COMPOSITION AND METHOD FOR PLANARIZING SURFACES

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a composition and method for planarizing or polishing a surface, such as the surface of a semiconductor.

BACKGROUND OF THE INVENTION

Compositions for planarizing or polishing the surface of a substrate are well known in the art. Polishing slurries typically contain an abrasive material in an aqueous solution and are applied to a surface by contacting the surface with a polishing pad saturated with the slurry composition. Typical abrasive materials include silicon dioxide, cerium oxide, aluminum oxide, zirconium oxide, and tin oxide. U.S. Patent 5,527,423, for example, describes a method for chemically-mechanically polishing a metal layer by contacting the surface with a polishing slurry comprising high purity fine metal oxide particles in an aqueous medium.

Conventional polishing compositions typically are not entirely satisfactory at planarizing semiconductor wafers. In particular, polishing slurries can have less than desirable polishing rates, and their use in chemically-mechanically polishing semiconductor surfaces can result in poor surface quality. Because the performance of a semiconductor wafer is directly associated with the planarity of its surface, it is crucial to use a polishing composition that has a high polishing efficiency, uniformity, and removal rate and leaves a high quality polish with minimal surface defects.

The difficulty in creating an effective polishing composition for semiconductor wafers stems from the complexity of the semiconductor wafer. Semiconductor wafers are typically composed of a substrate, on which a plurality of transistors has been formed. Integrated circuits are chemically and physically connected into a substrate by patterning regions in the substrate and layers on the substrate. To produce an operable semiconductor wafer and to maximize the yield, performance, and reliability of the wafer, it is desirable to polish select surfaces of the wafer without adversely affecting underlying structures or topography. In fact, various problems in semiconductor fabrication can occur if the process steps are not performed on wafer surfaces that are adequately planarized.

There have been many attempts to improve the polishing efficiency and uniformity of conventional polishing agents, while minimizing defectivity of the polished surface and damage to underlying structures or topography. For

example, U.S. Patent 5,264,010 describes a polishing composition comprising cerium oxide, fumed silica, and precipitated silica, which purportedly yields an improved removal rate and polishing efficiency.

A need remains, however, for compositions and methods that will exhibit desirable planarization efficiency, uniformity, and removal rate during the polishing and planarization of substrates, while minimizing defectivity, such as surface imperfections and damage to underlying structures and topography during polishing and planarization. The present invention seeks to provide such a composition and method. These and other advantages of the present invention will be apparent from the description of the invention provided herein.

BRIEF SUMMARY OF THE INVENTION

The present invention is directed to a composition for planarizing or polishing a surface. The polishing composition of the present invention comprises (a) a liquid carrier and (b) solids comprising about 5-90 wt.% of fumed metal oxide and about 10-95 wt.% of abrasive particles, wherein about 90% or more of the abrasive particles (i.e., by number) have a particle size no greater than 100 nm. The present invention also provides a method of planarizing or polishing a surface comprising contacting the surface with the composition of the present invention.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a plot of the packing density versus the removal rate of various polishing compositions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides a composition comprising (a) a liquid carrier and (b) solids comprising about 5-90 wt.% of fumed metal oxide and about 10-95 wt.% of abrasive particles, wherein about 90% or more of the abrasive particles (by number) have a particle size no greater than 100 nm. The composition is useful in planarizing or polishing a surface. The present invention allows for a high polishing efficiency, uniformity, and removal rate of a surface with minimal defectivity, such as field loss of underlying structures and topography.

The total solids can be present in any suitable concentration in the composition of the present invention. The solids desirably are present in a concentration of about 0.1 wt.% or more (e.g., about 0.1-40 wt.%). Preferably, the

total solids concentration is about 0.1-30 wt.% (e.g., about 1-30 wt.%) of the composition.

The solids of the composition of the present invention comprise about 5-90 wt.% of fumed metal oxide and about 10-95 wt.% of abrasive particles (i.e., the abrasive particles are at least about 10 wt.% of the total solids). The solids of the composition desirably comprise about 10-85 wt.% (e.g., about 15-75 wt.%) of fumed metal oxide and about 15-90 wt.% (e.g., about 25-85 wt.%) of abrasive particles (i.e., the abrasive particles are at least about 15 wt.% (e.g., at least about 25 wt.%) of the total solids). Preferably, the solids comprise about 15-60 wt.% (e.g., about 20-50 wt.%) of fumed metal oxide and about 40-85 wt.% (e.g., about 50-80 wt.%) of abrasive particles (i.e., the abrasive particles are at least about 40 wt.% (e.g., at least about 50 wt.%) of the total solids).

The fumed metal oxide of the composition of the present invention can be any suitable fumed (pyrogenic) metal oxide. Suitable fumed metal oxides include, for example, fumed alumina, fumed silica, fumed titania, fumed ceria, fumed zirconia, fumed germania, fumed magnesia, coformed products thereof, cofumed products thereof, and mixtures thereof. Preferably, the fumed metal oxide of the composition of the present invention is fumed silica.

Any suitable abrasive particles can be present in the composition of the present invention. Desirable abrasive particles are metal oxides. Suitable metal oxides include alumina, silica, titania, ceria, zirconia, and magnesia. Also suitable for use in the composition are abrasive particles prepared in accordance with U.S. Patent 5,230,833 and various commercially available products, such as the Akzo-Nobel Bindzil 50/80 product and the Nalco 1050, 2327, and 2329 products, as well as other similar products available from DuPont, Bayer, Applied Research, Nissan Chemical, and Clariant. Preferably, the abrasive particles of the composition of the present invention are a condensation-polymerized metal oxide, e.g., condensation-polymerized silica. Condensation-polymerized silica typically is prepared by condensing $Si(OH)_4$ to form colloidal particles.

The abrasive particles of the composition of the present invention are such that about 90% or more of the abrasive particles (by number) have a particle size no greater than 100 nm. Preferably, the abrasive particles are such that at least about 95%, 98%, or even substantially all (or actually all) of the abrasive particles (by number) have a particle size no greater than 100 nm. These particle size preferences for the abrasive particles (i.e., whereby at least about 90%, 95%, 98%, substantially all, and all of the abrasive particles (by number) are no greater than a

specific size of abrasive particle) also can pertain to other particle sizes, such as 95 nm, 90 nm, 85 nm, 80 nm, 75 nm, 70 nm, and 65 nm.

Similarly, the abrasive particles of the composition of the present invention can be such that at least about 90%, 95%, 98%, or even substantially all (or actually all) of the abrasive particles (by number) have a particle size no less than 5 nm. These particle size preferences for the abrasive particles (i.e., whereby at least about 90%, 95%, 98%, substantially all, and all of the abrasive particles (by number) are no less than a specific size of abrasive particle) also can pertain to other particle sizes, such as 7 nm, 10 nm, 15 nm, 25 nm, and 30 nm.

The abrasive particles of the composition of the present invention can be essentially bimodal in distribution in terms of particle diameter, with about 30-70% (e.g., about 50%) of abrasive particles (by number) ranging in size from about 30-50 nm and about 30-70% (e.g., about 50%) of abrasive particles (by number) ranging in size from about 70-90 nm. Preferably, the abrasive particles are essentially bimodal in distribution in terms of particle diameter, with about 30-70% (e.g., about 50%) of abrasive particles (by number) ranging in size from about 35-45 nm and about 30-70% (e.g., about 50%) of abrasive particles (by number) ranging in size from about 75-85 nm.

The percentage values used herein to describe the nature of the abrasive particles in terms of particle size are percentages "by number," rather than being weight percentages, unless otherwise noted. The particle size of the abrasive particles refers to the particle diameter. The particle size can be measured by any suitable technique. The particle size values set forth herein are based on a visual inspection, specifically by way of transmission electron micrography (TEM), of a statistically significant sample of the abrasive particles, preferably at least 200 particles.

The particle size distribution of abrasive particles can be characterized by geometric standard deviation by number, referred to as sigma-g (σ_g). The σ_g values can be obtained by dividing (a) the diameter at which 84% of the abrasive particles (by number) are less than by (b) the diameter at which 16% of the abrasive particles (by number) are less than (i.e., $\sigma_g = d_{84}/d_{16}$). Monodispersed abrasive particles have a σ_g value of about 1. As the abrasive particles become polydispersed (i.e., include particles of increasingly different size), the σ_g value of the abrasives particles increases above 1. The abrasive particles typically have a σ_g value of about 2.5 or less (e.g., about 2.3 or less). The abrasive particles desirably have a σ_g value of at least about 1.1 (e.g., about 1.1-2.3 (e.g., 1.1-1.3),

preferably a σ_g value of at least about 1.3 (e.g., about 1.5-2.3 or even about 1.8-2.3).

The composition of the present invention also can be characterized by packing density. The packing density is one minus the sedimentation volume of all of the composition components mixed together divided by the addition of the separate sedimentation volumes of the individual composition components. Thus, the packing density (PD) is $1-(V_{total}/(V_{fmo} + V_{ap}))$, wherein V_{fmo} is the volume of the fumed metal oxide (in the absence of the abrasive particles), V_{ap} is the volume of the abrasive particles (in the absence of the fumed metal oxide), and V_{total} is the volume of the fumed metal oxide and abrasive particles mixed together. These volumes of the fumed metal oxide alone, abrasive particles alone, and the combination of the two in a mixed condition are determined by centrifuging the samples at any suitable G-force for a duration equal to 1.2 x Stokes settling time of the smallest particle in the material for which the volume is being determined.

The composition desirably has a packing density value of at least about 0.1, preferably a packing density value of at least about 0.15. More preferably, the composition has a packing density value of at least about 0.2. Most preferably, the composition of the present invention has a packing density value of at least about 0.3 (e.g., about 0.3-0.6) or even at least about 0.4 (e.g., about 0.4-0.6 or about 0.5-0.6). The composition of the present invention typically has a packing density value of about 0.7 or less (e.g., about 0.65 or less or even about 0.6 or less).

The composition of the present invention can further comprise one or more other components. Such other components can include surfactants, polymeric stabilizers or other surface active dispersing agents, pH adjusters, regulators, or buffers, polishing accelerators, and the like. Suitable surfactants can include, for example, cationic surfactants, anionic surfactants, nonionic surfactants, amphoteric surfactants, fluorinated surfactants, mixtures thereof, and the like. Suitable polymeric stabilizers or other surface active dispersing agents can include, for example, phosphoric acid, organic acids, tin oxides, organic phosphonates, mixtures thereof, and the like. Suitable pH adjusters, regulators, or buffers can include, for example, sodium hydroxide, sodium carbonate, sulfuric acid, hydrochloric acid, nitric acid, phosphoric acid, citric acid, potassium phosphate, mixtures thereof, and the like.

Suitable polishing accelerators can include, for example, oxidizers, chelating or complexing agents, catalysts, and the like. Suitable oxidizers can include, for example, oxidized halides (e.g., chlorates, bromates, iodates, perchlorates, perbromates, periodates, mixtures thereof, and the like). Suitable

oxidizers also can include, for example, perboric acid, perborates, percarbonates, nitrates, persulfates, peroxides, peroxyacids (e.g., peracetic acid, perbenzoic acid, m-chloroperbenzoic acid, salts thereof, mixtures thereof, and the like), permanganates, chromates, cerium compounds, ferricyanides (e.g., potassium ferricyanide), mixtures thereof, and the like. Suitable chelating or complexing agents can include, for example, carbonyl compounds (e.g., acetylacetonates, and the like), simple carboxylates (e.g., acetates, aryl carboxylates, and the like), carboxylates containing one or more hydroxyl groups (e.g., glycolates, lactates, gluconates, gallic acid and salts thereof, and the like), di-, tri-, and poly-carboxylates (e.g., oxalates, phthalates, citrates, succinates, tartrates, malates, edetates (e.g., disodium EDTA), mixtures thereof, and the like), carboxylates containing one or more sulfonic and/or phosphonic groups, and the like. Suitable chelating or complexing agents also can include, for example, di-, tri-, or poly-alcohols (e.g., ethylene glycol, pyrocatechol, pyrogallol, tannic acid, and the like) and amine-containing compounds (e.g., amino acids, amino alcohols, di-, tri-, and poly-amines, and the like). Suitable polishing accelerators also can include, for example, sulfates, halides (i.e., fluorides, chlorides, bromides, and iodides), and the like.

It will be appreciated that many of the aforementioned compounds can exist in the form of a salt (e.g., a metal salt, an ammonium salt, or the like), an acid, or as a partial salt. For example, citrates include citric acid, as well as mono-, di-, and tri-salts thereof; phthalates include phthalic acid, as well as mono-salts (e.g., potassium hydrogen phthalate) and di-salts thereof; perchlorates include the corresponding acid (i.e., perchloric acid), as well as salts thereof. Furthermore, certain compounds or reagents may perform more than one function. For example, some compounds can function both as a chelating and an oxidizing agent (e.g., certain ferric nitrates and the like).

Any suitable carrier (e.g., solvent) can be used in the composition of the present invention. A carrier is used to facilitate the application of the fumed metal oxide and abrasive particles onto the surface of a suitable substrate. A preferred carrier is water.

The pH of the composition of the present invention is maintained in a range suitable for its intended end-use. The composition desirably has a pH of about 2-12, preferably about 3-10.

The present invention also provides a method of planarizing or polishing a surface. This method comprises contacting a surface with a composition as described herein. A surface can be treated with the composition by any suitable

technique. For example, the composition can be applied to the surface through use of a polishing pad.

The composition of the present invention is capable of planarizing or polishing a substrate at a relatively high rate, e.g., removing the silicon dioxide layer from a layered substrate at a relatively high rate. Furthermore, the composition of the present invention is well-suited for the planarizing or polishing of many hardened workpieces, such as memory or rigid disks, metals (e.g., noble metals), ILD layers, micro-electro-mechanical systems, ferroelectrics, magnetic heads, polymeric films, and low and high dielectric constant films. The composition also can be used in the manufacture of integrated circuits and semiconductors. The composition of the present invention exhibits desirable planarization efficiency, uniformity, removal rate, and low defectivity during the polishing and planarization of substrates.

EXAMPLES

The following examples further illustrate the present invention but, of course, should not be construed as in any way limiting its scope.

The silicon wafers, referenced in all but one of the following examples (i.e., Example 2), were blanket films with a step height of approximately 9000 Å.

Each silicon wafer was planarized using an Applied Materials Mirra® 1270 μm (50 mil) IC1000 polishing pad. The wafers were polished for 120 seconds using a table speed of 93 rpm, a head speed of 87 rpm, and a slurry flow rate of 500 ml/min. The wafers were polished for 60-second intervals.

Silicon removal rates were determined by directly measuring the step height of the silicon wafer before and after polishing using a Tencor Surfscan® UV 1050 machine.

The memory or rigid disks, referenced in Example 2, were commercially available memory or rigid disks obtained from Seagate Technology. The memory or rigid disks were nickel-phosphor coated (plated) disks with aluminum substrates. The memory or rigid disks had undergone a pre-polishing process prior to being used in the following examples, and each memory or rigid disk had a surface roughness of 30-50 Å.

The memory or rigid disks were polished using a table top polishing machine manufactured by Streuers (West Lake, Ohio). The table top polishing machine employed a Rotopol 31 base and Rotoforce 3 downforce unit. The polishing pads used in example 2 were 30.48 cm (12 inch) diameter Polytex Hi pads manufactured by Rodel. The memory or rigid disks were polished for 10

minutes per side using a platen speed of 150 rpm, a polishing carrier speed of 150 rpm, and a slurry flow rate of 100 ml/min. The polishing force used was 50 N.

Nickel-phosphor removal rates in Example 2 were calculated by weighing the clean, dry memory or rigid disk prior to polishing and following polishing. The weight loss was converted to a memory or rigid disk thickness loss using a nickel-phosphor density of 8.05 g/cm^3.

EXAMPLE 1

This example illustrates the enhancement of planarization uniformity of a surface that is achieved by using a mixture of a fumed metal oxide and abrasive particles in accordance with the present invention.

Silicon wafers were polished separately with ten compositions: (A) two compositions with about 12 wt.% total solids consisting of 100 wt.% fumed silica, (B) two compositions with about 25 wt.% total solids consisting of 100 wt.% condensation-polymerized silica, (C) two compositions with about 25 wt.% total solids consisting of 25 wt.% fumed silica and 75 wt.% condensation-polymerized silica, (D) two compositions with about 25 wt.% total solids consisting of 47 wt.% fumed silica and 53 wt.% condensation-polymerized silica, and (E) two compositions with about 25 wt.% total solids consisting of 37 wt.% fumed silica and 63 wt.% condensation-polymerized silica. The fumed silica was added to the compositions in the form of Cab-O-Sperse® SS-25, which is an aqueous dispersion of Cab-O-Sil® L-90 fumed silica (Cabot Corporation). The condensation-polymerized silica was Bindzil® 50/80 (Akzo-Nobel), wherein about 90% or more of the particles thereof (by number) have a particle size no greater than 100 nm and about 90% or more of the particles thereof (by number) have a particle size no less than 5 nm. Following use of the polishing compositions, planarization uniformity values were obtained for each composition by measuring the oxide thickness of each silicon wafer, following polishing, along the diameter of the silicon wafer except for a portion of the wafer edge (edge exclusion = 6 mm). The lowest recorded thickness value was subtracted from the highest recorded thickness value for each silicon wafer to yield the planarization uniformity values for each composition set forth in Table 1. A lower planarization uniformity value reflects less thickness variation and, therefore, greater planarization uniformity across the silicon wafer.

Table 1:

Composition	Planarization Uniformity Value (Å)
1A1	794.23
1A2	828.01
1B1	1306.07
1B2	1219.62
1C1	797.63
1C2	548.05
1D1	519.01
1D2	625.77
1E1	495.93
1E2	618.46

As is apparent from the data set forth in Table 1, the planarization uniformity exhibited by the compositions with solids consisting of mixtures of fumed silica and condensation-polymerized silica (Compositions 1C, 1D, and 1E) generally was greater than the planarization uniformity for compositions with solids consisting of only fumed silica or only condensation-polymerized silica (Compositions 1A and 1B). These results demonstrate the significance of a combination of fumed metal oxide and abrasive particles possessing the particle size characteristics described herein, as well as the ratio of fumed metal oxide to abrasive particles, on the planarization uniformity achievable by the composition of the present invention.

EXAMPLE 2

This example illustrates the significance of the ratio of fumed metal oxide to abrasive particles in the composition of the present invention in maximizing the removal rate of a surface.

Nickel-phosphor plated memory or rigid disks were polished separately with five different compositions with total solids concentrations of 4 wt.%, comprising varying relative concentrations of fumed silica (i.e., 0 wt.%, 25 wt.%, 50 wt.%, 75 wt.%, and 100 wt.%) and condensation-polymerized silica (i.e., 100 wt.%, 75 wt.%, 50 wt.%, 25 wt.%, and 0 wt.%) (measured median particle size of about 20 nm, σ_g=2.26). The fumed silica was added to the compositions in the form of Cab-O-Sperse® SC-E fumed silica aqueous dispersion (Cabot Corporation). The condensation-polymerized silica was Bindzil® 50/80 (Akzo-Nobel), wherein about 90% or more of the particles thereof (by number) have a

particle size no greater than 100 nm and about 90% or more of the particles thereof (by number) have a particle size no less than 5 nm. Following use of the polishing compositions, the removal rate of each composition was determined, with the resulting data set forth in Table 2.

Table 2:

Composition	Relative Wt.% Fumed Silica	Relative Wt.% Condensation-polymerized Silica	Removal Rate (micro inch per minute) [Å/min]
2A	0	100	2.10 [534]
2B	25	75	2.28 [579]
2C	50	50	2.28 [579]
2D	75	25	2.10 [534]
2E	100	0	1.41 [358]

As is apparent from the data set forth in Table 2, the removal rates exhibited by the compositions with solids consisting of about 25-50 wt.% fumed silica and 50-75 wt.% condensation-polymerized silica (Compositions 2B and 2C) were greater than the removal rates for compositions with solids consisting of 100 wt.% fumed silica or 100 wt.% condensation-polymerized silica (Compositions 2A and 2E). These results demonstrate the significance of a combination of fumed metal oxide and abrasive particles possessing the particle size characteristics described herein, as well as the ratio of fumed metal oxide to abrasive particles, on the removal rate achievable by the composition of the present invention.

EXAMPLE 3

This example illustrates the significance of the distribution of abrasive particle sizes in, and the packing density of, the composition of the present invention in maximizing the removal rate of a surface during planarization or polishing of that surface.

Ten different compositions were prepared, all having a total solids concentration of 28 wt.%, wherein the solids consisted of a fixed concentration of fumed silica (8 wt.% of the composition, or 28.57 wt.% of the total solids), and a fixed concentration of condensation-polymerized silica (20 wt.% of the composition, or 71.43 wt.% of the total solids), with the condensation-polymerized silica having varying relative concentrations of nominal 20 nm, 40 nm, and 80 nm condensation-polymerized silica particles (i.e., 0 wt.%, 23.57 wt.%, 47.50 wt.%,

and 71.43 wt.% of the total solids). The fumed silica was added to the compositions in the form of Cab-O-Sperse® SS-25, which is an aqueous dispersion of Cab-O-Sil® L-90 fumed silica (Cabot Corporation). The 20 nm, 40 nm, and 80 nm condensation-polymerized silicas were 1050, PR-4291, and 2329 products (Nalco), respectively. The nominal 20 nm condensation-polymerized silica particles had a median particle size of about 25 nm and a σ_g value of 1.20. The nominal 40 nm condensation-polymerized silica particles had a median particle size of about 46 nm and a σ_g value of 1.22. The nominal 80 nm condensation-polymerized silica particles had a median particle size of about 78 nm and a σ_g value of 1.16. The condensation-polymerized silicas are commercially available materials wherein about 90% or more of the particles thereof (by number) have a particle size no greater than 100 nm and about 90% or more of the particles thereof (by number) have a particle size no less than 5 nm.

The packing density of each of the ten compositions was determined as described above. In particular, the component volumes used in the calculation of the packing densities of the compositions were determined after the components of the composition were centrifuged for about 5 hours at 5000 rpm using a Fisher Scientific Marathon centrifuge and a National Labnet Model No. 220.72 Vo4 swing-out rotor.

Silicon wafers were polished separately with the ten different compositions, and the removal rate of each composition was determined, with the resulting data set forth in Table 3.

Table 3:

Composition	Wt.% Fumed Silica	Wt.% Nomina l 20 nm Silica	Wt.% Nomina l 40 nm Silica	Wt.% Nomina l 80 nm Silica	Packing Density	Removal Rate [Å/min]
3A	28.57	0	0	71.43	0.062	3264.4
3B	28.57	0	23.57	47.50	0.210	4001.7
3C	28.57	0	47.50	23.57	0.210	4228.3
3D	28.57	0	71.43	0	0.166	3966.6
3E	28.57	23.57	0	47.50	0.176	3892.7
3F	28.57	23.57	23.57	23.57	0.300	4382.8
3G	28.57	23.57	47.50	0	0.263	4214
3H	28.57	47.50	0	23.57	0.500	4563.4
3I	28.57	47.50	23.57	0	0.400	4428.7
3J	28.57	71.43	0	0	0.437	4459.4

As is apparent from the data set forth in Table 3, the removal rates exhibited by the compositions with higher packing densities are significantly greater than the removal rates exhibited by the compositions with lower packing densities. A plot of the packing density versus the removal rate is depicted in Figure 1 and further illustrates the relationship between these two characteristics. These results demonstrate that the distribution of abrasive particle sizes in the composition of the present invention affects the removal rate achievable by the composition.

EXAMPLE 4

This example illustrates the significance of the distribution of abrasive particle sizes in the composition of the present invention in maximizing the removal rate of a surface during polishing or planarization of that surface.

Silicon wafers were polished separately with different compositions, all having a total solids concentration of 28 wt.%, wherein the solids consisted of a varying concentration of fumed silica (0 wt.%, 6 wt.%, and 12 wt.% of the composition, or 0 wt.%, 21.43 wt.%, and 42.86 wt.% of the total solids, respectively) and a varying concentration of condensation-polymerized silica (16 wt.%, 22 wt.%, and 28 wt.% of the composition, or 57.14 wt.%, 78.57 wt.%, and 100 wt.% of the total solids, respectively), with the condensation-polymerized silica having varying relative concentrations of nominal 20 nm, 40 nm, and 80 nm

condensation-polymerized silica particles (i.e., 0 wt.%, 18.93 wt.%, 28.57 wt.%, 33.33 wt.%, 39.29 wt.%, 50.00 wt.%, 57.14 wt.%, 78.57 wt.%, and 100 wt.% of the total solids). The fumed silica was added to the compositions in the form of Cab-O-Sperse® SS-25, which is an aqueous dispersion of Cab-O-Sil® L-90 fumed silica (Cabot Corporation). The 20 nm, 40 nm, and 80 nm condensation-polymerized silicas were 1050, PR-4291, and 2329 products (Nalco), respectively. The nominal 20 nm condensation-polymerized silica particles had a median particle size of about 25 nm and a σ_g value of 1.20. The nominal 40 nm condensation-polymerized silica particles had a median particle size of about 46 nm and a σ_g value of 1.22. The nominal 80 nm condensation-polymerized silica particles had a median particle size of about 78 nm and a σ_g value of 1.16. The condensation-polymerized silicas are commercially available materials wherein about 90% or more of the particles thereof (by number) has a particle size no greater than 100 nm and about 90% or more of the particles thereof (by number) have a particle size no less than 5 nm. Following use of the polishing compositions, the removal rate of each composition was determined, with the resulting data set forth in Table 4.

Table 4:

Composition	Wt.% Fumed Silica	Wt.% Nominal 20 nm Silica	Wt.% Nominal 40 nm Silica	Wt.% Nominal 80 nm Silica	Removal Rate [Å/min]
4A	0	0	50.00	50.00	3824
4B	0	0	100.00	0	3837
4C	0	50.00	0	50.00	3897
4D	0	33.33	33.33	33.33	4105
4E	21.43	0	0	78.57	3594
4F	21.43	0	78.57	0	3976
4G	21.43	78.57	0	0	4254
4H	21.43	0	39.29	39.29	4062
4I	21.43	39.29	39.29	0	4172
4J	21.43	39.29	0	39.29	4240
4K	42.86	57.14	0	0	4372
4L	42.86	0	28.57	28.57	4107
4M	42.86	28.57	28.57	0	4615
4N	42.86	18.93	18.93	18.93	4415

As is apparent from the data set forth in Table 4, the removal rates exhibited by the compositions with solids consisting of a mixture of fumed silica and condensation-polymerized silica (Compositions 4E-4N) were comparable to, and in some instances significantly greater than, the removal rates exhibited by the compositions with solids consisting of only condensation-polymerized silica (Compositions 4A-4D). Also apparent from the data set forth in Table 4 is that the removal rates exhibited by the compositions with solids consisting of a mixture of fumed silica and condensation-polymerized silica varied significantly with the particle sizes of the condensation-polymerized silica. These results demonstrate that the distribution of abrasive particle sizes in the composition of the present invention affects the removal rate achievable by the composition.

All of the references cited herein, including patents, patent applications, and publications, are hereby incorporated in their entireties by reference.

While this invention has been described with an emphasis upon preferred embodiments, it will be obvious to those of ordinary skill in the art that variations of the preferred embodiments may be used and that it is intended that the invention may be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications encompassed within the spirit and scope of the invention as defined by the following claims.

WHAT IS CLAIMED IS:

1. A composition for planarizing or polishing a surface comprising (a) a liquid carrier and (b) solids comprising about 5-90 wt.% of fumed metal oxide and about 10-95 wt.% of abrasive particles, wherein about 90% or more of the abrasive particles (by number) have a particle size no greater than 100 nm.

2. The composition of claim 1, wherein the solids have a packing density of at least about 0.1.

3. The composition of claim 2, wherein the solids have a packing density of at least about 0.3.

4. The composition of any of claims 1-3, wherein the solids have a packing density of about 0.7 or less.

5. The composition of any of claims 1-4, wherein the solids comprise about 10-85 wt.% of fumed metal oxide and about 15-90 wt.% of abrasive particles.

6. The composition of claim 5, wherein the solids comprise about 15-75 wt.% of fumed metal oxide and about 25-85 wt.% of abrasive particles.

7. The composition of any of claims 1-6, wherein the fumed metal oxide is fumed silica.

8. The composition of any of claims 1-7, wherein the abrasive particles are condensation-polymerized metal oxide particles.

9. The composition of any of claims 1-8, wherein about 95% or more of the abrasive particles (by number) have a particle size no greater than 100 nm.

10. The composition of claim 9, wherein about 98% or more of the abrasive particles (by number) have a particle size no greater than 100 nm.

11. The composition of claim 10, wherein substantially all of the abrasive particles (by number) have a particle size no greater than 100 nm.

* C L M S *

12. The composition of any of claims 1-11, wherein about 90% or more of the abrasive particles (by number) have a particle size no less than 5 nm.

13. The composition of claim 12, wherein about 95% or more of the abrasive particles (by number) have a particle size no less than 5 nm.

14. The composition of claim 13, wherein about 98% or more of the abrasive particles (by number) have a particle size no less than 5 nm.

15. The composition of claim 14, wherein substantially all of the abrasive particles (by number) have a particle size no less than 5 nm.

16. The composition of any of claims 1-15, wherein the abrasive particles have a particle size distribution of abrasive particles characterized by a geometric standard deviation by number (σ_g) of at least about 1.3.

17. The composition of any of claims 1-16, wherein the solids are present in a concentration of about 0.1-40 wt.% of the composition.

18. The composition of any of claims 1-17, wherein the carrier is water.

19. A method of planarizing or polishing a surface comprising contacting a surface with the composition of any of claims 1-18.

