clears (i.e., erases) when exposed to heat. A sheet is therefore cleared by inserting it into a device that applies heat momentarily to the sheet until it clears or erases. In some cases the alignment layer is not necessary when the function of the alignment layer is served by other means to be described later.

Using a stand-alone device with electronics that provide a voltage pulse or pulses to electrodes on a sheet of liquid crystal paper will clear it. A sheet that needs to be cleared is inserted in or attached to the device that applies a voltage pulse or pulses to the electrodes of sufficient magnitude to clear the sheet.

In the case of mechanisms 1 and 2 above, multiple sheets can be cleared whereby they are inserted sequentially in an automatic fashion into one of the devices described above.

Cholesteric liquid crystalline materials are ideally suited for replacement of typical paper because of their unique optical features. When cast as a film the cholesteric material can be mechanically or electrically switched to either one of two stable textures: a visible reflective texture (planar texture) or non-visible texture (focal conic texture) that is not reflective as described, for example, in U.S. Pat. No. 5,453,863, which is incorporated herein by reference in its entirety. In the reflective texture, the material reflects light at a pre-selected wavelength and band width depending upon the material selected. In the non-reflective texture it does not reflect light and light passes through the material. On a black background the reflective texture appears as a brilliant color and the non-reflective texture appears black. Both textures are stable. These bistable structures can be electronically or mechanically switched between each other at rapid rates (on the order of milliseconds). The image can be in gray scale in which the texture of the liquid crystal includes a combination of the focal conic and planar textures that provides a reflective brightness or intensity between that produced by the planar only and focal conic only textures.

Liquid crystal paper is made by sandwiching the liquid crystal material between two substrates that are spaced to a particular gap. The substrates can be thin plastic sheets which carry transparent electrodes facing the liquid crystal. The electrodes can be unpatterned or patterned but are ideally unpatterned so as to cover the entire writing surface. The bottom substrate is painted with a light absorbing (black or colored) back layer. Alternatively, for example, one of the electrodes can be light absorbing. The cell gap is usually set by plastic spacers that are either cylindrical or spherical in shape. Other ways of setting the cell gap that are apparent to those skilled in the art in view of this disclosure may be used. However, when one presses on the top substrate, the liquid crystal is displaced; flowing laterally out of the area. When the non-reflective liquid crystal is induced to flow such as under the pressure of a pointed stylus the reflective texture is induced under the tip of the stylus. The reflective texture contrasts well with the dark background. The U.S. Pat. No. 6,104,448 patent, which is incorporated herein by reference in its entirety, discloses a polymer network that is soluble with the chiral nematic liquid crystal and phase separates to form separated polymer domains that control the flow. Alternatively, the 2012/0099030 publication discloses the use of a spacer network that may be used in the liquid crystal paper where the density and placement of the spacers control the flow.

Pressure with a stylus draws a monochromatic color image which is the reflective color of the cholesteric planar texture on a black or contrasting color background. The image is erased by applying a voltage pulse from the erasing device to electrodes on the liquid crystal paper, which drives the entire cell to the non-reflective or black state (the focal conic texture).

Referring now to various aspects of this disclosure, a first aspect features liquid crystal paper in combination with a separate erasing device for erasing the liquid crystal paper. A sheet of liquid crystal paper comprises flexible polymeric substrates. A polymer network or spacer network is used in which bistable cholesteric reflective liquid crystal material is dispersed; this is disposed between two of the substrates. Optional alignment layers or optional electrically conductive layers sandwich the liquid crystal material therebetween. The alignment layers favor formation of a focal conic nonreflective texture in the liquid crystal material but are not necessary if the surface of the bare substrate is sufficient to form the focal conic nonreflective texture alone. Application of pressure to an upper substrate changes the focal conic nonreflective texture of the liquid crystal material to a reflective planar texture. An erasing device for erasing the liquid crystal paper is not permanently connected to the liquid crystal paper. The erasing device includes a source of voltage or a source of heat for erasing the liquid crystal paper by changing the reflective planar texture to the focal conic nonreflective texture.

Referring to specific features that are applicable to all aspects of this disclosure, a layer of light absorbing material can be disposed near one of the substrates. All of the substrates that are upstream of the light absorbing layer in a direction of incident light can be transparent. The polymer network in which the liquid crystal material is dispersed can be in the form of a liquid crystal layer. At least two of the liquid crystal layers can be used. Each of the liquid crystal layers can be sandwiched by the electrically conductive layers. At least one of the substrates can be disposed between adjacent electrically conductive layers. The liquid crystal layer can have a thickness ranging from 2 to 10 microns. Each substrate can have a thickness ranging from 12.5 μm to 200 μm. Application of pressure to the upper substrate can create gray scale caused by a presence of a combination of the focal conic nonreflective texture and the reflective planar texture. A stylus that applies the pressure can be untethered to the liquid crystal paper or to the erasing device, the stylus containing no lead or ink.

A second aspect of the disclosure features liquid crystal paper in combination with a separate erasing device for electrically erasing the liquid crystal paper. A sheet of liquid crystal paper comprises flexible polymeric substrates. A polymer network or a spacer network is used in which bistable cholesteric reflective liquid crystal material is dispersed; this is disposed between two of the substrates. Electrically conductive layers sandwich the liquid crystal material therebetween. A layer of light absorbing material is disposed near one of the substrates. Electrically conductive leads extend from the electrically conductive layers so as to be exposed exterior to the substrates. Application of pressure to an upper substrate changes a focal conic nonreflective texture of the liquid crystal material to a reflective planar texture. An erasing device that erases the liquid crystal paper is not permanently connected to the liquid crystal paper. The erasing device comprises a housing including electrical contacts that detachably connect with the electrically conductive leads. Drive electronics apply a voltage to the contacts for erasing the liquid crystal paper by changing the reflective planar texture to the focal conic nonreflective texture.

Referring to specific features of the second aspect of this disclosure, the specific features discussed above in connection with the first aspect, may be used with the second aspect in any combination. The erasing device can include a switch enabling the voltage from the drive electronics to be applied to the contacts and to erase the liquid crystal paper. The erasing device can include sockets in which the contacts are disposed. The sockets are configured and arranged to receive the leads. Application of pressure to the upper substrate can create gray scale caused by a presence of a combination of the focal conic nonreflective texture and the reflective planar texture. There can be a plurality of the sheets of the liquid crystal paper and a document feeder that feeds individual sheets to the erasing device. A casing in contact with the substrates can ruggedize the liquid crystal paper.

A third aspect of this disclosure features liquid crystal paper in combination with a separate erasing device for erasing the liquid crystal paper with heat. A sheet of liquid crystal paper comprises flexible polymeric substrates. A polymer network in which bistable cholesteric reflective liquid crystal material is dispersed, is disposed between two of the substrates. Alternatively, a spacer network may be used in place of the polymer network as described in the 2012/0099030 publication. Optional alignment layers sandwich the liquid crystal material therebetween in cases where the surface of the polymer is not suitable for forming the non-reflective focal conic texture. The alignment layers favor formation of a focal conic nonreflective texture in the liquid crystal material when necessary A layer of light absorbing material is disposed near one of the substrates. Application of pressure to an upper substrate changes the focal conic nonreflective texture of the liquid crystal material to a reflective planar texture. An erasing device is used for erasing the liquid crystal paper that is not permanently connected to the liquid crystal paper. The erasing device applies heat effective to cause the liquid crystal material to reach a clearing temperature such that after the liquid paper cools it returns to the focal conic nonreflective texture.

Some of the specific features discussed above in connection with the first and second aspects may be used in connection with this aspect of the disclosure. In addition, the specific features discussed in the Detailed Description may be used in the aspects of the disclosure discussed above in any combination.

Many additional features, advantages and a fuller understanding of the invention will be had from the accompanying drawings and the detailed description that follows. It should be understood that the above Brief Description of the Invention describes the invention in broad terms while the following Detailed Description describes the invention more narrowly and presents preferred embodiments that should not be construed as necessary limitations of the broad invention as defined in the claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**: Illustration of liquid crystal paper that can be thermally erased.

FIG. **2**: Illustration of liquid crystal paper that can be electronically erased.

FIG. **3**: Illustration of a clearing device for clearing liquid crystal paper with electrodes.

FIG. **4**: Illustration of a device for clearing multiple sheets of liquid crystal paper.

FIG. **5**: Illustration of a device for storing and erasing a plurality of sheets of liquid crystal paper.

## DETAILED DESCRIPTION

A first embodiment of liquid crystal paper **10** is illustrated in FIG. **1**. In that embodiment the liquid crystal paper **10** is addressed with an image **12** using a pointed stylus **14** moving in a direction indicated by the arrow **16**. That is, the image **12** is drawn onto the liquid crystal paper using the stylus **14** that leaves no marks on the top outer surface of the liquid crystal paper that it contacts. The stylus **14** contains no lead or ink. Rather, the image **12** (comprised of line **18** on background **19**) is formed by flow of liquid crystal material induced by pressure of the stylus **14** causing the liquid crystal material to change from the nonreflective focal conic texture to the reflective planar texture in regions or lines **18** where the stylus has pressed on the liquid crystal paper. The image can be erased when the liquid crystal paper **10** is momentarily exposed to heat.

The liquid crystal paper **10** includes two transparent plastic or otherwise flexible upper and lower substrates **20** and **22**. Examples of materials for the substrates **20**, **22** include polyethylene terephthalate, PET, or polycarbonate polymer sheet material. Substrate sheet thicknesses in a range of 12.5 μm to 200 μm can be used but the substrate is not necessarily restricted to this range of thickness. The substrates **20**, **22** may optionally be coated with a surface treatment of alignment layer materials **24** and **26** that sandwich a liquid crystal layer **28** of cholesteric liquid crystal material, which includes cholesteric liquid crystal dispersed in a polymer network or spacer network (disclosed in the 2012/0099030 publication). This surface treatment is applied to cause the cholesteric liquid crystal in the polymer dispersion of the liquid crystal layer **28** to favor the non-reflective texture upon application of heat sufficient to untwist the cholesteric liquid crystal or drive the liquid crystal to the isotropic state. Upon cooling, the liquid crystal phase is established. The surface treatment may be replaced by the polymer network as the polymer network may provide a suitable polymer coating on the surface. In cases where a spacer network is used in place of the polymer network, a surface treatment may be used when the bare surface of the substrate is not suitable for forming the non-reflective focal conic texture. In all embodiments herein, in the spacer network the density and placement of the spacers control the flow of the liquid crystal material. The polymer network can include spacers to control the cell gap, at a lower concentration than in the spacer network, and is not a network of spacers to control liquid crystal flow.

There are many surface treatments that favor the non-reflective focal conic state as described in U.S. Pat. No. 5,453,863, which is incorporated herein by reference in its entirety. The alignment layer materials are generally known in the art of liquid crystal displays to cause the long axis of the liquid crystal molecules to align perpendicular to the surface or at an angle that favors the non-reflective (focal conic) texture. Normally the alignment material is a polymer that is polymerized and phase separated from the cholesteric liquid crystal as described next. The cholesteric liquid crystal dispersion of the liquid crystal layer **28** is a material as described for example in U.S. Pat. No. 6,104,448 or more recently in U.S. Patent Application Publications 2009/0033811 and 2009/0096942, which are incorporated herein by reference in their entireties. In this material the cholesteric liquid crystal is dispersed in a polymer network created by polymerization induced phase separation, which is a well-known procedure (see for example U.S. Pat. No. 6,104,448). The phase separated polymer will also form a thin layer on the surface of the substrate to form the alignment layers **24** and **26**. Alternatively, alignment layer coatings can be used for alignment layers **24** and **26** as is well known in the art of liquid crystal displays (see U.S. Pat. No. 5,453,863). The thickness of the polymer dispersed cholesteric liquid crystal material is typically about 4 microns but can be in the range of 2-10 microns. In the polymer network, the uniformity of the liquid crystal layer thickness is established by plastic or glass spacers, which is also a well-known art in the liquid crystal display technology. A light absorbing layer **30** (e.g., typically a black layer) is coated on the back of the lower substrate **22** to absorb light that is not reflected by the liquid crystal, providing contrast to the reflected image. In this embodiment, the liquid crystal paper **10** is erased by momentarily heating it to a temperature that melts the liquid crystal into a normal liquid called the clearing temperature in the art of liquid crystalline materials. When the liquid crystal paper cools, the liquid crystal returns to the non-reflective texture removing the image.

A second embodiment of liquid crystal paper **32** is shown in FIG. **2**. The liquid crystal paper **32** is addressed with an image **12** (comprised of the line **18** on background **19**) using the untethered pointed stylus **14** moving in a direction indicated by the arrow **16** (as in the first embodiment). The liquid crystal paper **32** includes two transparent plastic or otherwise flexible substrates **20** and **22**, the same as described in the embodiment above. The substrates are coated with a transparent electrically conductive material **34** and **36** to serve as electrodes used for clearing the liquid crystal paper. These electrodes are connected to interconnects **38**, **40**, respectively, (composed of nonconductive material **42** and conductive lead **44**) for the purpose of electrically connecting the liquid crystal paper to a clearing device for erasing the paper for further use. The interconnects are made as part of the upper and lower substrates along with the electrodes on them. A preferred conductive material **34** and **36** is a conducting polymer (see for example

Cao, *Appl Phy Lett* 60 (1992), which is incorporated herein by reference in its entirety). The cholesteric liquid crystal layer **28** in the form of the polymer network (including spacers) or the spacer network, and the backcoat **30** are the same as described in the embodiment above.

Liquid crystal paper **32** is cleared with the clearing or erasing device **46** as shown in FIG. **3**. Interconnects **38** and **40** of the sheet of liquid crystal paper **32** are inserted into sockets **48** and **50** of the housing **52** of the erasing device **46** that are configured and arranged to receive the interconnects. Inside the sockets **48**, **50** are electrically conductive contacts that are electrically connected inside the housing to erasing electronics **56**, which are activated by button or switch **58**. An upper housing section **60** and a lower housing section **62** encase the clearing device into a single unit. The clearing device **46** may be designed so that the button **58** or other switch of suitable structure is located internally and is activated by the liquid crystal paper when it is inserted.

In the case where there are a plurality of sheets **68** of the liquid crystal paper **10**, **32** of either the first or the second embodiment to be cleared, such as for example a stack of sheets, using a device **66** the sheets **68** may all be cleared automatically as shown in FIG. **4**. FIG. **4** shows how a stack of sheets **68** may be fed into a clearing or erasing device **67** using concepts of the first or second embodiments using a document feeder **70** and a collecting tray **72**. After the sheets are moved one at a time in a direction **71** by the document feeder into the clearing device **67**, the clearing device **67** either applies heat or a clearing voltage, which places the liquid crystal in the focal conic texture. The documents are moved in a direction **74** where they can then be stacked onto the collecting tray **72**.

In another embodiment, sheets of liquid crystal paper as illustrated in FIG. **2** are configured to be placed or stored on a special receptacle that erases each sheet when placed on the receptacle. Such an example is shown in FIG. **5** where each sheet contains a hole that fits to a post on which each sheet can be placed and stored. The post contains an electrode that connects with the electrodes on each sheet to an erasing device to allow them to be erased either in mass or one at a time while they are placed on the post. This is illustrated in detail in FIG. **5** as an exploded view of several identical sheets of liquid crystal paper being placed over a post. Each sheet of liquid crystal paper includes an electrically erasable sheet **32** that is contained within a bezel **80**. The bezel could be a clear flexible plastic material in which the sheet is partially or fully encapsulated Bezel **80** contains a hole and on the rim of the hole two electrically conductive electrodes **39** and **41** are electrically connected to interconnects **38** and **40** that are used to erase the sheet. The erasing device contains a post **84** which holds electrically conductive electrodes **48** and **50** and makes electrical contact with both rim electrodes **39** and **41** when the hole of the sheet is placed over the post **84**. Electrodes **48** and **50** may be spring loaded so that they make firm electrical contact with interconnects **38** and **40**. The sheet of liquid crystal paper is erased or cleared when voltage pulses of a suitable waveform are applied via the electrodes. The waveform is supplied by the erasing circuit **56** that is activated by the button switch **58**. In the erasure process the liquid crystal is driven to the focal conic texture with a wave form such as described in U.S. Pat. Nos. 5,625,477 and 5,644,330, which are incorporated herein by reference in their entireties. The electronic erasing circuit that is able to produce these waveforms would be apparent to one of ordinary skill in the art in view of this disclosure, such as is disclosed in the 2009/0033811 publication.

The liquid crystal paper will now be described by reference to the following examples which should not be used to limit the invention as defined by the claims.

## Example 1

Liquid crystal paper **32** (FIG. **2**) and clearing device **46** (FIG. **3**) were fabricated to demonstrate the inventive concept. The liquid crystal paper **32** was constructed from two transparent substrates and a polymer dispersed cholesteric liquid crystal layer. The top and bottom substrates were made from 2 mil (50 μm) thick Polyethylene Terephthalate (PET). An unpatterned transparent electrode made from PEDOT-based conducting polymer (AGFA) covered the entire surface area of the interior surface of both substrates. The polymer-dispersed liquid crystal layer consisted of a yellow (580 nm) cholesteric liquid crystal (Merck) with a layer thickness of 4.0 μm established by spherical spacers. The dispersion was made from a blend of polymerizable monomer (prepolymer) and cholesteric liquid crystal. The dispersion was created by non-encapsulating polymerization induced phase separation of a cholesteric liquid crystal using monomer chemistry similar to what is described in U.S. Pat. No. 7,351,506, which is incorporated herein by reference in its entirety. This layer was made using a UV curable methacrylate-based monomer, acrylate-based cross-linker, diphenyl photoinitiator, and 4 micron spherical polyvinylidine spacers. The mixture consisted of:

75% (wt.) KLC19 (Kent Displays, Inc.) cholesteric liquid crystal premixed to selectively Bragg reflect yellow light at the desired peak reflective wavelength of 580 nm; and

25% (wt.) photo-polymerizable monomer consisting of:
81.6% (wt.) methyl methacrylate
14.7% (wt.) trimethylolpropane triacrylate
2.0% (wt.) Irgacure 651 (Ciba Specialty Chemicals)
1.7% (wt.) lauryl methacrylate.

The spherical plastic spacers were added to the system at 3% (wt.) of the total weight of the liquid crystal/monomer mixture. The mixture was than laminated between the two conductive polymer coated PET substrates. The system was cured by exposure to UV light at 0.92 mW/cm$^2$ irradiance for 15 minutes. After curing the polymerizable mixture, the cell was backpainted black and then laser-singulated (as described in U.S. Patent Application Publication 2007/0277659A1, which is incorporated herein by reference in its entirety) to the desired shape.

A ruggedizing packaging was used to ruggedize the liquid crystal paper and protect it from extreme mechanical conditions. Ruggedized packaging consisted of a 1.5 mm black acrylic sheet behind the display and a 200 um black PET frame in front of the display. The black PET frame had 50 um pressure sensitive adhesive (3M) laminated to it allowing the frame to adhere to the display perimeter and the edge of the acrylic backplane. The acrylic backplane was 0.5 mm wider than the display in all dimensions and the PET frame. Exposed ledges with conducting polymer were connected to electrical interconnects that can be detachably connected to external electronics.

The electrical interconnects connected to the clearing device that electrically switches the liquid crystal paper. Electrical interconnects **38** and **40** on liquid crystal paper **32** were made with silver conductive tape attached to the display ledges and then left exposed on the outside of the ruggedizing packaging. The electrical interconnects were put into mechanical contact with the clearing device to make an electrical connection between the liquid crystal paper and the switching electronics in the clearing device, The clearing device was put in mechanical contact with the liquid crystal paper to electrically switch and clear off any writing on the liquid crystal paper (planar texture lines on a focal conic texture background). Clearing device **46** consisted of a pressure point to contact the electrical interconnect, and drive electronics. The drive electronics were similar to those described in U.S. patent application Ser. No. 12/152,862, which is incorporated herein by reference in its entirety and can electrically drive the liquid crystal paper to the focal conic texture to erase the images (i.e., to change the entire exposed surface area of the liquid crystal paper to the focal conic texture, which removes the planar texture lines).

When the liquid crystal paper was inserted into the clearing device it created a voltage sufficient to clear the liquid crystal paper so that it may be reused. The clearing voltage applied to the liquid crystal paper was a sequence of pulses. Since the voltage pulses were around 50V the circuit contained a voltage boost circuit to transform the given battery voltage to a higher voltage optimized for clearing the liquid crystal paper. To create the pulses, analog switches selected either high voltage or ground for each electrode **48** and **50**. This selection was controlled by a microcontroller so that the analog switches can be switched in such a sequence to create the proper waveform. The waveform and magnitude of the voltage pulse to switch the display are well known in the art of a bistable cholesteric liquid crystal displays; e.g., U.S. Pat. Nos. 5,453,863 and 5,691,795, which patents are incorporated herein by reference in their entireties. Selecting the various waveforms and magnitudes of the clearing voltage for the liquid crystal layer would be apparent to one of ordinary skill in the art in view of these patents.

## Example 2

The liquid crystal paper described in Example 1 was cleared by momentarily heating it to a temperature that erased the image on the paper. The liquid crystal paper sample was warmed with an air gun. After clearing one could then reuse the liquid crystal paper. It was observed that the contrast of the written image was not as good with the heat clearing process as with the electronic process of Example 1. It is speculated that the contrast could be improved by the selection of a polymer in the dispersion that provided an alignment layer that better created the non-reflective texture upon clearing. However, an alignment layer should not be considered a necessary part of the liquid crystal paper.

Many modifications and variations of the invention will be apparent to those of ordinary skill in the art in light of the foregoing disclosure. Therefore, it is to be understood that, within the scope of the appended claims, the invention can be practiced otherwise than has been specifically shown and described.

What is claimed is:

**1**. Liquid crystal paper in combination with a separate erasing device for erasing the liquid crystal paper comprising:

a sheet of liquid crystal paper comprising:

flexible polymeric substrates,

a bistable dispersion layer including a polymer network or spacer network in which cholesteric reflective liquid crystal material is dispersed, disposed between two of said substrates;

electrically conductive layers that sandwich said dispersion layer therebetween;

wherein application of pressure to an upper said substrate changes said focal conic nonreflective texture of said liquid crystal material to a reflective planar texture;

wherein said liquid crystal paper is flexible and includes no casing that ruggedizes said liquid crystal paper;

wherein a through hole is in said liquid crystal paper which internally exposes said electrically conductive layers; and

an erasing device for erasing said liquid crystal paper that is not permanently connected to said liquid crystal paper, said erasing device including a source of voltage for erasing said liquid crystal paper by changing said reflective planar texture to said focal conic nonreflective texture;

wherein said erasing device comprises a post and electrically conductive contacts disposed on said post that detachably connect with said exposed electrically conductive layers, wherein said drive electronics apply said voltage to said electrically conductive contacts for erasing said liquid crystal paper.

**2**. The liquid crystal paper and separate erasing device of claim **1** comprising a spring mechanism for outwardly urging said electrically conductive contacts.

**3**. The liquid crystal paper and separate erasing device of claim **1**,

wherein each of said substrates has a thickness of not more than 50 microns.

**4**. The liquid crystal paper and separate erasing device of claim **1** comprising a layer of light absorbing material disposed near one of said substrates.

**5**. The liquid crystal paper and separate erasing device of claim **4** wherein all of said substrates that are upstream of said light absorbing layer in a direction of incident light are transparent.

**6**. The liquid crystal paper and separate erasing device of claim **1** wherein said dispersion layer includes said polymer network in which said liquid crystal material is dispersed.

**7**. The liquid crystal paper and separate erasing device of claim **6** comprising at least two of said dispersion layers.

**8**. The liquid crystal paper and separate erasing device of claim **7** wherein each of said dispersion layers is sandwiched by said electrically conductive layers.

**9**. The liquid crystal paper and separate erasing device of claim **8** wherein at least one of said substrates is disposed between adjacent said electrically conductive layers.

**10**. The liquid crystal paper and separate erasing device of claim **6** wherein said dispersion layer has a thickness ranging from 2 to 10 microns.

**11**. The liquid crystal paper and separate erasing device of claim **3** wherein each said substrate has a thickness of at least 12.5 μm.

**12**. The liquid crystal paper and separate erasing device of claim **1** wherein application of pressure to said upper substrate creates gray scale caused by a presence of a combination of said focal conic nonreflective texture and said reflective planar texture.

**13**. The liquid crystal paper and separate erasing device of claim **1** comprising a stylus for applying said pressure that is untethered to said liquid crystal paper or to said erasing device, said stylus containing no lead or ink.

**14**. The liquid crystal paper and separate erasing device of claim **1** comprising a seal around a periphery of said liquid crystal paper formed by laser singulation.

**15**. The liquid crystal paper of claim **1** wherein said electrically conductive layers comprise unpatterned conductors.

**16**. Liquid crystal paper in combination with a separate erasing device for electrically erasing the liquid crystal paper comprising:

a sheet of liquid crystal paper comprising:

flexible polymeric substrates;

a bistable dispersion layer including a polymer network or spacer network in which cholesteric reflective liquid crystal material is dispersed, disposed between two of said substrates;

electrically conductive layers that sandwich said dispersion layer therebetween;

a layer of light absorbing material disposed near one of said substrates;

electrically conductive leads extending from said electrically conductive layers so as to be exposed exterior to said substrates;

wherein application of pressure to an upper said substrate changes a focal conic nonreflective texture of said liquid crystal material to a reflective planar texture;

wherein said liquid crystal paper is flexible; and

an erasing device for erasing said liquid crystal paper that is not permanently connected to said liquid crystal paper, said erasing device comprising a housing including sockets including internal electrical contacts that detachably connect with said electrically conductive leads, and drive electronics that apply a voltage to said internal contacts for erasing said liquid crystal paper by changing said reflective planar texture to said focal conic nonreflective texture.

**17**. The liquid crystal paper and separate erasing device of claim **16** wherein all of said substrates that are upstream of said light absorbing layer in a direction of incident light are transparent.

**18**. The liquid crystal paper and separate erasing device of claim **16** wherein said dispersion layer includes said polymer network in which said liquid crystal material is dispersed.

**19**. The liquid crystal paper and separate erasing device of claim **18** comprising at least two of said dispersion layers.

**20**. The liquid crystal paper and separate erasing device of claim **19** wherein each of said dispersion layers is sandwiched by said electrically conductive layers.

**21**. The liquid crystal paper and separate erasing device of claim **20** wherein at least one of said substrates is disposed between adjacent said electrically conductive layers.

**22**. The liquid crystal paper and separate erasing device of claim **18** wherein said dispersion layer has a thickness ranging from 2 to 10 microns.

**23**. The liquid crystal paper and separate erasing device of claim **16** wherein each said substrate has a thickness up to 50 μm.

**24**. The liquid crystal paper and separate erasing device of claim **16** wherein said erasing device includes a switch enabling said voltage from said drive electronics to be applied to said contacts and to erase said liquid crystal paper.

**25**. The liquid crystal paper and separate erasing device of claim **16** wherein application of pressure to said upper substrate creates gray scale caused by a presence of a combination of said focal conic nonreflective texture and said reflective planar texture.

**26**. The liquid crystal paper and separate erasing device of claim **16** comprising a stylus for applying said pressure that is untethered to said liquid crystal paper or to said erasing device, said stylus containing no lead or ink.

**27**. The liquid crystal paper and separate erasing device of claim **16** comprising a seal around a periphery of said liquid crystal paper formed by laser singulation.

**28**. The liquid crystal paper and separate erasing device of claim **23** wherein each of said substrates has a thickness of at least 12.5 microns.

**29**. The liquid crystal paper of claim **16** wherein said electrically conductive layers comprise unpatterned conductors.

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