How Do You Optimise Your Laser Settings for Precise Micro Manufacturing?

"It's Like Lasing a Stick of Dynamite"

– VAL KILMER'S CHARACTER CHRIS KNIGHT
IN THE 1985 MOVIE REAL GENIUS

Understanding Laser Induced Surface Topography Using 3D Optical Profiling

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Laser-based manufacturing is one of the most rapidly growing areas in manufacturing, according to Purdue University's School of Mechanical Engineering[1] and, according to a 2014 article in Laser Technik Journal [2], the laser materials processing system market was 7.9 billion euros in 2012. "In just over half a century, the laser has become the most versatile tool available in modern manufacturing," according to Nadeem Rizvi of Laser Micromachining Ltd. "Laser micro machining is a powerful technique that allows new device designs to be evaluated quickly and cost-effectively."[3]

Measurement Challenges

One of the main strengths of using lasers for commercial micro manufacturing is the ability to vary so many process parameters to achieve the desired result. However, this is also one of the largest challenges in optimising a laser manufacturing process. How does varying one parameter quantifiably change the end result? Laser ablation creates surfaces that are a challenge for conventional methods of measurement due to issues around rapidly changing geometry, high aspect rations and very high roughness.

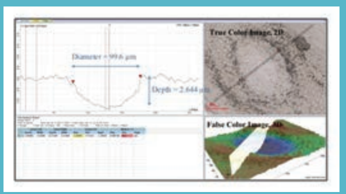
In general, analysing the performance of laser manufacturing challenges the industry in a number of ways: testing should be non-destructive, available for the variety of materials being machined with lasers, and be able to measure High Aspect Ratios. In addition, the data must be accurate, quantifiable & actionable, while not sacrificing convenience, speed or cost.

For many commercial applications, 3D Optical Profilometry can be used to accurately assess manufacturing performance. In this article, we will look at some specific cases:

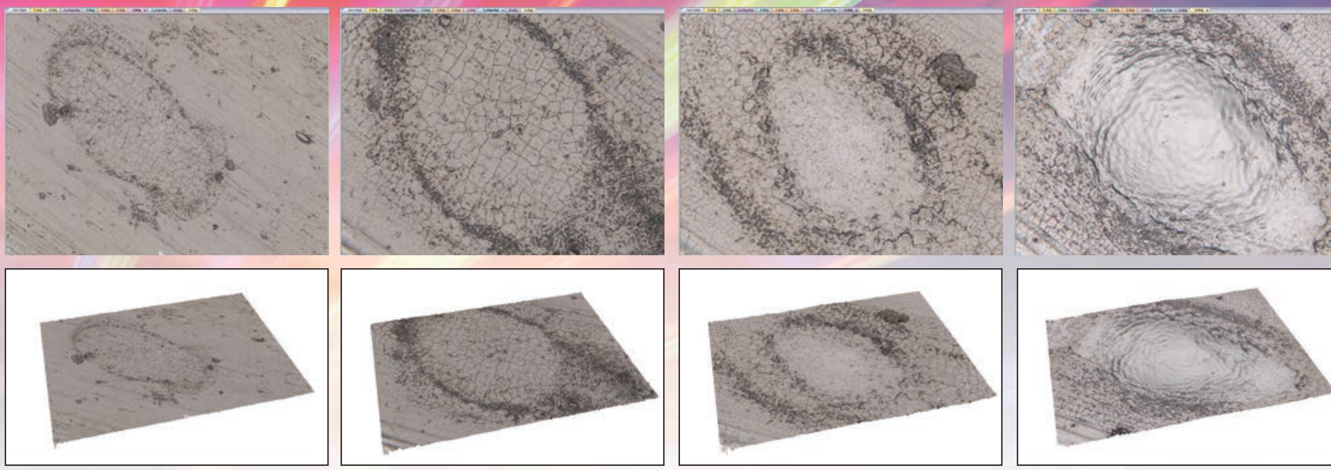
- *Testing of Laser Power*
- *Flexible Circuit Copper Vias*
- *Semiconductor use of soft laser marking*
- *Solar use of Laser Scribing*
- *Lab-on-a-chip (micro fluicis) Laser Scribing*
- *Flat Panel Display Laser Trench Scribing*
- *Light Emitting Diode (LED) die separation*

Testing of Laser Power

Lasers have several parameters that can be varied, and quantifiably testing parameter adjustment is critical in designing future lasing system. A leading university is researching pulsing wattage laser power and how it correlates to the depth and shape of the crater on a variety of materials. A 3D Optical Profiler is being used to monitor the morphology of the crater after each use. In figure 1, a crater is shown in 2D true colour, 3D false colour (blue is the deepest part of the crater), and a line scan is shown on both images, as well as the line scan data in the upper left-hand corner (similar to the data output of a



<< Figure 1: Measurement of a crater created by pulsing wattage laser power on a tungsten surface coated by aluminum; the 3D Optical Profiler line scan (shown as a plot on the upper left quadrant, a line on the upper right quadrant, and a white plan on the lower right quadrant) reveals a width of 99.6 microns and a depth of 2.6 microns. Image courtesy of Zeta Instruments. >>



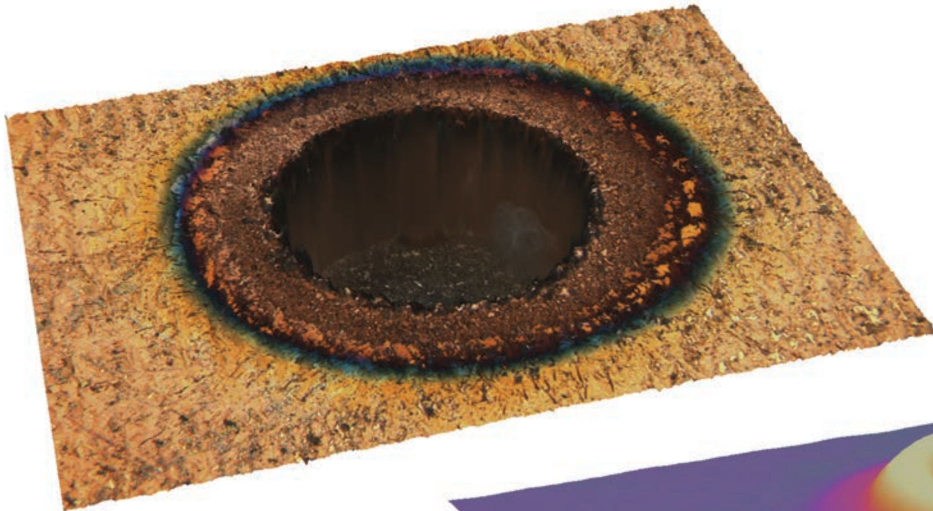
<< Figure 2: Scans taking approximately 30 seconds easily distinguish visual differences in the 2D true colour images. Image courtesy of Zeta Instruments. >>

stylus profilometer). Figure 2 shows four separate setting results evaluated by 2D true-colour imaging.

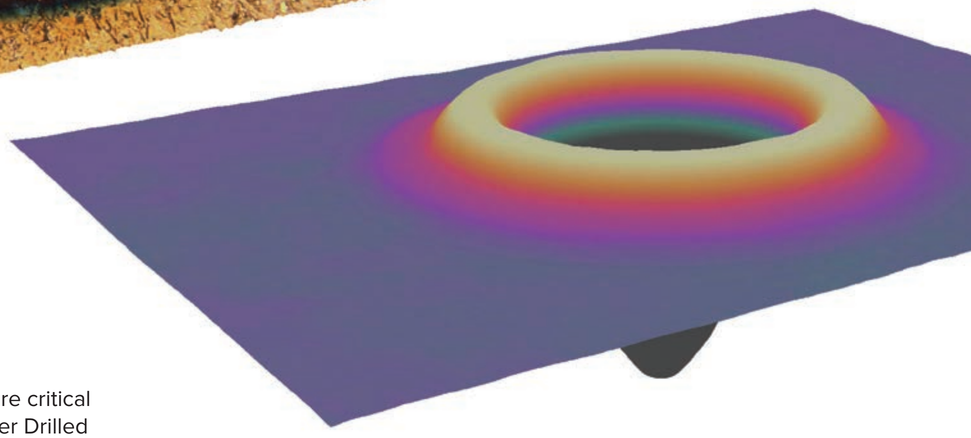
Flexible Circuit Copper Vias

Flexible circuits are widely used in automotive, medical, industrial, wearable, and consumer products. These circuits are built on large sheets of copper foil and other laminated flexible substrates that are easily deformed and difficult to handle. This poses challenges to traditional optical metrology methods such as white light interferometry.

> **Laser micro machining is a powerful technique that allows new device designs to be evaluated quickly and cost-effectively**



<< Figure 3: Laser drilled blind via on copper foil; measured dimensions of 100 µm in diameter and 28 µm in depth. >>



<< Figure 4: Data from a 3D Optical Profiler showing a laser mark on silicon, even capturing the nanometer scale ripples caused by the laser. The marking is shallow – just 706 nm deep – while the width is 36 microns. Image courtesy of Zeta Instruments; imaged using the ZX100 option. >>

A 3D optical profiler is able to automatically measure critical dimensions such as the diameter and depth of Laser Drilled Blind Vias on these flexible substrates at high throughput in a production environment, while also rendering a 3D true-colour image (as shown in figure 3). Note the colour variation in the surface around the via, likely created by thermal flux during the process. Image courtesy of Zeta Instruments; imaged on a Z-20 Optical Profiler using the ZDot (CGSI) mode.

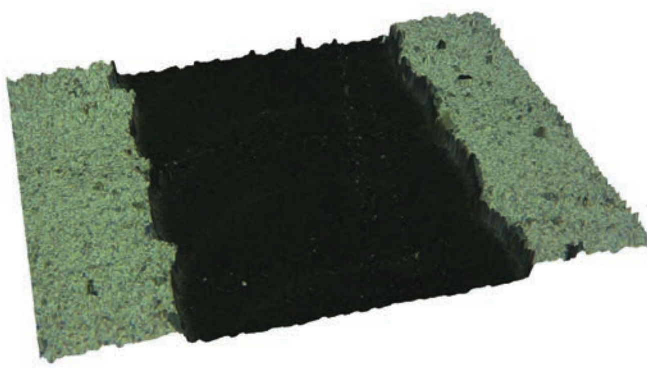
Semiconductor use of soft laser marking

The semiconductor industry is adopting soft laser Wafer ID marking techniques, due to the wafer warpage caused by the traditional hard laser marks. For fabs operating at the <16 nm node, wafer real estate is precious. Ideally wafer IDs should be shallow, while at the same time having enough contrast to be read by optical character recognition devices.

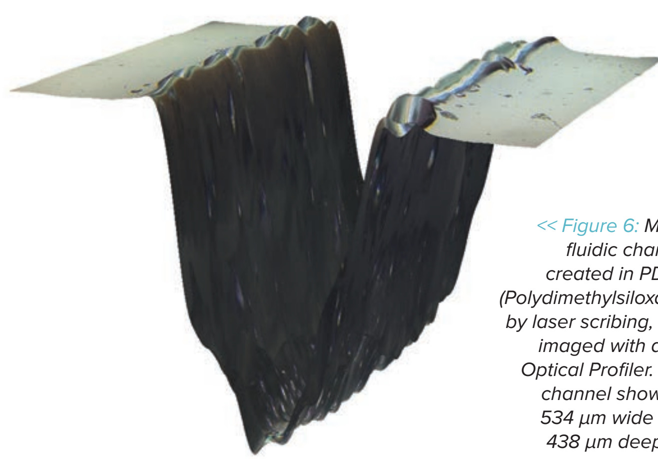
The challenge of measuring such features is to automatically locate these shallow markings on a bare wafer and profile them with nm resolution at fast throughput. Optical profilers are able to measure the nanometer ripples caused by the laser, as highlighted by the red marks on figure 4.

Solar use of Laser Scribing

In thin film solar cells, electrical isolation is important and for this, trenches are created to isolate the P and N-doped regions of the solar cell. In some thin film cells, the laser scribe shoud not breach the underlying glass substrate and must be contained within the thin films. The trench may also be heavily textured to increase the light absorption.



<< Figure 5: Shown is a 3D true colour image of a micro channel (trench) on a solar thin film (CIGS) on a glass substrate. Insert shows the full-size solar cell. A 3D profiler using a high precision motorised XY stage and pattern recognition software to automatically detect the scribe lines and scan multiple locations on the solar cell. The scribe shown above is 74 µm in width and 500 nm in depth. Image courtesy of Zeta Instruments. >>



<< Figure 6: Micro fluidic channel created in PDMS (Polydimethylsiloxane) by laser scribing, and imaged with a 3D Optical Profiler. The channel shown is 534 µm wide and 438 µm deep. >>

Controlling the trench dimensions and the surface texture is key to improving the efficiency of the solar cell. For this, ultrafast pulsing lasers are used to produce cleaner, sharper micro channels.

The challenge is to automatically locate these trenches on large panels and provide critical information about their roughness, depth and width. The results of a 3D profiler using a high-precision motorised XY stage and pattern recognition software to automatically detect the scribe lines and scan multiple locations on the solar cell are shown in figure 5.

Lab-on-a-chip (micro fluicis) Laser Scribing
Micro fluidic devices offer great potential for performing biological and chemical assays under carefully controlled conditions by integrating multiple fluidic functions onto a single device. Lithography techniques are being replaced by laser ablation, which consists in focusing very short laser pulses to a small area of the substrate.

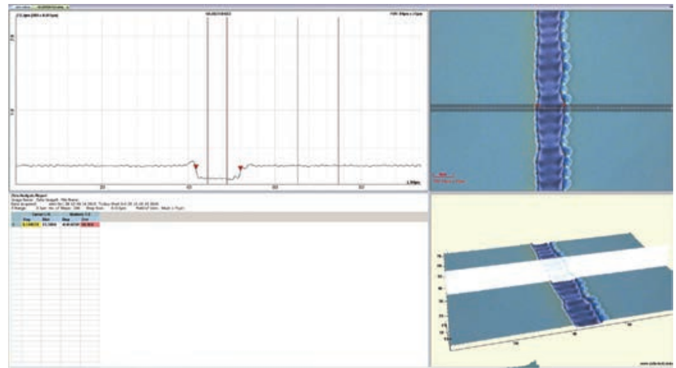
The laser focus size and the depth control the lateral size of the crater by adjusting the number of pulses. Heat induced deformations, irregular shapes, large side wall slope angles, low image contrast and low reflectivity are all the result of the laser processing and these pose measurement challenges for the traditional interferometer and confocal profilers. However, using feature detection software in conjunction with 3D Optical Profiling, can measure the irregular and often-complex laser induced surface topography.

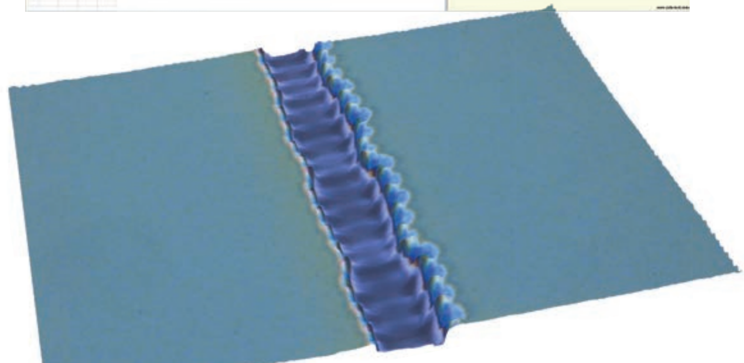
Flat Panel Display Laser Trench Scribing

Laser ablated trenches in Indium-tin oxide (ITO), typically used in flat panel displays and organics based electronics such as transparent electrodes and organic light emitting devices (OLED), offer possibility for high efficiency structuring of transparent conductors on glass and other substrates.

Laser direct write (LDW) is a maskless, dry process that allows easy change of the contact pattern. The well-defined edges and good electrical isolation at a short separation between conductor lines are required. Sharp edges are especially important when the distance between the conductor lines shrinks down to 10 µm.

A laser confocal tool will show interference artifacts on such transparent samples with irregular topography, whereas an optical profiler, like the Zeta3D Optical Profiler using the ZDot mode, is able to acquire meaningful data on such samples.

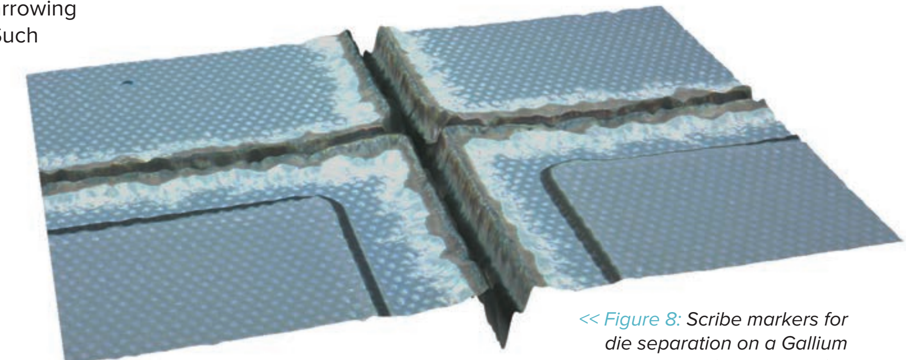




<< *Figure 7:* *A laser induced trench in a thin film of Indium Tin Oxide (ITO) on a glass substrate used in flat panel displays. This laser-scribed trench is 8.6 µm in width and 0.2 µm in depth.* >>

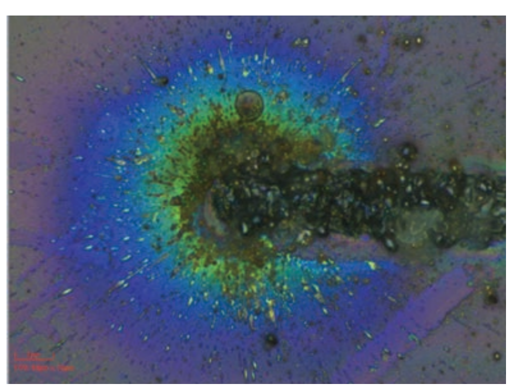
Flat Panel Display Laser Trench Scribing

Laser scribing is a widely used technique to separate a light emitting diode (LED) wafer into individual dies. The scribe process creates a deep and narrowing trench and leaves behind a lot of debris. Such geometry precludes the use of normal imaging tools such as interferometers and laser confocal microscopes. The high efficiency optical design of some optical profilometers allows the maximum possible light to be collected from such a sample, as shown in figure 8.



<< *Figure 8:* *Scribe markers for die separation on a Gallium Nitride coated Sapphire wafer. The scribe is 9.1 µm in diameter and 15.84 µm in depth, with very rough, tapering sidewalls.* >>

Laser scribes generate minimal debris and can accurately mark defects on a variety of substrates.



<< *Figure 9:* *A 3D image of the test of using a laser to scribe a particular kind of glass; the scribe marks will make it easier to find the feature of interest in other microscopes, such as an SEM or AFM.* >>

Defect Analysis on Glass

Defect review and root cause analysis is an integral part of any failure analysis lab. However, finding the defect on the microscope and transferring the samples to AFM or SEM becomes a challenge if the defect cannot be accurately located for further analysis. Laser scribes generate minimal debris and can accurately mark defects on a variety of substrates.

Shown is a test laser scribe generated on glass. High sample roughness, debris and low reflectivity present challenges for conventional interferometers, but can be imaged with an optical profiler.

Micro machining and lasers go hand-in-hand. Proper characterisation of the laser-ablated surfaces is critical for developing processes in advanced industries such as semiconductors, high brightness LED, bio-medical devices and optics. Such data is also relevant to the companies developing lasers and laser machining tools. For these industries, using a 3D Optical Profiler may be a cost-effective, yet incredibly powerful tool to use.

Dr. Diane Hickey-Davis obtained her Ph.D. in Materials Science and Engineering at the University of Florida, studying MEMS fabrication and ion-implantation into materials such as man-made single crystal diamond. She has worked professionally in business consulting, strategic sales & marketing management, and new product development of MEMS devices. She currently works with several start-up companies as a transition executive and consultant.

[1] (https://engineering.purdue.edu/ME/Research/Areas/MMP/index.html)
[2] © 2014 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim Industry Report Laser Technik Journal 2/2014 - http://onlinelibrary.wiley.com/store/10.1002/latj.201400023/asset/30_ftp.pdf;jsessionid=497C1D1DD-0B07019E55AED5933EB1803.f02t02?v=1&t=in-f2shgo&s=663dc829c2a9d99b38d-6d3e7539e70183429b5b8
[3] http://www.med-techinnovation.com/articles/articles/article/47