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(54) **CHEMICAL MECHANICAL POLISHING PAD**

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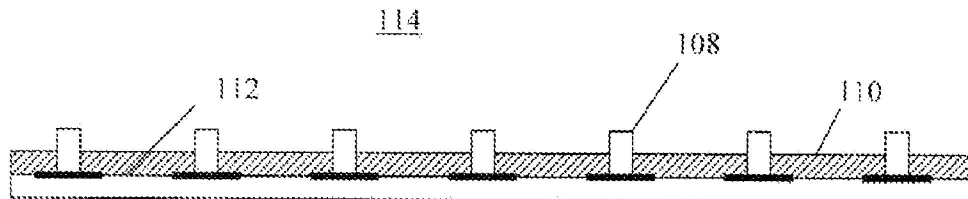
(57) **ABSTRACT**

A polishing pad has polishing elements of at least two different types of materials, each having a different coefficient of friction, and arranged over a surface of the pad so as to provide a non-planar material removal profile for the pad. The polishing elements may be arranged to provide different material removal profiles, such as an edge-fast, edge-slow, center-fast or center-slow material removal profile.



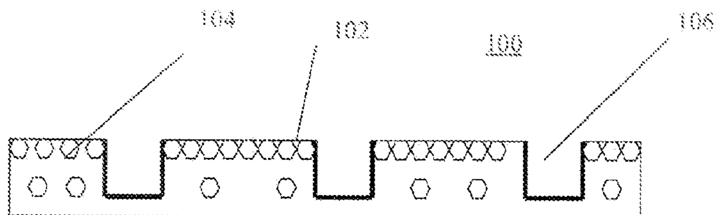


Figure 1A

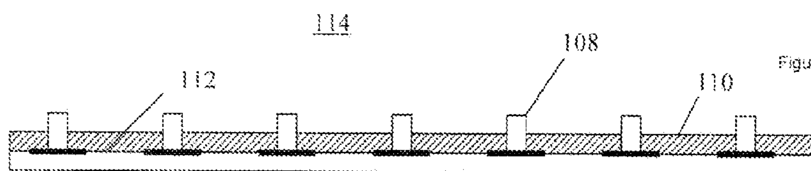


Figure 1B

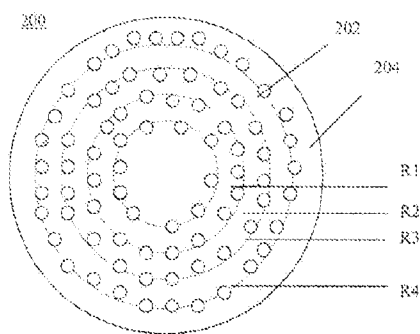


Figure 2A

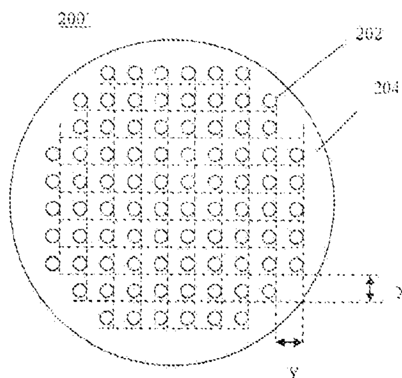


Figure 2B

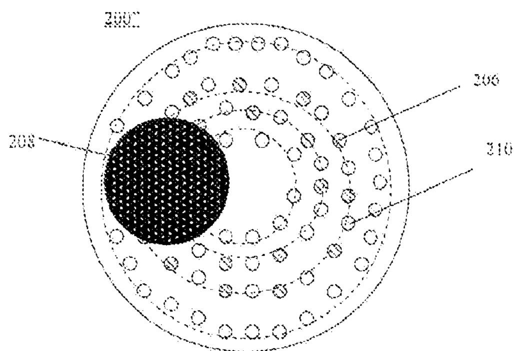


Figure 3

CHEMICAL MECHANICAL POLISHING PAD

RELATED APPLICATIONS

[0001] The present application is a nonprovisional of, claims priority to an incorporates by reference U.S. provisional patent application No. 60/784,263, filed 21 Mar. 2006.

FIELD OF THE INVENTION

[0002] The present invention relates to the field of chemical mechanical planarization (CMP) and relates specifically to a CMP polishing pad conditioning apparatus and its method of use.

BACKGROUND

[0003] In modem integrated circuit (IC) fabrication, layers of material are applied to embedded structures previously formed on semiconductor wafers. Chemical mechanical planarization (CMP) is an abrasive process used to remove these layers and polish the surface of a wafer to achieve the desired structure. CMP may be performed on both oxides and metals and generally involves the use of chemical slurries applied in conjunction with a polishing pad in motion relative to the wafer (e.g., pad rotation relative to the wafer). The resulting smooth flat surface is necessary to maintain the photolithographic depth of focus, for subsequent steps and to ensure that the metal interconnects are not deformed over contour steps. Damascene processing requires metal, such as tungsten or copper, to be removed from the top surface of a dielectric to define interconnect structures.

[0004] Polishing pads are typically made of urethanes, either in cast form and filled with micro-porous elements, or from non-woven felt coated with polyurethanes. One aspect of conventional polishing pads is that the polishing pad surface is a single continuous sheet of material, which may be grooved or perforated to facilitate slurry distribution across the surface.

[0005] During polishing, the polishing pad is rotated while contacting the wafer, which is also rotated, thus effecting polishing. One of the aspects of this process is that as a pad moves under a wafer, there is a sudden change in pad compression. This gives rise to "edge effects" on the wafer, wherein the material removal rate at the edge of the wafer is different from the material removal rate across the rest of the wafer.

[0006] Another aspect of existing polishing pads is that they have no ability to modulate the removal profile across the width of a wafer. In advanced processing processes there are multiple films being deposited, each of which has a specific deposition profile. For example, electroplated copper films tend to be edge thick, while some dielectric films tend to have a smooth "M" or "W" profile. In cases of critical process modules, such as copper and STI polishing, this can lead to over-polishing to complete processing across the width of the wafer. For advanced technologies, the available over-polish margins are shrinking rapidly and, in some cases, allow for less than 5% of the polish time. This leads to loss of performance or, worse, loss of yield for some parts. There is thus a need for the ability to tune the removal profile of a pad in polishing processes to minimize over-polishing.

SUMMARY OF THE INVENTION

[0007] An embodiment of the invention provides a polishing pad having polishing elements of at least two different types of materials, each having a different coefficient of friction, and arranged over a surface of the pad so as to provide a non-planar material removal profile for the pad. The polishing elements may be arranged to provide an edge-fast, edge-slow, center-fast or center-slow material removal profile.

[0008] A further embodiment of the invention provides a polishing pad having a plurality of polishing elements of at least two different materials, each having a different coefficient of friction, and arranged in different densities across a surface of the pad so as to provide a non-planar material removal profile for the pad.

[0009] Still another embodiment of the invention provides a polishing pad having a plurality of polishing elements, some of which are polyurethane and others of which are Delrin. The polishing elements may be arranged in a radial or other manner across a surface of the pad such that those of the polishing elements which are Delrin comprise approximately 5-50% of the total number of polishing elements in locations corresponding to areas of the pad configured to provide relatively lower material removal rates than other areas of the pad. The overall density of polishing elements may be uniform per unit area of the pad and/or the polishing elements may be laid out in a uniform radial arrangement. In some cases, both the Delrin and polyurethane polishing elements may have a common shape and size.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present invention is illustrated by way of example, and not limitation, in the figures of the accompanying drawings, in which:

[0011] FIG. **1**A illustrates a side cut-away view of a conventional polishing pad;

[0012] FIG. **1**B is a side cut-away view of a polishing pad having individual polishing elements which may be configured in accordance with embodiments of the present invention;

[0013] FIG. **2**A is a top view of a polishing pad configured in accordance with an embodiment of the present invention and having polishing elements arranged in circumferences of different radii;

[0014] FIG. **2**B is a top view of a polishing pad configured in accordance with an embodiment of the present invention and having polishing elements arranged in a grid-like fashion;

[0015] FIG. **3** is a top view of a polishing pad configured in accordance with and embodiment of the present invention and showing in detail the use of polishing elements having different coefficients of friction.

DETAILED DESCRIPTION

[0016] Described herein is a CMP polishing pad which allows for establishing a predefined, non-planar material removal profile. In one embodiment, the pad includes polishing elements, which are placed on an underlying com-

pressible foam and protrude through holes in a guide plate overlaid on that foam. The nominal size of each polishing element is 0.25 inches and the height thereof is 0.160 inches. The compressible foam is nominally 0.060" thick.

[0017] Note that although the present polishing pad is discussed with reference to certain illustrated embodiments, the scope of the present invention is not intended to be limited thereby. Instead, the present invention should only be measured in terms of the claims, which follow this description.

[0018] The present pad design enables the application very uniform pressure onto a wafer and eliminates (or at least substantially reduces) edge effect typically associated with full sheet polishing pads. This translates to a very uniform material removal profile.

[0019] Also described herein is a method to effect non-planar removal profiles, which may required to match non-planar deposition profiles. Polishing element density across the polishing pad may be varied to achieve non-planar removal profiles. For example, polishing element density may be reduced over that part of a pad in contact with a portion of a wafer requiring less material removal.

[0020] This method, while capable of achieving the desired objective, suffers from long term pad performance issues. Pad conditioning and pad wear have different affects on the pad in areas of different densities causing the pad to loose its flat profile, thereby accelerating the need for pad change. Accordingly, described herein is a method which overcomes this obstacle while providing desired non-planar material removal profiles.

[0021] Embodiments of the present polishing pad may have polishing elements made of different materials, each having a different coefficient of friction with respect to the film being polished. Polishing elements may be laid out such that areas contacting portions of a wafer requiring lower material removal rate contain a combination of polishing elements of conventional materials, such as polyurethane, and low friction materials, such as Delrin (Polyoxymethylene). The nominal coefficient of friction for polyurethane materials against an SiO_2 surface is 0.45, whereas the coefficient of friction for Delrin under similar conditions is 0.15. Therefore the present pad is expected to have a much lower material removal contribution from Delrin polishing elements, leading to a lower overall material removal rate.

[0022] The present polishing pad is thus provided with the ability to tune its material removal profile. The polishing elements of the pad can be arranged over the pad's surface in different configurations, such as configurations providing a fixed area density or fixed radial density. These two different layouts offer specific advantages in their ability to deliver uniform material removal profiles, depending on the motion of polishing table. An area profile may be more advantageous for linear or orbital motion, while a radial profile may be more suitable when rotary motion is employed for the polishing table.

[0023] In varying embodiments of the present invention, the polishing elements may be laid out in many different arrangements and/or may be made from different materials. In one embodiment a polishing pad includes polishing elements of two different materials, each having a different coefficient of friction for the film being polished. The polishing elements may be arranged such that the polishing elements with a lower coefficient of friction, such as polishing elements made from Delrin, may be arranged in alternating fashions with polyurethane polishing elements (which have a higher coefficient of friction). The ratio of one type of polishing element to another may be varied to achieve different combinations of material removal performance. During polishing, an area of a wafer in contact with a pad section containing Delrin and polyurethane polishing elements will have lower material removal rate than a area in contact with a pad section containing only polyurethane polishing elements.

[0024] FIG. **1**A illustrates a side cut-away view of a conventional polishing pad **100**, such as an IC **1000** pad manufactured by Rohm and Haas. Polishing pad **100** contains microelements **102** embedded in a polymeric matrix **104**, which may be polyurethane. The pad surface contains grooves **106** for slurry transport during polish process.

[0025] FIG. **1**B is a side cut-away view of a polishing pad **114** of the kind described in International Patent Application PCT/US2005/35979, filed 5 Oct. 2005 and assigned to the assignee of the present invention. Pad **114** includes polishing elements **108**, which rest on a compressible under layer **112** and protrude through holes in a guide plate **110**. Such a pad may be configured in accordance with an embodiment of th epresent invention, as discussed below.

[0026] FIG. **2**A is a top view of a polishing pad **200** having one particular arrangement of polishing elements **202** protruding through holes in a guide plate **204**. The polishing elements in this example are laid out along circumferences of different radii marked as R**1**, R**2**, R**3** and R**4**. Such an arrangement may be used for polishing elements having different coefficients of friction, in accordance with an embodiment of the present invention.

[0027] FIG. **2**B shows a polishing pad **200'** in which the polishing elements **202** are laid out in an orthogonal or grid-like arrangement. The inter-polishing element spacing is defined by a pitch in X-and Y-directions. Such an arrangement may be used for polishing elements having different coefficients of friction, in accordance with an embodiment of the present invention.

[0028] FIG. **3** shows polishing pad **200"** and wafer **208** overlaid on top of it. The pad contains polishing elements **206** and **210** arranged in a radial layout. The polishing elements are made of two different materials. Polishing elements **206** may be made of polyurethane, while polishing elements **210** may be made of material having a different coefficient of friction. Of course, other configurations of polishing elements may be used, for example, the grid-like pattern shown in FIG. **2**B, a combination of a grid-like patterns and a radial layout, or any other pattern. Moreover, the relative number of different types of polishing elements (i.e., the densities of the polishing elements of the different types) may be varied (and more than two such material types may be used) to provide a desired material removal profile for the pad. For example, the polishing elements may be arranged to provide an edge-fast, edge-slow, center-fast or center-slow material removal profile, as desired.

[0029] In one particular embodiment, a polishing pad has a plurality of polishing elements, some of which are made from polyurethane and others of which are made from Delrin. The polishing elements may be arranged in a radial manner across the pad such that Delrin elements make up approximately 5-50% of the total number of polishing elements in locations of the pad corresponding to areas configured to provide a relatively lower material removal rate than other areas of the pad. The overall density of

polishing elements may be uniform per unit area of the pad and/or the polishing elements may be laid out in a uniform radial arrangement. Both the Delrin and polyurethane polishing elements may have a common shape and size; or they may have different shapes and/or sizes.

[0030] Thus, a CMP polishing pad having a non-planar material removal profile has been described.

What is claimed is:

1. A polishing pad, comprising polishing elements of at least two different types of materials, each having a different coefficient of friction, and arranged over a surface of the pad so as to provide a non-planar material removal profile for the pad.

2. The polishing pad of claim **1**, wherein the polishing elements are arranged to provide an edge-fast material removal profile.

3. The polishing pad of claim **1**, wherein the polishing elements are arranged to provide an edge-slow material removal profile.

4. The polishing pad of claim **1**, wherein the polishing elements are arranged to provide a center-fast material removal profile.

5. The polishing pad of claim **1**, wherein the polishing elements are arranged to provide a center-slow material removal profile.

6. A polishing pad, comprising a plurality of polishing elements of at least two different materials, each having a different coefficient of friction, and arranged in different densities across a surface of the pad so as to provide a non-planar material removal profile for the pad.

7. A polishing pad, comprising a plurality of polishing elements, some of which are polyurethane and others of which are Delrin, the polishing elements arranged in a radial manner across a surface of the pad such that those of the polishing elements which are Delrin comprise approximately 5-50% of the total number of polishing elements in locations corresponding to areas of the pad configured to provide relatively lower material removal rates than other areas of the pad.

8. The polishing pad of claim **7**, wherein an overall density of polishing elements is uniform per unit area of the pad.

9. The polishing pad of claim **7**, wherein the polishing elements are laid out in a uniform radial arrangement.

10. The polishing pad of claim **7**, wherein both the Delrin and polyurethane polishing elements have a common shape and size.

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