

LOW SURFACE ROUGHNESS POLISHING PAD

FIELD OF THE INVENTION

[0001] The present invention relates to a polishing pad and a method of polishing a substrate; and in particular, the present invention relates to a polishing pad comprising a polishing pad body comprising a polishing surface, wherein the polishing body comprises pores, and wherein the polishing surface has a surface roughness of 0.1 μm to 10 μm .

BACKGROUND OF THE INVENTION

[0002] Chemical-mechanical polishing ("CMP") processes are used in the manufacturing of microelectronic devices to form flat surfaces on semiconductor wafers, field emission displays, and many other microelectronic substrates. For example, the manufacture of semiconductor devices generally involves the formation of various process layers, selective removal or patterning of portions of those layers, and deposition of yet additional process layers above the surface of a semiconducting substrate to form a semiconductor wafer. The process layers can include, by way of example, insulation layers, gate oxide layers, conductive layers, and layers of metal or glass, etc. It is generally desirable in certain steps of the wafer process that the uppermost surface of the process layers be planar, i.e., flat, for the deposition of subsequent layers. CMP is used to planarize process layers wherein a deposited material, such as a conductive or insulating material, is polished to planarize the wafer for subsequent process steps.

[0003] In a typical CMP process, a wafer is mounted upside down on a carrier in a CMP tool. A force pushes the carrier and the wafer downward toward a polishing pad. The carrier and the wafer are rotated above the rotating polishing pad on the CMP tool's polishing table. A polishing composition (also referred to as a polishing slurry) generally is introduced between the rotating wafer and the rotating polishing pad during the polishing process. The polishing composition typically contains a chemical that interacts with or dissolves portions of the uppermost wafer layer(s) and an abrasive material that physically removes portions of the layer(s). The wafer and the polishing pad can be rotated in the same direction or in opposite directions, whichever is desirable for the particular polishing process being carried out. The carrier also can oscillate across the polishing pad on the polishing table.

[0004] Polishing pads typically have an initial surface roughness of greater than 15 microns. During the polishing of several substrates with the same pad, normal wear on the pad surface results in a change in the surface roughness of the pad. As the surface roughness

of the pad changes, contact between the pad surface and a substrate being polished changes, and thus the polishing rate can change. As a result, the amount of time required for polishing the substrates to achieve desired surface properties, such as planarity, varies during a production run. Variances from uniformity between substrates can therefore result.

[0005] Thus, there remains in the art a need for improved polishing pads.

BRIEF SUMMARY OF THE INVENTION

[0006] The invention provides a polishing pad comprising a polishing pad body comprising a polishing surface, wherein the polishing body comprises pores, and wherein the polishing surface has a surface roughness of 0.1 μm to 10 μm .

[0007] The invention also provides a method of polishing a substrate, which method comprises (i) providing a substrate to be polished, (ii) contacting the substrate with the aforesaid polishing pad and a polishing composition, and (iii) moving the substrate relative to the polishing pad with the polishing composition therebetween to abrade at least a portion of the substrate to polish the substrate.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0008] FIG. 1 is a scanning electron microscope image of the surface of a polishing pad in accordance with an embodiment of the invention.

[0009] FIG. 2 is a scanning electron microscope image of the surface of a polishing pad in accordance with an embodiment of the invention.

[0010] FIG. 3 is a scanning electron microscope image of the surface of a conventional polishing pad.

[0011] FIG. 4 is a graphical representation of the silicon oxide removal rate versus the number of wafers polished using a polishing pad in accordance with an embodiment of the invention in comparison with a conventional polishing pad.

DETAILED DESCRIPTION OF THE INVENTION

[0012] The invention provides a polishing pad comprising a polishing pad body comprising a polishing surface, wherein the polishing pad body comprises pores, and wherein the polishing surface has a surface roughness of 0.1 μm to 10 μm .

[0013] The polishing pad body can have any suitable dimensions. Typically, the polishing pad body is circular in shape (as is used in rotary polishing tools) or is produced as a looped linear belt (as is used in linear polishing tools). Preferably, the polishing pad body is circular.

[0014] The polishing pad body can comprise, consist essentially of, or consist of any suitable material. Desirably, the polishing pad body comprises, consists essentially of, or consists of a polymer resin. The polymer resin can be any suitable polymer resin. Typically, the polymer resin is selected from the group consisting of thermoplastic elastomers, thermoset polymers, polyurethanes (e.g., thermoplastic polyurethanes), polyolefins (e.g., thermoplastic polyolefins), polycarbonates, polyvinylalcohols, nylons, elastomeric rubbers, elastomeric polyethylenes, polytetrafluoroethylenes, polyethyleneterephthalates, polyimides, polyaramides, polyarylenes, polyacrylates, polystyrenes, polymethylmethacrylates, copolymers thereof, and mixtures thereof. Preferably, the polymer resin is a polyurethane, more preferably a thermoplastic polyurethane.

[0015] The polishing pad body comprises pores. The pores can have an average pore diameter of 2 μm or more, 3 μm or more, 4 μm or more, 5 μm or more, 6 μm or more, 7 μm or more, 8 μm or more, 9 μm or more, 10 μm or more, 15 μm or more, 20 μm or more, 25 μm or more, 30 μm or more, 35 μm or more, 40 μm or more, 45 μm or more, or 50 μm or more. Alternatively, or in addition, the pores can have an average pore diameter of 150 μm or less, 125 μm or less, 100 μm or less, 90 μm or less, 80 μm or less, 70 μm or less, 60 μm or less, 50 μm or less, 45 μm or less, 40 μm or less, 35 μm or less, 30 μm or less, 25 μm or less, 20 μm or less, 15 μm or less, or 10 μm or less. Thus, the pores can have an average pore diameter bounded by any two of the endpoints recited for the average pore diameter. For example, the polishing pad body can have an average pore diameter of 2 μm to 150 μm , 3 μm to 125 μm , 4 μm to 100 μm , 5 μm to 90 μm , 5 μm to 80 μm , 5 μm to 70 μm , 5 μm to 60 μm , 5 μm to 50 μm , 5 μm to 45 μm , 5 μm to 40 μm , 5 μm to 35 μm , 5 μm to 30 μm , 5 μm to 25 μm , 5 μm to 20 μm , 5 μm to 15 μm , 5 μm to 10 μm , 10 μm to 50 μm , 10 μm to 45 μm , 10 μm to 40 μm , 10 μm to 35 μm , 10 μm to 30 μm , 10 μm to 25 μm , or 10 μm to 20 μm .

[0016] The polishing surface can have a surface roughness of 0.1 μm or more, 0.2 μm or more, 0.3 μm or more, 0.4 μm or more, 0.5 μm or more, 0.6 μm or more, 0.7 μm or more, 0.8 μm or more, 0.9 μm or more, or 1 μm or more. Alternatively, or in addition, the polishing surface can have a surface roughness of 4 μm or less, 3.8 μm or less, 3.6 μm or less, 3.5 μm or less, 3.4 μm or less, 3.2 μm or less, 3 μm or less, 2.8 μm or less, 2.6 μm or less, 2.5 μm or less, 2.4 μm or less, 2.2 μm or less, 2 μm or less, 1.8 μm or less, or 1.6 μm or less. Thus, the polishing surface can have a surface roughness bounded by any two of the endpoints recited for the surface roughness. For example, the polishing pad body can have a surface roughness of 0.1 μm to 4 μm , 0.1 μm to 3.8 μm , 0.1 μm to 3.6 μm , 0.1 μm to 3.4 μm , 0.1 μm to 3.2 μm ,

0.1 μm to 3 μm , 0.1 μm to 2.8 μm , 0.1 μm to 2.6 μm , 0.1 μm to 2.4 μm , 0.1 μm to 2.2 μm , 0.1 μm to 2 μm , 0.1 μm to 1.8 μm , 0.1 μm to 1.6 μm , 0.5 μm to 4 μm , 0.5 μm to 3.5 μm , 0.5 μm to 3 μm , 0.5 μm to 2.5 μm , 0.5 μm to 2 μm , 1 μm to 4 μm , 1 μm to 3.6 μm , 1 μm to 3 μm , 1 μm to 2.5 μm , or 1 μm to 2 μm .

[0017] The surface roughness can be expressed as the average surface roughness as determined at several regions of the polishing surface. A non-limiting example of a suitable method for determining the surface roughness of the polishing surface or of a region thereof is ISO13565.

[0018] The polishing pad body can be produced using any suitable technique, many of which are known in the art. For example, the polishing pad can be formed by methods such as casting and extrusion. The polymer resin may be a thermoplastic material which is heated to a temperature at which it will flow and is then formed into a desired shape by casting or extrusion. The polymer resin may provide a porous structure by its natural configuration. In other embodiments, the porous structure may be introduced through the use of various production techniques known in the art (e.g., foaming, blowing, and the like). Representative methods of providing a porous structure comprising closed-cell pores include foaming processes such as a muccell process, a phase inversion process, a spinodal or bimodal decomposition process, or a pressurized gas injection process, all of which are well known in the art. A representative method providing a porous structure comprising open-cell pores comprises sintering particles of a thermoplastic polymer, such as a polyurethane, to provide an open-cell porous structure.

[0019] The polishing surface can be produced using any suitable method. In an embodiment, the polishing surface is produced by skiving the polishing pad body.

[0020] The polishing pad body can have a storage modulus of elasticity at 30° C of 5 MPa or more, 10 MPa or more, 20 MPa or more, 30 MPa or more, 40 MPa or more, 50 MPa or more, 60 MPa or more, 70 MPa or more, 80 MPa or more, 90 MPa or more, 100 MPa or more, 200 MPa or more, 300 MPa or more, 400 MPa or more, or 500 MPa or more.

Alternatively, or in addition, the polishing pad body can have a storage modulus of elasticity at 30° C of 600 MPa or less, 550 MPa or less, 500 MPa or less, 450 MPa or less, 400 MPa or less, 350 MPa or less, or 300 MPa or less. Thus, the polishing pad body can have a storage modulus of elasticity at 30° C bounded by any two of the endpoints recited for the storage modulus of elasticity at 30° C. For example, the polishing pad body can have a storage modulus of elasticity at 30° C of 5 MPa to 600 MPa, 20 MPa to 600 MPa, 30 MPa to 600

MPa, 40 MPa to 550 MPa, 50 MPa to 500 MPa, 60 MPa to 450 MPa, 70 MPa to 400 MPa, 80 MPa to 350 MPa, 90 MPa to 300 MPa, 5 MPa to 500 MPa, 10 MPa to 500 MPa, 20 MPa to 400 MPa, or 20 MPa to 300 MPa.

[0021] A polishing pad in accordance with the invention can be used alone or optionally can be used as one layer of a multi-layer stacked polishing pad. For example, the inventive polishing pad can be used in combination with a subpad. The subpad can be any suitable subpad. Suitable subpads include polyurethane foam subpads, impregnated felt subpads, microporous polyurethane subpads, or sintered urethane subpads. The subpad typically is softer than the polishing pad of the invention and therefore is more compressible than the polishing pad. In some embodiments, the subpad is harder and is less compressible than the polishing pad. The subpad optionally comprises grooves, channels, hollow sections, and the like. When the polishing pad of the invention is used in combination with a subpad, typically there is an intermediate backing layer, such as a polyethyleneterephthalate film, coextensive with and between the polishing pad and the subpad.

[0022] In an embodiment, the polishing pad is prepared by sandwiching the polishing pad body between two layers of a backing material. The resulting sandwiched polishing pad body can then be skived to produce two polishing pads. In some embodiments, the sandwiched polishing pad body can be produced by curing a prepolymer, for example, a thermoplastic polyurethane, between two backing layers. The backing material can be any suitable backing material and can comprise a polymeric sheet. In some embodiments, the backing material can comprise a subpad as described herein. In these embodiments, the sandwiched polishing pad can be prepared in the form of an elongated sheet which is then skived and cut into segments to form the polishing pad in a continuous process.

[0023] As is illustrated in Figs. 1 and 2, the surface of the inventive polishing pad comprises open pores resulting from the formation of the polishing surface by skiving of the polishing pad body. The surface roughness of the polishing surface refers to the surface roughness of the polishing surface exclusive of the pores. FIG. 3 illustrates the surface of a conventional polishing pad for purposes of comparison.

[0024] The surface roughness can be measured with an optical type surface roughness tester, such as a three-dimensional surface profiler, laser scanning microscope, electron beam surface profiler, a contact type surface roughness tester, such as a surface roughness tester with contact stylus, and the like. Preferably, the surface roughness is determined according to ISO 13565.

[0025] The invention further provides a method of polishing a substrate, which method comprises (i) providing a substrate to be polished, (ii) contacting the substrate with the inventive polishing pad described herein and a polishing composition, and (iii) moving the substrate relative to the polishing pad, with the polishing composition therebetween, to abrade at least a portion of the substrate to polish the substrate.

[0026] The polishing composition can be any suitable polishing composition. The polishing composition typically comprises an aqueous carrier, a pH adjustor, and optionally an abrasive. Depending on the type of substrate (workpiece) being polished, the polishing composition optionally can further comprise one or more oxidizing agents, organic acids, complexing agent, pH buffers, surfactants, corrosion inhibitors, anti-foaming agents, biocides, and the like.

EXAMPLE

[0027] This example demonstrates the removal rate for silicon oxide exhibited by the inventive polishing pad as a function of the number of substrates polished therewith.

[0028] Similar substrates comprising a blanket layer of silicon oxide derived from tetraethylorthosilicate were polished with a polishing pad in accordance with an embodiment of the invention and with a conventional polishing pad in conjunction with a polishing composition. The inventive polishing pad was prepared using a thermoplastic polyurethane resin (the 87A thermoplastic polyurethane resin from Lubrizol, Wickliffe, OH) and had a Shore D hardness of 42D, an average pore diameter of 25-45 μm , an average surface roughness as measured by a confocal microscope of 1.4 μm , and a storage modulus of elasticity (E') as shown in the Table.

Table

E' at 20° C	E' at 40° C	E' at 60° C
27.46 Mpa	22.45 Mpa	15.9 Mpa

[0029] The comparative polishing pad was a commercial thermoplastic polyurethane pad having a milled surface and an average surface roughness as measured by a confocal microscope of 5.6 μm .

[0030] Following polishing of the substrates, the removal rate was determined for each substrate, and the results are illustrated graphically in FIG. 4.

[0031] As is apparent from the data shown in FIG. 4, the inventive polishing pad exhibited a silicon oxide removal rate that stabilized at approximately 530 Å/min after polishing approximately 40 substrates. The comparative polishing pad exhibited a silicon oxide removal rate that increased during polishing of successive substrates and approached approximately 370 Å/min after polishing over 200 substrates.

[0032] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0033] The use of the terms “a” and “an” and “the” and “at least one” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term “at least one” followed by a list of one or more items (for example, “at least one of A and B”) is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0034] Preferred embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as

specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

CLAIM(S):

1. A polishing pad comprising a polishing pad body comprising a polishing surface, wherein the polishing body comprises pores, and wherein the polishing surface has a surface roughness of 0.1 μm to 4 μm .
2. The polishing pad of claim 1, wherein the polishing surface has a surface roughness of 0.5 μm to 2 μm .
3. The polishing pad of claim 1, wherein the pores have an average pore diameter of 2 μm to 150 μm .
4. The polishing pad of claim 1, wherein the polishing pad has a storage modulus of elasticity at 30° C of 5 MPa to 600 MPa.
5. The polishing pad of claim 1, wherein the polishing pad body comprises thermoplastic polyurethane.
6. The polishing pad of claim 1, wherein the polishing pad further comprises a pad substrate.
7. The polishing pad of claim 6, wherein the polishing pad body has a non-polishing surface that is opposite to the polishing surface, and wherein the pad substrate is bonded to the non-polishing surface.
8. The polishing pad of claim 1, wherein the polishing pad further comprises an optically transmissive region extending from the polishing surface to a surface opposite to the polishing surface.
9. A method of polishing a substrate, which method comprises:
 - (i) providing a substrate to be polished,
 - (ii) contacting the substrate with a polishing pad of claim 1 and a polishing composition, and
 - (iii) moving the substrate relative to the polishing pad with the polishing composition therebetween to abrade at least a portion of the substrate to polish the substrate.