# Brush core and brush driving method

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A brush core for engaging and rotating a generally cylindrical brush having a hollow bore is provided. The brush core includes, but is not limited to, a body section forming an outer surface for engaging the hollow bore of the cylindrical brush. The outer surface of the body section includes three or more sides.

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## Description

### CROSS-REFERENCES TO RELATED APPLICATIONS

The Present Application claims priority to U.S. Provisional Patent Application No. 61/178,843, filed 15 May 2009. The content of this U.S. Provisional Patent Application is hereby incorporated herein in its entirety.

## FIELD OF THE INVENTION

The present invention relates generally to processes and devices for cleaning articles. More specifically, it relates to a brush core for retaining a brush used for cleaning semiconductor substrates.

## BACKGROUND

Cast cylindrical polyvinyl alcohol brushes are conventionally used in automatic cleaning systems to provide a post CMP (Chemical Mechanical Planarization) process to effectively clean surfaces of substrates such as semiconductor wafers or other disc-shaped substrates. Cylindrical polyvinyl alcohol brushes are also used in cleaning systems to clean and dry glass and other non-disc-shaped substrates in flat panel display manufacture, glass production, and printed circuit board assembly. Cylindrical brushes preferably have a length as short as 50 millimeters or as long as 10 meters, for example.

The cylindrical brushes are located on and driven by a central brush core in the cleaning process. An accurate and stable connection between the cylindrical brush and the central brush core is desirable. The cylindrical brushes may have nodules on their outer surface to help clean the substrate.

The cylindrical brushes are expected to accurately rotate on their axis and provide a generally cylindrical surface with a generally consistent nodule pressure pattern over their useful life, which defines optimum cleaning of the entire substrate surface in the least amount of time with minimal damage to the substrate surface.

At times, over the life of the cylindrical brush, there will typically be a tendency for the brush to move axially or rotationally by partially slipping on the brush core and this is regarded as unsatisfactory performance. As a result, it would be desirable to have an accurate and stable connection between the cylindrical brush and the central brush core.

## SUMMARY

In one aspect, a brush core for engaging and rotating a generally cylindrical brush having a hollow bore is provided. The brush core includes, but is not limited to, a body section forming an outer surface for engaging the hollow bore of the cylindrical brush. The outer surface of the body section includes three or more sides.

In one aspect, a cleaning system for cleaning substrates is provided. The system includes, but is not limited to, a brush having a hollow bore and a brush core having a body section forming an outer surface engaging the hollow bore of the brush. The outer surface of the body section includes three or more sides.

In one aspect, a method for cleaning substrates is provided. The method includes, but is not limited to, engaging a substrate with a cleaning system having a generally cylindrical brush with a hollow bore and a brush core. The brush core has a body section forming an outer surface engaging the hollow bore of the cylindrical brush. The outer surface of the body section includes three or more sides.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

FIGS. 1A-1L depict cross-sectional views of various illustrative brush and core combinations, in accordance with one embodiment of the present invention.

FIGS. 2A-2D depict various views of an illustrative hex brush core, in accordance with one embodiment of the present invention.

FIGS. 2E-2F depict various views of an illustrative splined brush core, in accordance with one embodiment of the present invention.

FIG. 3 depicts a perspective view of a cleaning system for cleaning and polishing substrates, in accordance with one embodiment of the present invention.

FIG. 4 depicts a load-deflection curve for one ½″ disc, in accordance with one embodiment of the present invention.

FIG. 5 depicts a load-deflection curve for two ½″ discs, in accordance with one embodiment of the present invention.

FIG. 6 depicts a load-deflection curve for three ½″ discs, in accordance with one embodiment of the present invention.

## DETAILED DESCRIPTION

Methods and systems consistent with the present invention overcome the disadvantages of conventional brushes and brush-core systems by eliminating rotational slippage of the brush. In particular, a cylindrical brush is mounted on a brush core having an outer surface with three or more sides, forming a splined or polygonal contour section. The sides meet and form edges which help to better engage the cylindrical brush and prevent slippage between the cylindrical brush and the brush core. The cylindrical brush may have a similar splined or polygonal contour section along an inner surface of the cylindrical brush defining a bore of the cylindrical brush.

Referring to FIG. 3, there is shown a cleaning system **100** for cleaning and polishing substrates **104**. Preferably, the cleaning system **100** is an automatic cleaning system which can automatically or manually be set to polish and/or clean a substrate **104**, and more particularly a surface **106** of the substrate **104**. Substrate **104** includes any one of a variety of disc-shaped or non-disc-shaped substrates, such as: silicon based substrates including glass, dry glass, semiconductor wafers, flat panel display glass panels, glass production panels, and printed circuit boards; polymer-based substrates; and various types of semiconductor substrates such as silicon-based semiconductor substrates, single element semiconductor substrates, silicon on insulator (SOI) substrates, III-V semiconductor substrates, II-VI semiconductor substrates, other binary semiconductor substrates, ternary semiconductor substrates, quaternary semiconductor substrates; fiber optic substrates; superconducting substrates; glass substrates; fused quartz substrates; fused silica substrates; epitaxial silicon substrates; and organic semiconductor substrates.

Referring to FIGS. 1A-1L, FIGS. 2A-2F, and FIG. 3, cleaning system **100** includes a generally cylindrical brush **110** having a hollow bore **112**, a brush core **130** engaging the brush **110** within the hollow bore **112**, and a rotational device **102** engaging the brush core **130**. The brush **110** may be any brush which is or may be conventionally used in an automatic cleaning system to provide a post chemical mechanical planarization (CMP) process to effectively clean the surface **106** of substrate **104**, such as a cast cylindrical polyvinyl alcohol (PVA) foam brush, or a similar brush. Referring to FIG. 1E, brush **110** includes an outer cleaning surface **114** opposed to an inner engagement surface **116**.

Outer cleaning surface **114** may be generally smooth, as shown in FIG. 3, or outer cleaning surface **114** may have nodules **118** with channels **120** formed between the nodules **118**, as shown in FIG. 1A. Having nodules **118** with channels **120** may help brush **110** to better clean certain substrates **104**. Surface features on the outer cleaning surface **114**, such as channels **120**, lines, edges, points, or other raised surfaces or nodules **118**, may be incorporated and have a beneficial effect at increasing torque transmission levels but may be limited due to their effect on outer cleaning surface **114** geometry changes and also on the difficulty of mounting the brush **110** on the brush core **130**.

Inner engagement surface **116** defines the contour of hollow bore **112**. Referring to FIGS. 3, 1E, 1K, and 1L, the cross-section of inner engagement surface **116**, along a line A-A which is perpendicular to a rotational axis $a_1$ of the brush core **130**, defines the contour of hollow bore **112**, both of which are circular, splined, or polygonal in shape. Referring to FIG. 1E, the cross-section of inner engagement surface **116** and the contour of hollow bore **112** have a polygonal shape, referring to FIG. 1K the cross-section of inner engagement surface **116** and the contour of hollow bore **112** have a circular shape, and referring to FIG. 1L the cross-section of inner engagement surface **116** and the contour of hollow bore **112** have a splined shape.

Referring to FIG. 3 and FIGS. 2A-2F, the brush core **130** engages the brush **110** within the hollow bore **112**. The brush core **130** includes a body section **132** which forms an outer surface **133** engaging the hollow bore **112** of the brush **110**. Referring to FIGS. 3 and 2A-2F, the outer surface **133** of the body section **132** includes three or more sides **134** forming a contour and having a cross-section, along a line A-A which is perpendicular to the rotational axis $a_1$ of the brush core **130**, both of which are either splined or polygonal in shape. In one embodiment, the outer surface **133** forms a contour having a splined cross-section, wherein each side **134** of the body section **132** is curved, as shown in FIGS. 2E and 2F. In one embodiment, the outer surface **133** forms a contour having a polygonal cross-section, wherein each side **134** of the body section **132** is generally flat, as shown in FIGS. 2B and 2C. Edges **135** are formed where two sides **134** meet to better engage the inner engagement surface **116** of the brush **110**, as shown in FIGS. 2A-2F. By having an outer surface **133** which includes three or more sides **134**, edges **135** are formed on the outer surface **133** which help to better engage the inner engagement surface **116** of the brush **110** and prevent slippage between the brush **110** and the brush core **130**.

Preferably, the outer surface **133** of the body section **132** includes four or more even number of sides **134**, allowing for the body section **132** to apply a more even rotational force onto the surface **106** of the substrate **104** being polished or cleaned.

In addition to edges **135**, to further prevent axial movement between the brush **110** and the brush core **130**, the profile or contour of the outer surface **133** or each side **134** may be interrupted by a brush engagement member **140**. Axial movement is defined herein as movement along a rotational direction α about the rotational axis $a_1$. Brush engagement member **140** is any feature which interrupts the general contour of outer surface **133** in order to better engage the inner engagement surface **116** of the brush **110**. Brush engagement member **140** includes such features as a band **142** or a series of bands **142** or a ridge **145** or series of ridges **145** at any number of locations along the outer surface **133** or along a side **134** to effectively axially secure the brush **110** to the brush core **130**, as shown in FIGS. 2A-2F and 3.

Bands **142** extend along a length of the brush core **130**, parallel to the rotational axis a**1** of the brush core **130**, as shown in FIGS. 2A and 2B. Preferably, pores **156** are formed from the outer surface **133** of the body section **132** to a fluid channel **150** for flowing polishing fluid from the fluid channel **150** to the outer surface **133** of the body section **132** and to the brush **110**. Ridges **145** are formed on the outer surface **133** between a pair of depressions **144**, as seen in FIG. 2B. The bands **142** and ridges **145** help to better engage the inner engagement surface **116** of the brush **110** by creating an outer surface **133** with interruptions.

As a result of edges **135** and brush engagement members **140**, the physical fit between the outer surface **133** of the brush core **130** and the inner engagement surface **116** of the brush **110** provides significant resistance to slipping. This resistance to slipping could be further enhanced by other methods including adhesives, surface preparation of the core (chemical, physical, corona, and the like), or such additional surface features as knurls, sharp edges, hooks, points, keys, or other linking features.

Referring to FIG. 3, in one embodiment the brush core **130** also includes a rotational engagement member **160** for engaging and connecting with a rotational device **102**. The rotational engagement member **160** is any device which can be used to connect with or fasten to another device, and includes things such as a nut-shaped piece that is integrally formed with the brush core **130** and can be fastened to the rotational device **102**. The rotational device **102** includes any device which can induce a rotational movement onto the brush core **130**, such as an electrical motor, a gas motor or engine, a crank shaft power by a motor or manually powered, and any combination of pulleys, wheels, mechanical linkages, and/or gears moved automatically or manually. The rotational device **102** has a complimentary engagement member which connects with the rotational engagement member **160** for engaging and connecting the brush core **130** with the rotational device **102**.

Through testing of the brush core **130**, the inventors have demonstrated an effective driving connection between the brush core **130** and the brush **110** using a brush core **130** with an outer surface **133** forming a contour having a regular hexagonal cross-section, as shown in FIG. 2C. However, any contour with more than three sides, regular or not, may be used to provide a variety of benefits. In one embodiment, the brush core **130** could have a different contour and cross-section along line A-A than the hollow bore **112** of the brush **110**. For example, in one embodiment the brush core **130** may have a polygonal or similar cross-section along line A-A, while the hollow bore **112** of the brush **110** could have a cylindrical cross-section along line A-A. By incorporating a non-cylindrical core-to-brush connection, wherein the brush core **130** includes three or more sides **134**, methods and devices consistent with the present invention provide a novel technique that adds another dimension of cleaning efficiency for better cleaning in less time on the same equipment.

The elastic and resilient material of a typical polyvinyl alcohol foam brush **110**, when it is expanded during assembly to a rigid brush core **130**, reacts in two ways. First, the brush material of the brush **110** at the core near the hollow bore **112** will compress locally; and second, the outside diameter of the brush **110** to the outer cleaning surface **112** will expand a small amount, typically, 60% of the press fit is for compression at the hollow bore **112** and 40% goes to the expansion of the brush **110** and nodules **118** at the outside diameter. A greater press fit between the brush **110** and the brush core **130** provides better and more accurate transmission of drive torque from the rotational device **102** to the outer cleaning surface **114** of the brush **110** into cleaning the surface **106** of the substrate **104**, such as a wafer substrate surface.

With the ability to create and control a significant amount of core expansion, methods and systems consistent with the present invention capitalize on cleaning efficiency by creating large, intermittent raised patches or ridges **145** on the surface **133** of the brush core **130** which are reflected in bumps on the outer cleaning surface **114**.

Typical radial compression of the outer cleaning surface **114** is 2 mm, and these raised features, such as ridges **145**, could add another 1 mm, which would cause an additional, semi-random surface pressure pattern variation in addition to the passing of the rows of regularly spaced nodules **118** to impart an added scrubbing action during the rotation of the brush **110** and the substrate **104**. Varying the size of the brush core **130**, the shape of the brush core **130**, and the ratio of the outer diameter of the brush core **130** to the outer diameter of the brush **110** will result in significant flexibility in changing the profile and contour of the outer cleaning surface **114** and its compression. The pressure pattern formed by the nodule **118** and the radial compression of the outer cleaning surface **114** would thus incorporate a regular overlying pressure variation which could be shown to be beneficial.

To elaborate on the above, examples of regular polygonal cross-sections with various brush engaging areas for both pentagonal, splined, and hexagonal cross-section of the brush core **130** are shown in FIGS. 1A-1L. In addition, Load Deflection Curves for when the outer cleaning surface **114** is engaging the surface **106** of substrate **104** are shown in FIGS. 4-6 and depict the resulting pressure from various amounts of brush deflection.

In one embodiment, the brush **110** may be molded onto the brush core **130** in order to prevent slippage between the outer surface **133** of the brush core **130** and the inner engagement surface **116** of the brush **110**.

In operation, the brush **110** is mounted to the brush core **130** by inserting the brush core **130** into the hollow bore **112** of the brush **110**. Upon insertion into the hollow bore **112**, the brush core **130** and the brush **110** are then connected with the rotational device **102** by connecting the rotational engagement member **160** with an engagement member on connecting with the rotational device **102**. Then, the brush **110** is rotated along the rotational direction α about the rotational axis $a_1$. While rotating the brush **110**, or before rotating the brush **110**, the brush **110** is placed near and engages the surface **106** of the substrate **104**. The rotational motion of the brush **110** on the surface **106** helps to clean and/or polish the surface **106**. Referring to FIG. 3, in one embodiment, the substrate **104** is also rotated along a rotational direction β about a rotational axis $a_2$. In one embodiment, polishing fluid is pumped through fluid channel **150** formed in the body section **132** and into the brush **110** through pores **156** formed through the outer surface **133** of the body section **132** and to the fluid channel **150**. The polishing fluid helps to further clean and/or polish the substrate **104**.

Although the illustrative examples above describe cylindrical PVA brushes **110** used to clean semiconductor substrates **104**, one having skill in the art will appreciate that methods and systems consistent with the present invention are not limited thereto. For example, the brush **110** may include other materials and may be used to clean other types of surfaces **106** or substrates **104**. Further, the brush **110** is not limited to having a cylindrical shape, but may have any shape or configuration.

The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing

Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that other embodiments and implementations are possible within the scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.

# Claims

1. A brush and brush core comprising:

> a one-piece cylindrical brush having a length, and an inner engagement surface defining a hollow bore; the brush being continuous along its length; and
>
> a brush core comprising a one-piece body section having a length and forming an outer surface for directly engaging the inner engagement surface of the cylindrical brush, a rotational axis is defined along the length of the brush core, the outer surface of the one-piece body section defining a perimeter of the one-piece body section and forming a contour along the length of the one-piece body section, the contour including three or more apexes, each apex configured as an edge which directly engages the inner engagement surface of the brush, the apexes extending along the length of the brush core, the contour further including a flat side extending continuously between each set of adjacent apexes, the flat side extending along the length of the brush core, the edges and sides continuously alternating around the perimeter of the one-piece body section.

2. The brush and brush core of claim 1, wherein the outer surface of the one-piece body section is interrupted by at least one brush engagement member.

3. The brush and brush core of claim 1, wherein the one-piece body section forms a fluid channel for receiving fluid along an axis of the one-piece body section, and wherein the b one-piece body section forms a pore from the outer surface of the one-piece body section to

the fluid channel for flowing fluid from the fluid channel to the outer surface of the one-piece body section.

4. The brush and brush core of claim 1, further comprising a rotational engagement member extending from one end of the one-piece body section, the rotational engagement member having an outer engagement surface which has two or more sides, the outer engagement surface capable of engaging a rotational device for causing rotation of the brush core and brush.

5. The brush and brush core of claim 2, wherein the brush engagement members are bands or ridges.

6. The brush and brush core of claim 1, further comprising

> a plurality of spaced apart depressions formed in the outer surface, the depressions being spaced from each other along the length of the brush core.

7. The brush and brush core of claim 6, wherein the depressions are linearly aligned along the length of the brush core.

8. The brush and brush core of claim 6, wherein a plurality of sets of the depressions are provided, each set having depressions which are linearly aligned along the length of the brush core.

9. The brush and brush core of claim 8, further comprising at least one band extending along a predetermined portion of the length of the brush core, the band being formed as an elongated depression in the outer surface of the brush core.

10. The brush and brush core of claim 9, wherein the band separates adjacent depressions around a perimeter of the brush core.

11. The brush and brush core of claim 9, wherein the band does not extend the entire length of the brush core.

12. The brush and brush core of claim 6, further comprising at least one band extending along a predetermined portion of the length of the brush core, the band being formed as an elongated depression in the outer surface of the brush core.

13. The brush and brush core of claim 12, wherein respective bands separate adjacent depressions around a perimeter of the brush core.

14. The brush and brush core of claim 12, wherein the respective bands do not extend the entire length of the brush core.

15. The brush and brush core of claim 1, wherein a plurality of brush engagement members interrupt the outer surface of the one-piece body section, each brush engagement member extending along a portion of the length of the one-piece body section such that each brush engagement member does not extend along the entire length of the one-piece body section.

16. The brush and brush core of claim 1, wherein the plurality of brush engagement members interrupt the edges of the one-piece body section.

17. The brush and brush core of claim 1, wherein the plurality of brush engagement members interrupt the sides of the one-piece body section.

18. The brush and brush core of claim 1, wherein the hollow bore of the brush has a circular contour.

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# Patent History

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# Classifications

**Current U.S. Class**: **By Treating Occluded Solids (264/49)**

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