US 20110244768A1

(19) United States
(12) Patent Application Publication
Bajaj
(10) Pub. No.: US 2011/0244768 A1
(43) Pub. Date: Oct. 6, 2011

(54) **POLISHING PAD AND METHOD OF USE**

(76) Inventor: **Rajeev Bajaj**, Fremont, CA (US)

(21) Appl. No.: **13/162,508**

(22) Filed: **Jun. 16, 2011**

Related U.S. Application Data

(63) Continuation of application No. 11/846,304, filed on Aug. 28, 2007, now abandoned.

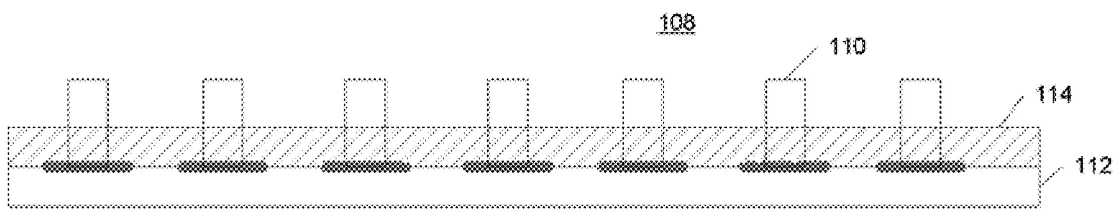
Publication Classification

(51) **Int. Cl.**
B24D 11/00 (2006.01)

(52) **U.S. Cl.** **451/527**; 451/533

(57) **ABSTRACT**

A polishing pad has one or more polishing elements made from a hydrogel material having an intrinsic ability to absorb water. The hydrogel material may or may not have micropores, but has a water absorption capability of 4%-60% by weight, a wet tensile strength greater than 1000 psi, a flexural modulus greater than 2000 psi, and a wet Shore D hardness between 25-80, inclusive. The hydrogel material may be made from one or a combination of the following moieties: urethane, alkylene oxides, esters, ethers, acrylic acids, acrylamides, amides, imides, vinylalcohols, vinylacetates, acrylates, methacrylates, sulfones, urethanes, vinylchlorides, etheretherketones, and/or carbonates.



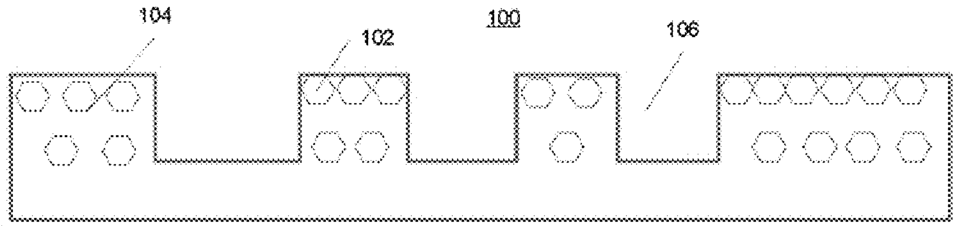


FIG. 1A

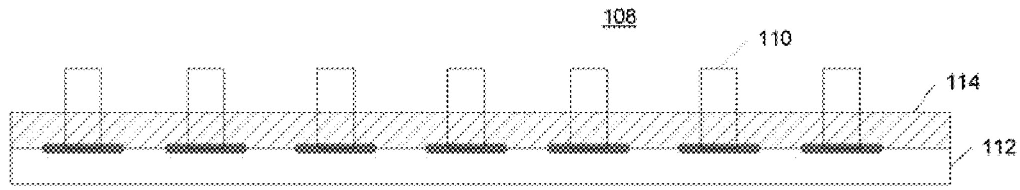


FIG. 1B

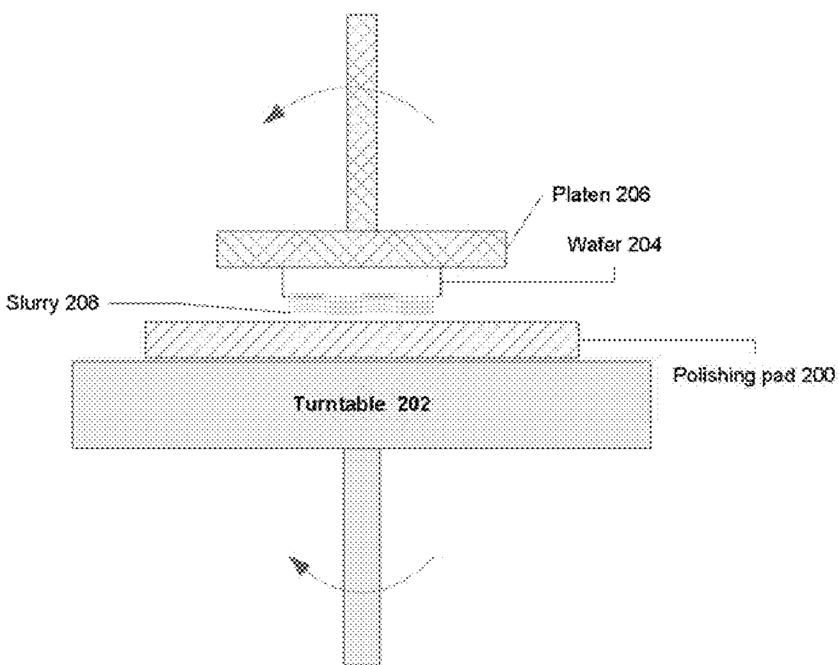


FIG. 2

POLISHING PAD AND METHOD OF USE

RELATED APPLICATIONS

[0001] This is a CONTINUATION of U.S. patent application Ser. No. 11/846,304, filed 28 Aug. 2007, incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to the field of chemical mechanical planarization (CMP) and, more specifically, to a CMP pad for reduced defectivity.

BACKGROUND

[0003] In modern integrated circuit (IC) fabrication, layers of material are applied to embedded structures formed on semiconductor wafers. Chemical mechanical planarization (CMP) is an abrasive process used to remove these layers and polish the surface of a wafer. CMP may be performed on both oxides and metals and generally involves the use of chemical slurries applied in conjunction with a polishing pad that is in motion relative to the wafer (e.g., the pad is often in rotational motion relative to the wafer). The resulting smooth, flat surface is necessary to maintain the photolithographic depth of focus, for subsequent wafer processing 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 dielectric to define interconnect structures, using CMP.

[0004] Polishing pads are typically made of urethanes, either in cast form filled with micro-porous elements, or from non-woven felt coated with polyurethanes. In use, the pad is rotated while contacting the wafer, which is also rotating, thus effecting polishing. Typically, two types of polishing pads are used: hard polishing pads and soft polishing pads. Hard pads are typically used for applications requiring planarization of micro-scale features on the wafer surface, while soft pads are used for applications where planarization is not required. For example, soft pads may be used in a multi-step polishing process where wafers are first polished with a hard pad to planarize the surface, followed by polishing with a soft pad to create a smooth finish. Hard pads typically create surface defects such as micro-scratches and are not efficient at effecting the removal of slurry particles. Therefore, a soft pad is used to polish the surface of the wafer to smooth the micro-scratches as well as to enable more efficient removal of particle defects.

SUMMARY OF INVENTION

[0005] An embodiment of the present invention provides a polishing pad having one or more polishing elements (e.g., a single polishing surface or multiple polishing surfaces or elements) made from a hydrogel material having an intrinsic ability to absorb water. The hydrogel material may have no micro-porosity, a water absorption capability of 4%-60% by weight, a wet tensile strength greater than 1000 psi, a flexural modulus greater than 2000 psi, and a wet Shore D hardness between 25-80, inclusive. In other embodiments, the hydrogel material may have a water absorption capability of 4%-60% by weight, a microporosity of 1% to 20% by volume, micropores of 20-100 microns, a wet tensile strength greater than 1000 psi, a flexural modulus greater than 2000 psi, and a wet Shore D hardness between 25-80, inclusive. In either instance, the hydrogel material may be made from one or a combination of the following moieties: urethane, alkylene oxides, esters, ethers, acrylic acids, acrylamides, amides, imides, vinylalcohols, vinylacetates, acrylates, methacrylates, sulfones, urethanes, vinyl chlorides, etheretherketones, and/or carbonates.

[0006] In accordance with an embodiment of the present invention, polishing may be effected by bringing a polishing pad constructed from a material having an intrinsic ability to absorb water in proximity to a semiconductor wafer in the presence of a polishing composition disposed between the polishing pad and a top layer disposed on the wafer, and rotating the wafer and the polishing pad with respect to one another so as to effect removal of some or all of the top layer (e.g., copper) disposed on the wafer. The polishing pad may be soaked in solution (e.g., water, the polishing composition, an electrolytic solution such as copper sulfate, etc.) prior to commencing polishing operations. In cases where an electrolytic solution is used, the polishing pad may be coupled to an electrical source during the polishing operations.

[0007] In some cases, an anodic current is applied to the polishing pad (or to the polishing surface thereof) while a cathodic bias is provided by external means, and the semiconductor wafer is pressed against the polishing surface. In other cases, cathodic current is applied to the polishing pad or surface while an anodic bias is provided by external means, and the semiconductor wafer is pressed against the polishing surface.

[0008] A polishing pad having a polishing surface constructed from a material having an intrinsic ability to absorb water may be manufactured using one of: injection molding, extrusion, reaction injection molding or sintering. Surface features may be formed on the polishing surface of the polishing pad during such manufacturing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention is illustrated by way of example, and not limitation, in the figures of the accompanying drawings, in which:

[0010] FIG. **1**A illustrates a conventional polishing pad of conventional form which, in accordance with an embodiment of the present invention, may include a polishing surface constructed from a hydrogel material having an intrinsic ability to absorb water.

[0011] FIG. **1**B illustrates a polishing pad having a plurality of polishing elements, one or more of which are constructed from a hydrogel material having an intrinsic ability to absorb water in accordance with a further embodiment of the present invention.

[0012] FIG. **2** illustrates a method of using a polishing pad configured with a polishing surface made of a hydrogel material having an intrinsic ability to absorb water in accordance with the present invention.

DETAILED DESCRIPTION

[0013] Described herein are a polishing pad with reduced defectivity, methods of using such a pad, and materials useful for making CMP polishing pads with reduced defectivity. As indicated above, CMP involves removing films from the surface of a wafer by pressing a polishing pad against the wafer and rotating these elements relative to one another in the presence of a polishing composition (e.g., a slurry). During the polishing process, a slurry layer forms between the wafer and the pad, thus forming a hydrodynamic boundary layer. Maintaining a uniform fluid layer between the pad and wafer during polishing is important. In cases where the boundary layer is minimized or completely eliminated, the pad may directly contact the wafer leading to a two-body interaction causing higher defectivity. In contrast, a highly lubricated interface will allow more uniform polishing, as well as minimize defectivity. This is particularly important in the case of copper CMP, where the film being polished is very soft and can be easily scratched by direct, wafer-pad contact.

[0014] Conventional polishing pads are made of polymers, typically urethane, having structures to provide means for distributing slurry under the wafer during the polishing process. These structures include voids or micro-pores, which are included by adding hollow micro-elements as described in U.S. Pat. No. 5,578,362, or through introduction of bubbles formed during the casting process. U.S. Pat. No. 6,896,593 describes the use of supercritical CO_2 to form pores during the molding process.

[0015] Once the pad layer is formed, it maybe further machined on the top surface by mechanical or laser means to add grooves. For example, U.S. Pat. No. 5,489,233 describes the use of a solid plastic sheet, with no intrinsic ability to absorb or transport slurry, and a surface texture, or pattern, with flow channels to transport slurry across the wafer and enabling polishing. The surface texture is mechanically produced upon the pad through machining.

[0016] During polishing, a pad may be conditioned using a fine, diamond-coated disk to create a micro-texture, which creates micro-groove channels to further enhance slurry distribution under a wafer. During wafer polishing processes the pad surface also undergoes plastic deformation, which reduces slurry distribution, leading to poor material removal and removal uniformity. Conditioning processes remove the plastic deformation layer and restore polish performance.

[0017] In conventional pads, the material itself does not have any intrinsic ability to absorb significant water or polishing solution and externally created structures such as micro-pores, grooves and micro-grooves actively participate in slurry distribution. Slurry distribution ability is important not only for material removal uniformity but also for defectivity. In cases of poor slurry distribution between the pad and the wafer there is a potential for a slurry-poor region under the wafer to cause direct, pad-wafer contact, leading to defectivity.

[0018] In one embodiment, the present invention provides a polymer polishing pad with an intrinsic ability to absorb water or polishing solution, and thereby provide a very low defectivity polishing surface. The subject polishing pad may be made from a hydrogel material having the ability to absorb water or polishing solution in the range of 5-60 percent by weight. Water absorption ability is controlled during material synthesis. A pad material with the intrinsic ability to absorb water or polishing solution will provide a lubricious surface during polish processes and minimize the probability of direct, pad-wafer contact and, by extension, eliminate or minimize defectivity and particularly scratch defectivity. Methods of making hydrophilic urethane formulations are described in U.S. Pat. Nos. 5,859,166; 5,763,682; 5,424,338; 5,334,691; 5,120,816; 5,118,779; and 4,008,189, each of which is incorporated herein by reference.

[0019] Pad material properties play an important role in defectivity caused on a wafer surface. A hard pad is typically associated with higher defectivity, which is substantially scratch defectivity, while softer pads typically are associated with lower defectivity. One important aspect of soft pads is the ability of the pad surface to conform locally to prevent a "hard contact" between the wafer and the pad surface. Another aspect of local surface conformality is the ability of the pad-wafer interface to retain an aqueous interface. An aqueous interface provides necessary lubricity between the wafer and the pad, thus minimizing or eliminating the potential to cause scratches. A polymeric material capable of absorbing water provides a very stable polishing interface, thus minimizing potential for defectivity.

[0020] U.S. Pat. No. 5,763,682 states that many conventional isocyanate-based foams are non-hydrophilic (i.e., relatively hydrophobic). Typical urethane-based foams exhibit an aversion to aqueous fluids, which results in such foams being unable to absorb or pick up significant quantities of aqueous fluids. Accordingly, typical polyurethane foams may be deemed inadequate for providing a highly lubricated polishing interface.

[0021] As urethanes are made of reactions of isocyanate and a polyol, the hydrophilic aspect of the final polymer chain can be controlled through selection of polyol. U.S. Pat. Nos. 5,859,166; 5,763,682; 5,424,338; 5,334,691; 5,120,816; 5,118,779; and 4,008,189 describe methods to improve hydrophilicity of urethane compositions. Hydrophilic polyurethanes can be made by adding ethylene oxide units and alkylene oxide units to the polyol molecule.

[0022] Total hydroxyl content of the polyol is also an important factor in hydrophilicity of the polyurethane. It is known in this particular art that in order to achieve satisfactory hydrophilic properties in the foam, the polyhydric alcohol-alkylene oxide adduct reactant that is used must contain a certain proportion of ethylene oxide in the molecule. See U.S. Pat. No. 3,457,203, incorporated herein by reference. Early hydrophilic polyurethane foams were prepared from such adducts, which are products of condensing a polyhydric alcohol with a mixture of ethylene oxide and a higher alkylene oxide such as propylene oxide. However, when wet, these compositions showed deterioration in mechanical properties.

[0023] U.S. Pat. No. 4,008,189 describes compositions that can minimize such deterioration in physical properties by using a mixture of polyols comprised of three oxyalkylated polyether polyol reactants. The first of these is characterized by a trihydroxy alcohol nucleus, polyoxyethylene chain segments attached through one end thereof to the nucleus, and polyoxypropylene chain segments attached through one end thereof to the polyoxyethylene chain segments. Such a polyol can be prepared by methods well known in the art wherein a triol initiator is sequentially condensed, in the presence of an alkaline catalyst such as KOH, first with ethylene oxide and then with propylene oxide.

[0024] It is expected that such compositions would be particularly suitable for polishing applications as they enable a highly lubricated polishing interface. Moreover, it is expected a cross-linked polymer network will provide the best properties, though thermoplastic formulations can be used. Tecophilic® Extrusion Molding formulations from Lubrizol Corp are one such class of materials. These materials are tailored to absorb between 20% to 100% by weight of water. The degree of water absorption is linked to a loss of mechanical properties, with the higher the percentage by weight of water absorbed, the greater the loss in mechanical strength. It would therefore be advantageous to use formulations that absorb approximately 5-20 percent by weight of water, though water absorption as high as 100 percent by weight maybe used.

[0025] FIG. **1**A illustrates a cross-sectional view of a conventional polishing pad **100**, such as the IC **1000** pad provided 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 processes. Such commercially available polishing pads may include multiple surface modifications to affect slurry distribution across the surface of the pad.

[0026] FIG. **1**B shows a cross-sectional view of a polishing pad **108** made by SemiQuest, Inc. and described in U.S. patent application Ser. No. 11/697,622, filed 6 Apr. 2007, assigned to the assignee of the present invention and incorporated herein by reference. Pad **108** consists of polishing elements **110**, which rest on a compressible under-foam **112** disposed beneath a guide plate **114**. Polishing action is provided by the polishing elements, which are made of solid polymer material, while slurry distribution is effected by open spaces between the polishing elements. The open spaces are filled with open cell foam.

[0027] In embodiments of the present invention, polishing surfaces **104** and/or **110** of either or both of the pads discussed above may be made using hydrophilic polymer material. For example, these polishing surfaces may be formed of a hydrogel material having the ability to absorb water or polishing solution in the range of 4-60 percent by weight. The hydrogel material may be one or a combination of following moieties: urethane, alkylene oxides, esters, ethers, acrylic acids, acrylamides, amides, imides, vinylalcohols, vinylacetates, acrylates, methacrylates, sulfones, urethanes, vinylchlorides, etheretherketones, and/or carbonates. An imide is a functional group consisting of two carboxylic acid groups, or one dicarboxylic acid, bound to a primary amine or ammonia, and is generally prepared directly from ammonia or the primary amine, and the either the acid(s) or their acid anhydrides.

[0028] In particular embodiments of the present invention, the polishing surfaces of the pad may be made from hydrogel materials that have no micro-porosity, have a wet tensile strength greater than 1000 psi, a flexural modulus greater than 2000 psi, and/or a wet Shore D hardness of between 25-80, inclusive. In other cases, the hydrogel material may have a microporosity of approximately 1%-20% by volume, micropores of between approximately 20-100 microns, a wet tensile strength greater than 1000 psi, flexural modulus greater than 2000 psi, and a wet Shore D hardness of between 25-80, inclusive.

[0029] During polishing operations, a polishing pad constructed from hydrogel material in accordance with the present invention is brought into contact with a surface of a semiconductor wafer (e.g., a wafer having one or more thin films, oxides and/or metal layers disposed thereon) in the presence of a polishing compound, and the two are rotated with respect to one another so as to effect removal of some or all of a top layer disposed over the surface of the wafer substrate. FIG. **2** illustrates this arrangement. A polishing pad **200** is affixed to a turntable **202** and brought in proximity with a wafer **204** that is on a platen **206**. A slurry or other polishing compound **208** is introduced between the polishing pad and the wafer and the pad and/or the wafer are rotated relative to one another.

[0030] In some cases, the polishing pad may be soaked in water or polishing solution prior to being used for polishing operations. For example, the pad may be so soaked for a period of time (e.g., at least 10 minutes) to create a stable polishing surface prior to processing the wafer.

[0031] Further, a polishing pad constructed in accordance with the present invention may be soaked in electrolyte solution to create a conductive matrix and surface. One example of such an electrolyte solution is copper sulfate. Such a pad may be attached to an external electrical source during polishing operations. Such connections may be anodic and anodic or cathodic bias may be applied by external means. A polishing pad saturated with electrolyte solution (such as copper sulfate) in this fashion and having anodic current applied to it, while a cathodic bias is provided by external means, may be pressed against a semiconductor wafer having a top conductive layer (such as copper) deposited thereon so as to fill structures formed into the underlying film to affect removal of the conductive layer. Alternatively, a polishing pad constructed in accordance with the present invention and saturated with electrolyte solution (such as copper sulfate) may have an anodic current applied to it, while an anodic bias is provided by external means. The pad may be pressed against a semiconductor wafer with top conductive layer (such as copper) deposited thereon so as to fill structures formed into the underlying film to affect deposition of the conductive layer.

[0032] Polishing pads constructed from hydrogel material in accordance with the present invention may be manufactured using injection molding, extrusion, reaction injection molding or sintering. Surface features may be formed on such pads during the manufacturing process. Such features may aid in slurry distribution during polishing operations.

[0033] Thus, polishing pads with reduced defectivity, methods of making and using such pads, and materials useful for making same have been described. Although discussed with reference to certain illustrated embodiments, however, the present invention should not be limited thereby and, instead, measured only in terms of the claims, which follow.

What is claimed is:

1. A polishing pad comprising a plurality of polishing elements, said polishing elements backed by a compressible under-foam disposed beneath a guide plate for the polishing elements, said polishing elements made from a hydrogel polymer having an intrinsic ability to absorb water and having no micro-porosity, the hydrogel material having a water absorption capability of 4%-60% by weight, a wet tensile strength greater than 1000 psi, a flexural modulus greater than 2000 psi, and a wet Shore D hardness between 25-80, inclusive.

2. The polishing pad of claim **1**, wherein the hydrogel material is made from one or a combination of the following moieties: urethane, alkylene oxides, esters, ethers, acrylic acids, acrylamides, amides, imides, vinylalcohols, vinylacetates, acrylates, methacrylates, sulfones, urethanes, vinyl chlorides, etheretherketones, and/or carbonates.

3. A polishing pad comprising a plurality of polishing elements, said polishing elements backed by a compressible under-foam disposed beneath a guide plate for the polishing elements, said polishing elements made from a hydrogel material having a water absorption capability of 4%-60% by weight, a microporosity of 1% to 20% by volume, micropores of 20-100 microns, a wet tensile strength greater than 1000 psi, a flexural modulus greater than 2000 psi, and a wet Shore D hardness between 25-80, inclusive.

4. The polishing pad of claim **3**, wherein the hydrogel material is made from one or a combination of the following moieties: urethane, alkylene oxides, esters, ethers, acrylic acids, acrylamides, amides, imides, vinylalcohols, vinylacetates, acrylates, methacrylates, sulfones, urethanes, vinylchlorides, etheretherketones, and/or carbonates.

* * * * *