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(54) **Title**: COBALT INHIBITOR COMBINATION FOR IMPROVED DISHING

(57) **Abstract**: The invention provides a chemical-mechanical polishing composition that contains (a) abrasive particles, (b) an azole compound having an octanol-water logP of about 1 to about 2, (c) a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group, (d) a cobalt accelerator, (e) an oxidizing agent that oxidizes cobalt, and (f) water, wherein the polishing composition has a pH of about 3 to about 8.5. The invention further provides a method of chemically-mechanically polishing a substrate with the inventive chemical-mechanical polishing composition. Typically, the substrate contains cobalt.

COBALT INHIBITOR COMBINATION FOR IMPROVED DISHING

BACKGROUND OF THE INVENTION

[0001] In the fabrication of integrated circuits and other electronic devices, multiple layers of conducting, semiconducting, and dielectric materials are deposited onto or removed from a substrate surface. As layers of materials are sequentially deposited onto and removed from the substrate, the uppermost surface of the substrate may become non-planar and require planarization. Planarizing a surface, or "polishing" a surface, is a process whereby material is removed from the surface of the substrate to form a generally even, planar surface. Planarization is useful in removing undesired surface topography and surface defects, such as rough surfaces, agglomerated materials, crystal lattice damage, scratches, and contaminated layers or materials. Planarization is also useful in forming features on a substrate by removing excess deposited material used to fill the features and to provide an even surface for subsequent levels of metallization and processing.

[0002] Compositions and methods for planarizing or polishing the surface of a substrate are well known in the art. Chemical-mechanical planarization, or chemical-mechanical polishing (CMP), is a common technique used to planarize substrates. CMP utilizes a chemical composition, known as a CMP composition or more simply as a polishing composition (also referred to as a polishing slurry), for selective removal of material from the substrate. Polishing compositions typically are applied to a substrate by contacting the surface of the substrate with a polishing pad (e.g., polishing cloth or polishing disk) saturated with the polishing composition. The polishing of the substrate typically is further aided by the chemical activity of the polishing composition and/or the mechanical activity of an abrasive suspended in the polishing composition or incorporated into the polishing pad (e.g., fixed abrasive polishing pad).

[0003] Cobalt is emerging as a metal for integration into advanced integrated circuit devices. Effective integration of cobalt will require CMP methods with high removal rates, good planarization efficiency, low dishing and erosion, and low defectivity. At pH 9.5 and above, cobalt forms an insoluble, passivating oxide-hydroxide coating. Below that pH, cobalt readily reacts with water to form soluble, hydrated Co(II) species. U.S. Patent Application Publication 2014/0243250 A1 discloses polishing compositions exhibiting moderate cobalt removal rates at pH 9.0 and above, but requires high particle loading and high downforce pressure, which are disadvantageous from economic and processing viewpoints.

[0004] Aggressive formulations are normally required to achieve acceptable cobalt rates. Integrated circuit devices typically comprise patterned wafers having circuit lines etched into substrates which typically comprise dielectric materials such as silicon oxide. Layering cobalt over the surface of the patterned substrates allows for formation of cobalt circuit lines. The cobalt is then removed by polishing to the level of the underlying dielectric. Erosion refers to the loss of dielectric materials within the patterned region, and may be mitigated by control of abrasive content. Dishing refers to the loss of cobalt within circuit traces. Dishing control is more challenging and requires polishing compositions with the ability to stop or reduce cobalt removal within the traces once the overlying blanket of cobalt is removed to expose underlying dielectric materials. Recess control refers to dishing control of smaller feature sizes and is encompassed by the term dishing control.

[0005] Thus, a need remains in the art for polishing compositions that provide high cobalt removal rates while exhibiting acceptable dishing, erosion, corrosion, and low defectivity.

BRIEF SUMMARY OF THE INVENTION

[0006] The invention provides a chemical-mechanical polishing composition comprising (a) abrasive particles, (b) an azole compound having an octanol-water logP of about 1 to about 2, (c) a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group, (d) a cobalt accelerator, (e) an oxidizing agent that oxidizes cobalt, and (f) water, wherein the polishing composition has a pH of about 3 to about 8.5.

[0007] The invention also provides a method of chemically mechanically polishing a substrate comprising (i) contacting a substrate with a polishing pad and a chemical-mechanical polishing composition comprising (a) abrasive particles, (b) an azole compound having an octanol-water logP of about 1 to about 2, (c) a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group, (d) a cobalt accelerator, (e) an oxidizing agent that oxidizes cobalt, and (f) water, wherein the polishing composition has a pH of about 3 to about 8.5, (ii) moving the polishing pad and the chemical mechanical polishing composition relative to the substrate, and (iii) abrading at least a portion of the substrate to polish the substrate.

DETAILED DESCRIPTION OF THE INVENTION

[0008] The invention provides a chemical-mechanical polishing composition comprising, consisting essentially of, or consisting of (a) abrasive particles, (b) an azole compound having an octanol-water logP of about 1 to about 2, (c) a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group, (d) a cobalt accelerator, (e) an oxidizing agent that oxidizes cobalt, and (f) water, wherein the polishing composition has a pH of about 3 to about 8.5.

[0009] The polishing composition comprises an abrasive (i.e., one or more abrasives). The abrasive can be any suitable abrasive or combination of abrasives in the form of particles. The abrasive can be any suitable abrasive, for example, the abrasive can be natural or synthetic, and can comprise metal oxide, carbide, nitride, carborundum, diamond, and the like. The abrasive also can be a polymer particle or a coated particle. The abrasive desirably comprises, consists essentially of, or consists of a metal oxide. Typically, the metal oxide is selected from the group consisting of silica, alumina, (e.g., alpha alumina particles (i.e., α-alumina), gamma alumina particles (i.e., γ-alumina), delta alumina particles (i.e., δ-alumina), or fumed alumina particles), ceria, zirconia, co-formed products thereof, and combinations thereof. The abrasive particles are desirably anionic in preferred embodiments.

[0010] Preferably, the chemical-mechanical polishing composition comprises a silica abrasive. The silica can be any suitable silica, for example, the silica can be a wet-process silica or a fumed silica. Preferably, the silica is a wet-process silica.

[0011] The wet-process silica can be any suitable wet-process silica. For example, the wet-process silica can be condensation-polymerized silica. Condensation-polymerized silica particles typically are prepared by condensing $Si(OH)_4$ to form colloidal particles, where colloidal is defined as having an average particle size between about 1 nm and about 1000 nm. Such abrasive particles can be prepared in accordance with U.S. Patent 5,230,833 or can be obtained as any of various commercially available products, such as the Akzo-Nobel Bindzil 50/80 product and the Nalco 1050, 1060, 2327, and 2329 products, as well as other similar products available from DuPont, Bayer, Applied Research, Nissan Chemical, Fuso, and Clariant.

[0012] The abrasive particles can have any suitable surface charge. Preferably, the abrasive particles are anionic abrasive particles. By "anionic" is meant that the abrasive particles have a negative surface charge at the pH of the polishing composition. The abrasive particles can be anionic in their natural state at the pH of the polishing composition, or the

abrasive particles can be rendered anionic at the pH of the polishing composition using any method known to those of ordinary skill in the art, such as, for example, by surface metal doping, e.g., by doping with aluminum ions, or by surface treatment with a tethered organic acid, a tethered sulfur-based acid, or a tethered phosphorus-based acid.

[0013] The abrasive can have any suitable average particle size (i.e., average particle diameter). The abrasive can have an average particle size of about 5 nm or more, e.g., about 10 nm or more, about 15 nm or more, about 20 nm or more, about 25 nm or more, about 30 nm or more, about 35 nm or more, or about 40 nm or more. Alternatively, or in addition, the abrasive can have an average particle size of about 150 nm or less, e.g., about 140 nm or less, about 130 nm or less, about 120 nm or less, about 110 nm or less, or about 100 nm or less. Thus, the abrasive can have a maximum in a particle size distribution bounded by any two of the above endpoints. For example, the abrasive can have an average particle size of about 5 nm to about 150 nm, about 10 nm to about 140 nm, about 15 nm to about 130 nm, about 20 nm to about 120 nm, about 20 nm to about 110 nm, about 20 nm to about 100 nm, about 30 nm to about 150 nm, about 30 nm to about 140 nm, about 30 nm to about 130 nm, about 30 nm to about 120 nm, about 30 nm to about 110 nm, about 30 nm to about 100 nm, about 35 nm to about 150 nm, about 35 nm to about 140 nm, about 35 nm to about 130 nm, about 35 nm to about 120 nm, about 35 nm to about 110 nm, or about 35 nm to about 100 nm. For spherical abrasive particles, the size of the particle is the diameter of the particle. For non-spherical abrasive particles, the size of the particle is the diameter of the smallest sphere that encompasses the particle. The particle size of the abrasive can be measured using any suitable technique, for example, using laser diffraction techniques. Suitable particle size measurement instruments are available from, for example, Malvern Instruments (Malvern, UK).

[0014] The abrasive particles preferably are colloidally stable in the inventive polishing composition. The term colloid refers to the suspension of particles in the liquid carrier (e.g., water). Colloidal stability refers to the maintenance of that suspension through time. In the context of this invention, an abrasive is considered colloidally stable if, when the abrasive is placed into a 100 mL graduated cylinder and allowed to stand unagitated for a time of 2 hours, the difference between the concentration of particles in the bottom 50 mL of the graduated cylinder ([B] in terms of g/mL) and the concentration of particles in the top 50 mL of the graduated cylinder ([T] in terms of g/mL) divided by the initial concentration of particles in the abrasive composition ([C] in terms of g/mL) is less than or equal to 0.5 (i.e.,

{[B] – [T]}/[C] ≤ 0.5). More preferably, the value of [B]-[T]/[C] is less than or equal to 0.3, and most preferably is less than or equal to 0.1.

[0015] The polishing composition can comprise any suitable amount of abrasive particles. If the polishing composition of the invention comprises too little abrasive, the composition may not exhibit a sufficient removal rate. In contrast, if the polishing composition comprises too much abrasive, then the polishing composition may exhibit undesirable polishing performance and/or may not be cost effective and/or may lack stability. The polishing composition can comprise about 10 wt.% or less of abrasive, for example, about 9 wt.% or less, about 8 wt.% or less, about 7 wt.% or less, about 6 wt.% or less, about 5 wt.% or less, about 4 wt.% or less, about 3 wt.% or less, about 2 wt.% or less, about 1.5 wt.% or less, about 1 wt. % or less, about 0.9 wt.% or less, about 0.8 wt.% or less, about 0.7 wt.% or less, about 0.6 wt.% or less, or about 0.5 wt.% or less of abrasive. Alternatively, or in addition, the polishing composition can comprise about 0.05 wt.% or more of abrasive, for example, about 0.1 wt.% or more, about 0.2 wt.% or more, about 0.3 wt.% or more, about 0.4 wt.% or more, about 0.5 wt.% or more, or about 1 wt.% or more. Thus, the polishing composition can comprise abrasive particles in an amount bounded by any two of the aforementioned endpoints. For example, the polishing composition can comprise about 0.05 wt.% to about 10 wt.% of abrasive, for example, 0.1 wt.% to about 10 wt.%, about 0.1 wt.% to about 9 wt.%, about 0.1 wt.% to about 8 wt.%, about 0.1 wt.% to about 7 wt.%, about 0.1 wt.% to about 6 wt.%, about 0.1 wt.% to about 5 wt.%, about 0.1 wt.% to about 4 wt.%, about 0.1 wt.% to about 3 wt.%, about 0.1 wt.% to about 2 wt.%, about 0.2 wt.% to about 2 wt.%, about 0.3 wt.% to about 2 wt.%, about 0.4 wt.% to about 2 wt.%, about 0.5 wt.% to about 2 wt.%, about 0.1 wt.% to about 1.5 wt.%, about 0.2 wt.% to about 1.5 wt.%, about 0.3 wt.% to about 1.5 wt.%, about 0.4 wt.% to about 1.5 wt.%, about 0.5 wt.% to about 1.5 wt.%, about 0.1 wt.% to about 1 wt.%, about 0.2 wt.% to about 1 wt.%, about 0.3 wt.% to about 1 wt.%, about 0.4 wt.% to about 1 wt.%, or about 0.5 wt.% to about 1 wt.% of abrasive.

[0016] The polishing composition comprises an azole compound having an n-octanol-water partition coefficient expressed as a logP of about 1 to about 2. The partition coefficient is the ratio of concentrations of an un-ionized compound between two liquid phases, for example, n-octanol and water. The logarithm of the ratio of the concentrations of the un-ionized solute in the solvents is commonly referred to as log P or logP. Azole compounds are a class of 5-membered nitrogen heteroaromatic ring compounds having at least one other non-carbon atom which is nitrogen, sulfur, or oxygen. Examples of suitable

azole compounds include azoles with two nitrogen atoms, triazoles with three nitrogen atoms, and tetrazoles with four nitrogen atoms. Preferably, the azole compound is benzotriazole (logP = 1.44) or 5-phenyltetrazole (logP = 1.65). More preferably, the azole compound is benzotriazole.

[0017] The azole compound can be present in the polishing composition in any suitable concentration. Typically, the azole compound can be present in the polishing composition in a concentration of about 0.1 mM or more, for example, about 0.5 mM or more, about 1 mM or more, about 1.5 mM or more, about 2 mM or more, about 2.5 mM or more, about 3 mM or more, about 3.5 mM or more, or about 4 mM or more. Alternatively, or in addition, the azole compound can be present in the polishing composition in a concentration of about 20 mM or less, for example, about 18 mM or less, about 16 mM or less, about 14 mM or less, about 12 mM or less, about 10 mM or less, about 9 mM or less, about 8 mM or less, or about 7 mM or less. Thus, the azole compound can be present in the polishing composition in a concentration bounded by any two of the aforementioned endpoints. For example, the azole compound can be present in the polishing composition in a concentration of about 0.1 mM to about 20 mM, for example, about 0.5 mM to about 18 mM, about 1 mM to about 16 mM, about 1 mM to about 14 mM, about 1 mM to about 12 mM, about 1 mM to about 10 mM, about 2 mM to about 10 mM, about 2 mM to about 9 mM, about 2 mM to about 8 mM, about 2 mM to about 7 mM, about 3 mM to about 7 mM, or about 3 mM to about 6 mM.

[0018] The polishing composition comprises a cobalt corrosion inhibitor. The cobalt corrosion inhibitor can be any suitable cobalt corrosion inhibitor. In an embodiment, the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group, for example, a C_8-C_{14} alkyl or a C_8-C_{14} alkenyl tail group. The anionic head group can be any suitable anionic head group. In a preferred embodiment, the cobalt corrosion inhibitor comprises a sarcosine derivative having the structure: R-CON(CH_3)CH_2COOH wherein CON(CH_3)CH_2COOH forms the head group and R forms the tail group. The R group is typically a C_8-C_{13} aliphatic group and can be a C_8-C_{13} alkyl group or a C_8-C_{13} alkenyl group, for example, a C_8 alkyl group, a C_9 alkyl group, C_{10} alkyl group, C_{11} alkyl group, C_{12} alkyl group, C_{13} alkyl group, C_8 alkenyl group, C_9 alkenyl group, C_{10} alkenyl group, C_{11} alkenyl group, C_{12} alkenyl group, or C_{13} alkenyl group. In a preferred embodiment wherein the cobalt corrosion inhibitor is a sarcosine derivative, conventional naming of the tail group includes the carbonyl to which the R group is attached for carbon counting purposes. Thus, a C_{12} sarcosinate refers to a lauroyl sarcosinate which has the structure:

$CH_3(CH_2)_{10}$-$CON(CH_3)CH_2COOH$. When the tail group is an alkenyl group, wherein the double bond is not at the terminus of the tail group, the alkenyl group can have the E configuration or the Z configuration, or can be a mixture of E and Z isomers. The cobalt corrosion inhibitor can be a single compound, or can be a mixture of two or more compounds having an anionic head group and a C_8-C_{14} aliphatic tail group or a mixture of two or more sarcosine derivatives as described herein having a C_8-C_{14} aliphatic R group, provided that about 75 wt.% or more (e.g., about 80 wt.% or more, about 85 wt.% or more, about 90 wt.% or more, or about 95 wt.% or more) of the compounds comprise an anionic head group and a C_8-C_{14} aliphatic tail group or are sarcosine derivatives having C_8-C_{14} aliphatic R groups.

[0019] The polishing composition can comprise any suitable amount of the cobalt corrosion inhibitor. The polishing composition can comprise about 1 ppm or more of the cobalt corrosion inhibitor, for example, about 5 ppm or more, about 10 ppm or more, about 20 ppm or more, about 30 ppm or more, about 40 ppm or more, or about 50 ppm or more. Alternatively, or in addition, the polishing composition can comprise about 1000 ppm or less of the cobalt corrosion inhibitor, for example, about 900 ppm or less, about 800 ppm or less, about 700 ppm or less, about 600 ppm or less, about 500 ppm or less, about 400 ppm or less, about 300 ppm or less, or about 200 ppm or less. Thus, the polishing composition can comprise the cobalt corrosion inhibitor in an amount bounded by any two of the aforementioned endpoints. For example, the polishing composition can comprise about 1 ppm to about 1000 ppm of the cobalt corrosion inhibitor, about 10 ppm to about 900 ppm, about 10 ppm to about 800 ppm, about 10 ppm to about 700 ppm, about 10 ppm to about 600 ppm, about 10 ppm to about 500 ppm, about 10 ppm to about 400 ppm, about 20 ppm to about 300 ppm, about 30 ppm to about 200 ppm, about 30 ppm to about 150 ppm, about 30 ppm to about 100 ppm, or about 50 ppm to about 100 ppm.

[0020] The polishing composition further comprises a cobalt accelerator. The cobalt accelerator can be any suitable compound that enhances the removal rate for cobalt when the polishing composition is used to polish a substrate comprising cobalt. The cobalt accelerator can be selected from a compound having the formula: $NR^1R^2R^3$ wherein R^1, R^2, and R^3 are independently selected from hydrogen, carboxyalkyl, substituted carboxyalkyl, hydroxyalkyl, substituted hydroxyalkyl and aminocarbonylalkyl, wherein none or only one of R^1, R^2, and R^3 is hydrogen; dicarboxyheterocycles; heterocyclylalkyl-α-amino acids; N-(amidoalkyl)amino acids; unsubstituted heterocycles; alkyl-substituted heterocycles; substituted-alkyl-substituted heterocycles; N-aminoalkyl-α-amino acids; and combinations thereof.

[0021] The cobalt accelerator can be any suitable cobalt accelerator selected from the classes of compounds recited herein. In preferred embodiments, the cobalt accelerator is iminodiacetic acid, 2-[bis(2-hydroxyethyl)amino]-2-(hydroxymethyl)-1,3-propanediol, bicine, picolinic acid, dipicolinic acid, histidine, [(2-amino-2-oxoethyl)amino]acetic acid, imidazole, N-methylimidazole, lysine, or combinations thereof.

[0022] The cobalt accelerator can be present in the polishing composition in any suitable concentration. Typically, the cobalt accelerator can be present in the polishing composition in a concentration of about 5 mM or more, for example, about 10 mM or more, about 15 mM or more, about 20 mM or more, about 25 mM or more, about 30 mM or more, about 35 mM or more, about 40 mM or more, about 45 mM or more, or about 50 mM or more. Alternatively, or in addition, the cobalt accelerator can be present in the polishing composition in a concentration of about 100 mM or less, for example, about 95 mM or less, about 90 mM or less, about 85 mM or less, about 80 mM or less, about 75 mM or less, about 70 mM or less, about 65 mM or less, or about 60 mM or less. Thus, the cobalt accelerator can be present in the polishing composition in a concentration bounded by any two of the aforementioned endpoints. For example, the cobalt accelerator can be present in the polishing composition in a concentration of about 5 mM to about 100 mM, for example, about 5 mM to about 90 mM, about 5 mM to about 80 mM, about 5 mM to about 70 mM, about 5 mM to about 60 mM, about 10 mM to about 100 mM, about 10 mM to about 90 mM, about 10 mM to about 80 mM, about 10 mM to about 70 mM, about 10 mM to about 60 mM, about 20 mM to about 100 mM, about 20 mM to about 90 mM, about 20 mM to about 80 mM, about 20 mM to about 70 mM, or about 20 mM to about 60 mM.

[0023] The polishing composition comprises an oxidizing agent that oxidizes a transition metal. Preferably, the oxidizing agent oxidizes cobalt. The oxidizing agent can be any suitable oxidizing agent having an oxidation potential of sufficient magnitude at the pH of the polishing composition to oxidize cobalt. In a preferred embodiment, the oxidizing agent is hydrogen peroxide.

[0024] The polishing composition can comprise any suitable amount of the oxidizing agent. The polishing composition preferably comprises about 10 wt.% or less (e.g., about 8 wt.% or less, about 6 wt.% or less, about 4 wt.% or less, about 2 wt.% or less, about 1 wt.% or less, or about 0.5 wt.% or less) of hydrogen peroxide.

[0025] The polishing composition can have any suitable pH. Typically, the polishing composition can have a pH of about 3 or more, e.g., about 3.5 or more, about 4 or more,

about 4.5 or more, about 5 or more, about 5.5 or more, about 6 or more, about 6.5 or more, or about 7 or more. Alternatively, or in addition, the polishing composition can have a pH of about 8.5 or less, e.g., about 8.4 or less, about 8.3 or less, about 8.2 or less, about 8.1 or less, or about 8 or less. Thus, the polishing composition can have a pH bounded by any two of the above endpoints recited for the polishing composition. For example the polishing composition can have a pH of about 3 to about 8.5, e.g., about 3.5 to about 8.5, about 4 to about 8.5, about 4.5 to about 8.5, about 5 to about 8.5, about 5.5 to about 8.5, about 6 to about 8.5, about 6.5 to about 8.5, about 6.5 to about 8.4, about 6.5 to about 8.3, about 6.5 to about 8.2, about 6.5 to about 8.1, about 6.5 to about 8, or about 7 to about 8.5.

[0026] The pH of the polishing composition can be adjusted using any suitable acid or base. Non-limiting examples of suitable acids include nitric acid, sulfuric acid, phosphoric acid, and organic acids such as acetic acid. Non-limiting examples of suitable bases include sodium hydroxide, potassium hydroxide, and ammonium hydroxide.

[0027] The chemical-mechanical polishing composition optionally further comprises one or more additives. Illustrative additives include conditioners, acids (e.g., sulfonic acids), complexing agents (e.g., anionic polymeric complexing agents), chelating agents, biocides, scale inhibitors, dispersants, etc.

[0028] A biocide, when present, can be any suitable biocide and can be present in the polishing composition in any suitable amount. A suitable biocide is an isothiazolinone biocide. The amount of biocide in the polishing composition typically is about 1 to about 50 ppm, preferably about 10 to about 40 ppm, more preferably about 20 to about 30 ppm.

[0029] The polishing composition can be prepared by any suitable technique, many of which are known to those skilled in the art. The polishing composition can be prepared in a batch or continuous process. Generally, the polishing composition can be prepared by combining the components thereof in any order. The term "component" as used herein includes individual ingredients (e.g., abrasive, azole compound, cobalt corrosion inhibitor, cobalt accelerator, oxidizing agent, optional pH adjustor, etc.) as well as any combination of ingredients (e.g., abrasive, azole compound, cobalt corrosion inhibitor, cobalt accelerator, oxidizing agent, optional pH adjustor, etc.).

[0030] For example, the abrasive can be dispersed in water. The azole compound, cobalt corrosion inhibitor, cobalt accelerator, and oxidizing agent can then be added and mixed by any method that is capable of incorporating the components into the polishing composition. The oxidizing agent can be added at any time during the preparation of the polishing

composition. The polishing composition can be prepared prior to use, with one or more components, such as the oxidizing agent, added to the polishing composition just before use (e.g., within about 1 minute before use, or within about 1 hour before use, within about 7 days before use, or within about 14 days before use). The polishing composition also can be prepared by mixing the components at the surface of the substrate during the polishing operation.

[0031] The polishing composition can be supplied as a one-package system comprising abrasive, azole compound, cobalt corrosion inhibitor, cobalt accelerator, oxidizing agent, optional pH adjustor, and water. Alternatively, the abrasive can be supplied as a dispersion in water in a first container, and the azole compound, cobalt corrosion inhibitor, cobalt accelerator, and optional pH adjustor can be supplied in a second container, either in dry form, or as a solution or dispersion in water. The oxidizing agent desirably is supplied separately from the other components of the polishing composition and is combined, e.g., by the end-user, with the other components of the polishing composition shortly before use (e.g., 2 weeks or less prior to use, 1 week or less prior to use, 1 day or less prior to use, 1 hour or less prior to use, 10 minutes or less prior to use, or 1 minute or less prior to use). The components in the first or second container can be in dry form while the components in the other container can be in the form of an aqueous dispersion. Moreover, it is suitable for the components in the first and second containers to have different pH values, or alternatively to have substantially similar, or even equal, pH values. Other two-container, or three or more-container, combinations of the components of the polishing composition are within the knowledge of one of ordinary skill in the art.

[0032] The polishing composition of the invention also can be provided as a concentrate which is intended to be diluted with an appropriate amount of water prior to use. In such an embodiment, the polishing composition concentrate can comprise the abrasive, azole compound, cobalt corrosion inhibitor, cobalt accelerator, oxidizing agent, and optional pH adjustor, with or without the oxidizing agent, in amounts such that, upon dilution of the concentrate with an appropriate amount of water, and the oxidizing agent if not already present in an appropriate amount, each component of the polishing composition will be present in the polishing composition in an amount within the appropriate range recited above for each component. For example, the abrasive, azole compound, cobalt corrosion inhibitor, cobalt accelerator, oxidizing agent, and optional pH adjustor can each be present in the concentration in an amount that is about 2 times (e.g., about 3 times, about 4 times, or about 5

times) greater than the concentration recited above for each component so that, when the concentrate is diluted with an equal volume of (e.g., 2 equal volumes of water, 3 equal volumes of water, or 4 equal volumes of water, respectively), along with the oxidizing agent in a suitable amount, each component will be present in the polishing composition in an amount within the ranges set forth above for each component. Furthermore, as will be understood by those of ordinary skill in the art, the concentrate can contain an appropriate fraction of the water present in the final polishing composition in order to ensure that other components are at least partially or fully dissolved in the concentrate.

[0033] The invention also provides a method of chemically-mechanically polishing a substrate comprising (i) contacting a substrate with a polishing pad and the chemical-mechanical polishing composition as described herein, (ii) moving the polishing pad relative to the substrate with the chemical-mechanical polishing composition therebetween, and (iii) abrading at least a portion of the substrate to polish the substrate.

[0034] The substrate to be polished using the method of the invention can be any suitable substrate, especially a substrate that contains cobalt. A preferred substrate comprises at least one layer, especially an exposed layer for polishing, comprising, consisting essentially of, or consisting of cobalt, such that at least a portion of the cobalt is abraded (i.e., removed) to polish the substrate. Particularly suitable substrates include, but are not limited to, wafers used in the semiconductor industry. The wafers typically comprise or consist of, for example, a metal, metal oxide, metal nitride, metal composite, metal alloy, a low dielectric material, or combinations thereof. In preferred embodiments, the wafers comprise patterns of circuit traces etched into the surface of a substrate that are filled with cobalt. The method of the invention is also useful for polishing substrates comprising cobalt and cobalt alloys useful in turbine blades for gas turbines and jet aircraft engines, orthopedic implants, prosthetic parts such as hip and knee replacements, dental prosthetics, high speed steel drill bits, and permanent magnets.

[0035] The polishing method of the invention is particularly suited for use in conjunction with a chemical-mechanical polishing (CMP) apparatus. Typically, the apparatus comprises a platen, which, when in use, is in motion and has a velocity that results from orbital, linear, or circular motion, a polishing pad in contact with the platen and moving with the platen when in motion, and a carrier that holds a substrate to be polished by contacting and moving relative to the surface of the polishing pad. The polishing of the substrate takes place by the substrate being placed in contact with the polishing pad and the polishing composition of the

invention and then the polishing pad moving relative to the substrate, so as to abrade at least a portion of the substrate to polish the substrate.

[0036] A substrate can be planarized or polished with the chemical-mechanical polishing composition with any suitable polishing pad (e.g., polishing surface). Suitable polishing pads include, for example, woven and non-woven polishing pads. Moreover, suitable polishing pads can comprise any suitable polymer of varying density, hardness, thickness, compressibility, ability to rebound upon compression, and compression modulus. Suitable polymers include, for example, polyvinylchloride, polyvinylfluoride, nylon, fluorocarbon, polycarbonate, polyester, polyacrylate, polyether, polyethylene, polyamide, polyurethane, polystyrene, polypropylene, polyisocyanurate, coformed products thereof, and mixtures thereof.

[0037] Desirably, the CMP apparatus further comprises an *in situ* polishing endpoint detection system, many of which are known in the art. Techniques for inspecting and monitoring the polishing process by analyzing light or other radiation reflected from a surface of the workpiece are known in the art. Such methods are described, for example, in U.S. Patent 5,196,353, U.S. Patent 5,433,651, U.S. Patent 5,609,511, U.S. Patent 5,643,046, U.S. Patent 5,658,183, U.S. Patent 5,730,642, U.S. Patent 5,838,447, U.S. Patent 5,872,633, U.S. Patent 5,893,796, U.S. Patent 5,949,927, and U.S. Patent 5,964,643. Desirably, the inspection or monitoring of the progress of the polishing process with respect to a workpiece being polished enables the determination of the polishing end-point, i.e., the determination of when to terminate the polishing process with respect to a particular workpiece.

[0038] A chemical-mechanical polishing process can be characterized in a number of ways, such as in terms of the removal rate of a substrate, dishing, and erosion.

[0039] The removal rate of a substrate can be determined using any suitable technique. Examples of suitable techniques for determining the removal rate of a substrate include weighing the substrate before and after use of the inventive polishing method to determine the amount of substrate removed per unit of polishing time, which can be correlated with the removal rate in terms of thickness of substrate removed per unit of polishing time, and determining the thickness of the substrate before and after use of the inventive polishing method to directly measure the removal rate of the substrate per unit of polishing time.

[0040] Dishing and erosion can be determined using any suitable techniques. Examples of suitable techniques for determining dishing and erosion include scanning electron

microscopy, stylus profiling, and atomic force microscopy. Atomic force microscopy can be performed using the Dimension Atomic Force Profiler (AFP™) from Veeco (Plainview, NY).

[0041] Without wishing to be bound by any particular theory, it is believed that BTA alone forms a layer having significant mass and a high degree of softness on a cobalt surface, while a cobalt corrosion inhibitor wherein the cobalt corrosion inhibitor comprising an anionic head group and a C_8-C_{14} aliphatic tail group (e.g., N-lauroyl sarcosinate or N-cocoyl sarcosinate) form a low mass, non-viscoelastic film on a cobalt surface. The presence of a cobalt corrosion inhibitor facilitates the formation of a BTA layer which is distinct from the layer formed by BTA alone. This cobalt corrosion inhibitor-BTA combination is believed to form a unique layer with increased hardness and decreased Co-BTA polymer growth that improves cobalt corrosion significantly. This unexpected synergy is manifested in the improved cobalt dishing performance of fine features on pattern wafers and is supported by electrochemical corrosion data.

[0042] The following examples further illustrate the invention but, of course, should not be construed as in any way limiting its scope.

EXAMPLE 1

[0043] This example demonstrates the effect of dishing observed on cobalt-coated patterned wafers exhibited by polishing compositions containing a cobalt corrosion inhibitor and a cobalt dishing control agent in accordance with an embodiment of the invention.

[0044] Patterned substrates comprising a layer of cobalt over a patterned silicon oxide substrate were polished with five different polishing compositions, Polishing Compositions 1A-1E. All of the polishing compositions contained 1 wt.% of wet-process silica having an average particle size of 70 nm (Fuso Chemical Co. Japan), 0.6 wt.% of iminodiacetic acid, 0.6 wt.% hydrogen peroxide, and 31 ppm Kordek MLX biocide in water at a pH of 7.0. Polishing Composition 1A (comparative) further contained 4 mM benzotriazole ("BTA"). Polishing Composition 1B (comparative) further contained 150 ppm N-lauroyl sarcosinate ("NLS"). Polishing Composition 1C (invention) further contained 4 mM BTA and 150 ppm NLS. Polishing Composition 1D (comparative) further contained 100 ppm N-cocoyl sarcosinate ("NCS"). Polishing Composition 1E (invention) further contained 4 mM BTA and 100 ppm NCS.

[0045] Blanket substrates comprising a layer of cobalt over an unpatterned silicon oxide substrate and patterned substrates comprising a layer of cobalt over a patterned silicon oxide

substrate were polished with five different polishing compositions, Polishing Compositions 1A-1E. The patterned substrates comprised pattern features comprising cobalt-filled lines on a silicon oxide substrate. The pattern dimensions were either 0.18 μm wide cobalt lines separated by 0.18 μm widths of silicon oxide ("0.18 μm x 0.18 μm pattern"), 0.25 μm wide cobalt lines separated by 0.25 μm widths of silicon oxide ("0.25 μm x 0.25 μm pattern"), or 50 μm wide cobalt lines separated by 50 μm widths of silicon oxide ("50 μm x 50 μm pattern"). Blanket substrates and 50 μm x 50 μm pattern substrates were used to determine cobalt removal rates, and polishing was stopped before reaching endpoint. The 0.18 μm x 0.18 μm and 0.25 μm x 0.25 μm pattern substrates were used to determine dishing. Polishing Compositions 1A-1D were used to polish substrates having a 0.25 μm x 0.25 μm pattern. Polishing Compositions 1D and 1E were used to polish substrates having a 0.18 μm x 0.18 μm pattern. For dishing determination, the substrates were overpolished to endpoint plus a time period past endpoint.

[0046] Following polishing, dishing was determined for each substrate at a mid-center position of the substrate. The dishing in pattern cobalt lines, time to endpoint, and pattern overpolish time past endpoint in seconds and as percentage of over polish are set forth in Table 1.

Table 1.

Polishing Composition	Additive(s)	Blanket Removal Rate (Å/min)	Pattern Removal Rate (Å/min)	Pattern Endpoint Time (s)	Pattern Overpolish Time (sec, %)	0.18 µm x 0.18 µm Pattern Dishing (Å)	0.25 µm x 0.25 µm Pattern Dishing (Å)
1A (comparative)	BTA	2026	2032	62	5 (8%)	-	225.78
1B (comparative)	NLS	3388	2100	60	5 (8%)	-	174.20
1C (invention)	BTA/NLS	1680	2333	54	5 (9%)	-	43.31
1D (comparative)	NCS	3480	1485	51	26 (50%)	88.88	-
1E (invention)	BTA/NCS	1099	763	83	42 (50%)	29.27	-

[0047] As is apparent from the results set forth in Table 1, the presence of BTA alone in Polishing Composition 1A results in a decrease of the cobalt removal rate to 2026 Å/min as compared to the presence of NLS and NCS in Polishing Compositions 1B and 1D, which exhibited cobalt removal rates of approximately 3400 Å/min. Polishing Composition 1C, which contained a combination of BTA and NLS, exhibited 19% of the dishing exhibited by Polishing Composition 1A and 25% of the dishing exhibited by Polishing Composition 1B, which contained NLS alone. Polishing Composition 1E, which contained a combination of BTA and NCS, exhibited 33% of the dishing when used to polish a 0.18 µm x 0.18 µm pattern substrate exhibited by Polishing Composition 1D, which contained NCS alone.

EXAMPLE 2

[0048] This example demonstrates that a combination of BTA (i.e., an azole compound having an octanol-water logP of about 1 to about 2) and NLS (i.e., a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a

C_8-C_{14} aliphatic tail group) minimizes the formation of an extended Co-BTA polymer when contacted with a cobalt substrate surface.

[0049] Solutions were prepared containing 2 mM Bis-Tris buffer, and 5 mM KNO_3 in water at a pH of 7.5. Solution A further contained 10 mM BTA. Solution B further contained 300 ppm NLS. Solution C further contained 300 ppm NLS and 10 mM BTA. Three separate cobalt wafers were exposed to Solution A, Solution B, and Solution C. A control cobalt wafer was exposed to a solution containing 2 mM Bis-Tris buffer, and 5 mM KNO_3 in water at a pH of 7.5.

[0050] Following exposure to the solutions, the cobalt wafers were analyzed by TOF-SIMS (Time-of-Flight Secondary Ion Mass Spectrometry). The intensities of the signals corresponding to the molecular ions BTA^- and $Co(BTA)_3^-$ were determined, and the results set forth in Table 2.

Table 2

Treatment	BTA^-	$Co(BTA)_3^-$	$Co(BTA)_3^-$/ BTA^- ratio
Control	0.09	0.02	-
Solution A	94.74	15.61	0.165
Solution B	0.08	0.01	-
Solution C	88.83	7.78	0.088

[0051] The signal intensity observed for $Co(BTA)_3^-$ is correlated with the formation of a Co-BTA polymer on the substrate surface. As is apparent from the results set forth in Table 2, the signal intensity for $Co(BTA)_3^-$ observed after treatment of a cobalt wafer with Solution C containing NLS and BTA was approximately 50% of the signal intensity for $Co(BTA)_3^-$ observed after treatment of a cobalt wafer with Solution A containing BTA alone. These results suggest that NLS influences the growth of a Co-BTA polymeric layer on the surface of the cobalt wafer by minimizing the formation of the Co-BTA polymeric layer. Those skilled in the art would not expect a cobalt wafer surface with a less extensive Co-BTA polymer to result in lower dishing upon polishing than a cobalt wafer surface with a more extensive Co-BTA polymer layer.

EXAMPLE 3

[0052] This example demonstrates that a combination of BTA (i.e., an azole compound having an octanol-water logP of about 1 to about 2) and NLS (i.e., a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group) minimizes the corrosion current (I_{corr}) when contacted with a cobalt substrate surface.

[0053] I_{corr} was measured for blanket substrates comprising a layer of cobalt over an unpatterned silicon oxide substrate with three different polishing compositions, Polishing Compositions 3A-3C. All of the polishing compositions contained 1 wt.% of wet-process silica having an average particle size of 70 nm (Fuso Chemical Co. Japan), 0.6 wt.% of iminodiacetic acid, 0.6 wt.% hydrogen peroxide, and 31 ppm Kordek MLX biocide in water at a pH of 7.5. Polishing Composition 3A (comparative) further contained 5 mM benzotriazole ("BTA"). Polishing Composition 3B (comparative) further contained 150 ppm N-lauroyl sarcosinate ("NLS"). Polishing Composition 3C (invention) further contained 5 mM BTA and 150 ppm NLS.

[0054] I_{corr} was determined by Tafel analysis, and the results set forth in Table 3 in the form of current densities ($\mu A/cm^2$).

Table 3

Composition	I_{corr} ($\mu A/cm^2$)
A (comparative)	54.8
B (comparative)	17.6
C (invention)	3.8

[0055] As is apparent from the results set forth in Table 3, the I_{corr} from a cobalt wafer in contact with Solution C containing BTA and NLS was approximately 6.9% of the current density observed for a cobalt wafer in contact with Solution A containing BTA alone and was approximately 21.6% of the current density observed for a cobalt wafer in contact with Solution B containing NLS alone. These results suggest that the combination of BTA and NLS minimizes corrosion compared with either BTA or NLS alone.

EXAMPLE 4

[0056] This example demonstrates the cobalt removal rate and dishing exhibited by polishing compositions containing an azole compound having an n-octanol-water partition coefficient expressed as a logP of about 1 to about 2.

[0057] Patterned substrates comprising a layer of cobalt over a patterned silicon oxide substrate were polished with five different polishing compositions, Polishing Compositions 4A-4G. All of the polishing compositions contained 0.5 wt.% of wet-process silica having an average particle size of 70 nm (Fuso Chemical Co. Japan), 0.6 wt.% of iminodiacetic acid, 0.6 wt.% hydrogen peroxide, 100 ppm of N-cocolyl sarcosinate ("NCS"), and 31 ppm Kordek MLX biocide in water at a pH of 7.0. Polishing Composition 4A (control) did not further contain an azole compound. Each of Polishing Compositions 4B-4G further contained 4 mM of an azole compound as shown in Table 3.

[0058] Cobalt removal rates were determined by polishing substrates having 50 μm cobalt lines separated by 50 μm widths of silicon oxide ("50 μm x 50 μm pattern"). Dishing was determined by polishing substrates having 0.18 μm cobalt lines separated by 0.18 μm widths of silicon oxide ("0.18 μm x 0.18 μm pattern"). Polishing was conducted with a downforce of 10.4 kPa using a IC1010™ concentric polishing pad (Dow Chemical Co., Midland, MI).

[0059] Following polishing, removal rates were determined for the 50 μm x 50 μm pattern substrates, and dishing was determined for the 0.18 μm x 0.18 μm pattern substrates. The results are set forth in Table 4.

Table 4

Polishing Composition	Azole Compound	Azole Compound logP	50 μm x 50 μm Pattern Removal Rate (Å/min)	0.18 μm x 0.18 μm Pattern Dishing (Å)
4A (control)	None	-	1485	88.88
4B (invention)	BTA	+1.44	763	29.27
4C (invention)	5-Phenyltetrazole	+1.65	1128	29.21
4D (comparative)	1,2,3-Triazole	-0.29	1455	100.91
4E (comparative)	5-Aminotetrazole	-0.92	1422	108.75
4F (comparative)	1H-Tetrazole-5-acetic acid	-1.54	643	196.11
4G (comparative)	3-Amino-1,2,4-triazole-5-carboxylic acid	-1.51	1242	119.73

[0060] As is apparent from the results set forth in Table 3, the use of Polishing Compositions 4B and 4C, which contained BTA having a logP of +1.44 (4B), or 5-phenyltetrazole having a logP of +1.65 (4C) in combination with NCS, resulted in dishing that was approximately 33% of the dishing observed with control Polishing Composition 4A, which contained NCS. Each of Polishing Compositions 4D-4G, which contained azole compounds having logP values outside the range of 1 to 2, in combination with NCS, exhibited higher dishing than observed with control Polishing Composition 4A, which contained NCS but not an azole compound.

[0061] 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.

[0062] 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.

[0063] 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 chemical-mechanical polishing composition comprising:
   (a) abrasive particles,
   (b) an azole compound having an octanol-water logP of about 1 to about 2,
   (c) a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group,
   (d) a cobalt accelerator,
   (e) an oxidizing agent that oxidizes cobalt, and
   (f) water,

wherein the polishing composition has a pH of about 3 to about 8.5.

2. The polishing composition of claim 1, wherein the polishing composition comprises about 0.1 wt.% to about 4 wt.% of abrasive particles.

3. The polishing composition of claim 1, wherein the azole compound is benzotriazole or 5-phenyltetrazole.

4. The polishing composition of claim 1, wherein the cobalt corrosion inhibitor has the formula: $RCON(CH_3)COOH$ wherein R is a C_8-C_{13} aliphatic group.

5. The polishing composition of claim 1, wherein the cobalt accelerator is selected from a compound having the formula: $NR^1R^2R^3$ wherein R^1, R^2, and R^3 are independently selected from hydrogen, carboxyalkyl, substituted carboxyalkyl, hydroxyalkyl, substituted hydroxyalkyl and aminocarbonylalkyl, and wherein none or only one of R^1, R^2, and R^3 is hydrogen; dicarboxyheterocycles; heterocyclylalkyl-α-amino acids; N-(amidoalkyl)amino acids; unsubstituted heterocycles; alkyl-substituted heterocycles; substituted-alkyl-substituted heterocycles; N-aminoalkyl-α-amino acids; and combinations thereof.

6. The polishing composition of claim 5, wherein the cobalt accelerator is selected from iminodiacetic acid, picolinic acid, dipicolinic acid, bicine, [(2-amino-2-oxoethyl)amino]acetic acid, lysine, imidazole, histidine, 2-[bis(2-hydroxyethyl)amino]-2-(hydroxymethyl)-1,3-propanediol, and combinations thereof.

7. The polishing composition of claim 1, wherein the polishing composition comprises about 10 ppm to about 1000 ppm of the azole compound and about 10 ppm to about 1000 ppm of the cobalt corrosion inhibitor.

8. The polishing composition of claim 1, wherein the oxidizing agent is hydrogen peroxide.

9. The polishing composition of claim 1, wherein the polishing composition has a pH of about 7 to about 8.5.

10. A method of chemically mechanically polishing a substrate comprising:

(i) contacting a substrate with a polishing pad and a chemical-mechanical polishing composition comprising:

(a) abrasive particles,

(b) an azole compound having an octanol-water logP of about 1 to about 2,

(c) a cobalt corrosion inhibitor, wherein the cobalt corrosion inhibitor comprises an anionic head group and a C_8-C_{14} aliphatic tail group,

(d) a cobalt accelerator,

(e) an oxidizing agent that oxidizes cobalt, and

(f) water,

wherein the polishing composition has a pH of about 3 to about 8.5,

(ii) moving the polishing pad and the chemical mechanical polishing composition relative to the substrate, and

(iii) abrading at least a portion of the substrate to polish the substrate.

11. The method of claim 10, wherein the polishing composition comprises about 0.1 wt.% to about 4 wt.% of abrasive particles.

12. The method of claim 10, wherein the azole compound is benzotriazole or 5-phenyltetrazole.

13. The method of claim 10, wherein the cobalt corrosion inhibitor has the formula: $RCON(CH_3)COOH$ wherein R is a C_8-C_{13} aliphatic group.

14. The method of claim 10, wherein the cobalt accelerator is selected from a compound having the formula: $NR^1R^2R^3$ wherein R^1, R^2, and R^3 are independently selected from hydrogen, carboxyalkyl, substituted carboxyalkyl, hydroxyalkyl, substituted hydroxyalkyl and aminocarbonylalkyl, and wherein none or only one of R^1, R^2, and R^3 is hydrogen; dicarboxyheterocycles; heterocyclylalkyl-α-amino acids; N-(amidoalkyl)amino acids; unsubstituted heterocycles; alkyl-substituted heterocycles; substituted-alkyl-substituted heterocycles; N-aminoalkyl-α-amino acids; and combinations thereof.

15. The method of claim 14, wherein the cobalt accelerator is selected from iminodiacetic acid, picolinic acid, dipicolinic acid, bicine, [(2-amino-2-oxoethyl)amino]acetic acid, lysine, imidazole, histidine, 2-[bis(2-hydroxyethyl)amino]-2-(hydroxymethyl)-1,3-propanediol, and combinations thereof.

16. The method of claim 10, wherein the polishing composition comprises about 10 ppm to about 1000 ppm of the azole compound and about 10 ppm to about 1000 ppm of the cobalt corrosion inhibitor.

17. The method of claim 10, wherein the oxidizing agent is hydrogen peroxide.

18. The method of claim 10, wherein the polishing composition has a pH of about 7 to about 8.5.

19. The method of claim 10, wherein the substrate comprises cobalt, and least a portion of the cobalt is abraded to polish the substrate.

20. The method of claim 19, wherein the substrate comprises a semiconductor device.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/057459

A. CLASSIFICATION OF SUBJECT MATTER

C09G 1/02(2006.01)i, C09K 3/14(2006.01)i, C09G 1/14(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C09G 1/02; C08F 2/10; C09K 13/00; C09G 1/18; C09K 13/02; C23F 1/02; C09K 3/14; C09K 3/00; C09G 1/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: chemical mechanical polishing, silica, benzotriazole, sarcosine, cobalt

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010-0193728 A1 (CHANG, SONG-YUAN et al.) 05 August 2010 See paragraphs [0005] and [0027]; claims 2 and 14; and Table 1.	1-20
A	US 2009-0184287 A1 (CHANG, SONG-YUAN) 23 July 2009 See abstract; paragraphs [0019], [0022], [0025], and [0034]; and Table 1.	1-20
A	US 2013-0186850 A1 (WANG, YOU et al.) 25 July 2013 See abstract; paragraph [0002]; and claims 1-10 and 15-17.	1-20
A	WO 2015-108113 A1 (HITACHI CHEMICAL COMPANY, LTD.) 23 July 2015 See paragraphs [0100] and [0102]; and claim 9.	1-20
A	US 2015-0232705 A1 (FUJIMI INCORPORATED) 20 August 2015 See paragraphs [0016], [0021], [0034]-[0037], [0049], [0055], and [0058].	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 January 2017 (16.01.2017)	**16 January 2017 (16.01.2017)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2016/057459

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