METHOD FOR CONTROLLING POLYSILICON REMOVAL

BACKGROUND OF THE INVENTION

[0001] This invention pertains to a method for chemically-mechanically polishing a silicon-containing substrate layer with a high selectivity ratio to polysilicon.

[0002] Compositions and methods for planarizing or polishing the surface of a substrate are well known in the art. Polishing compositions (also known as polishing slurries) typically contain an abrasive material in a liquid carrier and are applied to a surface by contacting the surface with a polishing pad saturated with the polishing 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. Polishing compositions are typically used in conjunction with polishing pads (e.g., a polishing cloth or disk). Suitable polishing pads are described in U.S. Patents 6,062,968, 6,117,000, and 6,126,532, which disclose the use of sintered polyurethane polishing pads having an open-celled porous network, and U.S. Patent 5,489,233, which discloses the use of solid polishing pads having a surface texture or pattern. Instead of or in addition to being suspended in the polishing composition, the abrasive material may be incorporated into the polishing pad. U.S. Patent 5,958,794 discloses a fixed abrasive polishing pad.

[0003] As a method for isolating elements of a semiconductor device, a great deal of attention is being directed towards a shallow trench isolation (STI) process where a silicon nitride layer is formed on a silicon substrate, shallow trenches are formed via etching or photolithography, and a dielectric layer is deposited to fill the trenches. Due to variation in the depth of trenches, or lines, formed in this manner, it is typically necessary to deposit an excess of dielectric material on top of the substrate to ensure complete filling of all trenches. The excess dielectric material (e.g., an oxide) is then typically removed by a chemical-mechanical planarization process to expose the silicon nitride layer. When the silicon nitride layer is exposed, the largest area of the substrate exposed to the chemical-mechanical polishing system comprises silicon nitride, which must then be polished to achieve a highly planar and uniform surface.

[0004] Generally, past practice has been to emphasize selectivity for oxide polishing in preference to silicon nitride polishing. Thus, the silicon nitride layer has served as a stopping

layer during the chemical-mechanical planarization process, as the overall polishing rate has decreased upon exposure of the silicon nitride layer. For example, U.S. Patent 6,544,892 and references cited therein describe polishing compositions which provide selectivity of silicon dioxide to silicon nitride. Also U.S. Patent 6,376,381 describes the use of certain nonionic surfactants to increase the polishing selectivity between silicon oxide and silicon nitride layers.

[0005] Recently selectivity for oxide polishing in preference to polysilicon polishing has also been emphasized. For example, the addition of a series of Brij® and polyethylene oxide surfactants, as well as Pluronic® L64, an ethylene oxide-propylene oxide-ethylene oxide triblock copolymer with an HLB of 15, is purported to increase the polishing selectivity of oxide to polysilicon (see Lee et al., "Effects of Nonionic Surfactants on Oxide-to-Polysilicon Selectivity during Chemical Mechanical Polishing," *J. Electrochem. Soc., 149(8)*: G477-G481 (2002)). Also, U.S. Patent 6,626,968 purports to obtain polishing selectivity of silicon oxide to polysilicon through the use of a polymer additive having hydrophilic and hydrophobic functional groups selected from polyvinylmethylether, polyethylene glycol, polyoxyethylene 23 lauryl ether, polypropanoic acid, polyacrylic acid, and polyether glycol bis ether.

[0006] Despite these polishing compositions and methods, there remains a need in the art for polishing compositions and methods that can provide good selectivity of silicon oxide and/or silicon nitride relative to polysilicon. The invention provides such a composition and method. These and other advantages of the invention, as well as additional inventive features, will be apparent from the description of the invention provided herein.

BRIEF SUMMARY OF THE INVENTION

[0007] The invention provides a method of chemically-mechanically polishing a substrate, which method comprises (i) contacting a substrate comprising polysilicon and a material selected from silicon oxide and silicon nitride with a chemical-mechanical polishing system; (ii) moving the polishing pad relative to the substrate, and (iii) abrading at least a portion of the substrate to polish the substrate. The chemical-mechanical polishing system comprises an abrasive, 1 ppm to 1000 ppm, based on the total weight of the liquid carrier and any components dissolved or suspended therein, of a polyethylene oxide/polypropylene oxide copolymer surfactant having an HLB of 15 or less, a liquid carrier, and a polishing pad.

DETAILED DESCRIPTION OF THE INVENTION

[0008] The invention is directed to a method of polishing a silicon-containing layer of a substrate with good selectivity to polysilicon. The method comprises (i) contacting substrate

comprising a layer selected from selected from silicon oxide and silicon nitride and polysilicon with a chemical-mechanical polishing system, (ii) moving the polishing pad relative to the substrate, and (iii) abrading at least a portion of the substrate to polish the substrate. It has surprisingly been discovered that the use of a small amount of a lipophilic polyethylene oxide/polypropylene oxide copolymer can inhibit the polishing rate of polysilicon while leaving the polishing rate of other layers such as silicon dioxide and silicon nitride relatively unchanged. Accordingly the chemical-mechanical polishing system comprises an abrasive, 1 ppm to 1000 ppm, based on the total weight of the liquid carrier and any components dissolved or suspended therein, of a polyethylene oxide/polypropylene oxide copolymer having an HLB of 15 or less, a liquid carrier, and a polishing pad.

[0009] The polyethylene oxide/polypropylene oxide copolymer can be any suitable copolymer and preferably is end-functionalized with a primary hydroxyl group or a secondary hydroxyl group. In order to have the desired HLB value of 15 or less, the number of ethylene oxide repeating units in the copolymer typically will be less than the number of propylene oxide repeating units. Preferably, the number of ethylene oxide units is less than 40 wt.%, less than 30 wt.%, less than 25 wt.%, or even less than 20 wt.% of the copolymer. The copolymer preferably has an HLB of 12 or less, 10 or less, 8 or less, or 6 or less. More preferably, the copolymer has an HLB of 8 or less or 6 or less. Preferably, the copolymer has an HLB of 2 or more (e.g., 2 to 12, 2 to 10, 2 to 8, or 2 to 6), or 3 or more (e.g., 3 to 12, 3 to 9, 3 to 7, or 3 to 5). The copolymer can have any suitable molecular weight. Desirably the copolymer has a molecular weight of 4000 g/mol or less (e.g., 3500 g/mol or less, or even 3000 g/mol or less). Preferably, the copolymer has a molecular weight of 500 g/mol to 2000 g/mol.

[0010] Typically the copolymer is a Pluronic® copolymer sold by BASF. Suitable Pluronic® copolymers include Pluronic® 17R2, Pluronic® 25R2, Pluronic® 25R4, Pluronic® 31R1, Pluronic® L10, Pluronic® L31, Pluronic® L35, Pluronic® L42, Pluronic® L43, Pluronic® L44, Pluronic® L61, Pluronic® L62, Pluronic® L62D, Pluronic® L62LF, Pluronic® L63, Pluronic® L64, Pluronic® L81, Pluronic® L92, Pluronic® L101, Pluronic® L121, Pluronic® P84, Pluronic® P103, Pluronic® P104, Pluronic® P105, and Pluronic® P123 copolymers. Preferably, the copolymer is selected from the group consisting of Pluronic® 17R2, Pluronic® 25R2, Pluronic® 31R1, Pluronic® L31, Pluronic® L42, Pluronic® L61, Pluronic® L62, Pluronic® L62D, Pluronic® L62LF, Pluronic® L81, Pluronic® L92, and Pluronic® L101 copolymers. More preferably the copolymer is selected from Pluronic® L31,

Pluronic® L42, Pluronic® L61, Pluronic® L62, Pluronic® L62D, and Pluronic® L62LF copolymers. Even more preferably the copolymer is Pluronic® L31 copolymer.

[0011] The polishing system desirably comprises only a small amount of the copolymer because using a large amount of copolymer can lead to unwanted inhibition of polishing rate of substrate layers other than the polysilicon layer. Accordingly the polishing system comprises 1 ppm to 1000 ppm of the copolymer, based on the total weight of the liquid carrier and any components dissolved or suspended therein. Preferably the amount of copolymer is 100 ppm to 800 ppm, 200 ppm to 700 ppm, or 300 ppm to 600 ppm. More preferably, the amount of copolymer is 400 ppm to 600 ppm, 450 to 550 ppm, or 500 ppm.

[0012] Any suitable abrasive can be used in conjunction with the inventive polishing system. Suitable abrasives are capable of polishing a substrate surface without introducing deleterious scratches or other imperfections in the substrate surface. The abrasive preferably is a metal oxide. Suitable metal oxide abrasives include, for example, alumina, silica, titania, ceria, zirconia, and magnesia, as well as co-formed products thereof, mixtures thereof, and chemical admixtures thereof. Typically the abrasive is selected from the group consisting of alumina, ceria, silica, zirconia, and combinations thereof. Silica, in particular fumed silica, and ceria are the preferred abrasives, with fumed silica being more preferred.

[0013] The abrasive can be combined with (e.g., suspended in) any suitable liquid carrier to form a dispersion or suspension (i.e., a "slurry"). Suitable liquid carriers generally include polar solvents, preferably water or an aqueous solvent. Where the abrasive is included in a dispersion, the dispersion can have any concentration of abrasive that is suitable for polishing. Generally, 0.1 wt.% abrasive or more is contemplated based on the total weight of the liquid carrier and any components dissolved or suspended therein. Desirably the polishing system will have 5 to 20 wt.% abrasive. Polishing systems containing 8 to 15 wt.% abrasive, in particular fumed silica abrasive, are preferred. The abrasive (when present and suspended in the liquid carrier), copolymer, liquid carrier, and optional components dissolved or suspended in the liquid carrier form the chemical-mechanical polishing composition of the polishing system.

[0014] The polishing composition can have any pH that provides a suitable polishing rate. Generally, the pH of the polishing composition is 5 or more (e.g., 6 or more, or 7 or more). Preferably, the pH of the polishing composition is 5 to 12. More preferably, the pH of the polishing composition is 6 to 10, or even 7 to 9. Even more preferably, the pH of the polishing composition is 8.

[0015] A variety of other additives can be used in conjunction with the polishing system depending on the substrate being polished so as to fine tune the polishing system and achieve the desired selectivity. In some embodiments, additives may be selected which suppress silicon nitride removal so as to achieve high polishing selectivity for silicon dioxide only. For example, amines, ammonium salts, alkali metal ions, film-forming agents, complexing agents, surfactants, rheological control agents, polymeric stabilizers or dispersing agents, and/or halide ions can be present in the polishing system. The additives can be present in the polishing system in any suitable concentrations.

[0016] The amine can be any suitable amine, many of which are known in the art. Typically the amine is selected from aliphatic amines, cyclic amines, heterocyclic amines, aromatic amines, polyamines, and combinations thereof. In some embodiments, the amine compound further comprises at least one polar moiety containing at least one oxygen atom (e.g., amino acids, amino alcohols, and the like). Such compounds can be any suitable such compound and can include dimethylpropanolamine (also known as 2-dimethylamino-2-methyl-1-propanol or DMAMP), 2-amino-2-methyl-1-propanol (AMP), 2-(2-aminoethylamino)ethanol, 2-(isopropylamino)ethanol, 2-(methylamino)ethanol, 2-(diethylamino)ethanol, 2-(2-(dimethylamino)ethoxy)ethanol, 1,1'-[[3-(dimethylamino)propyl]imino]-bis-2-propanol, 2-(butylamino)ethanol, 2-(*tert*-butylamino)ethanol, 2-(diisopropylamino)ethanol, N-(3-aminopropyl)morpholine, and mixtures thereof.

[0017] Preferably, the amine is present in the polishing composition in a concentration of 0.2 M or more (e.g., 0.5 M or more). More preferably, the amine is present in the polishing composition in a concentration of 0.7 M or more, 0.8 M or more, 0.9 M or more, or even 1 M or more. The amine also can be present in the polishing composition in a concentration of 1.1 M or more (e.g., 1.5 M or more). Generally, the amine is present in the polishing composition in a concentration that does not exceed 3 M, preferably in an amount that does not exceed 1.4 M (e.g., 0.2-1.4 M, or more preferably, 0.7-1.1 M).

[0018] The ammonium salt can be any suitable cationic amine-containing compound, such as, for example, hydrogenated amines (e.g., tetramethylammonium hydroxide (TMAH)) and quaternary ammonium compounds. Such ammonium salts can adsorb to a silicon nitride layer if present on the substrate being polished and reduce, substantially reduce, or even inhibit (i.e., block) the removal of silicon nitride during polishing. A preferred silicon nitride inhibitor

combination is a 1:1 equal weight ratio mixture of dimethylpropanolamine and tetramethylammonium hydroxide.

[0019] The alkali metal ion can be any suitable alkali metal ion. Suitable alkali metal ions include any of the univalent basic metals of group I of the periodic table. For example, sodium, potassium, rubidium, and cesium ions can be used. Potassium and cesium ions are preferred, with potassium ions being more preferred. Any suitable source of alkali metal ion can be used. For example, alkali metal salts or alkali metal hydroxides (e.g., KCl or KOH) are suitable sources of alkali metal ions.

[0020] Preferably, the alkali metal ion is present in the polishing composition in a concentration of 0.15 M or more (e.g., 0.2 M or more). More preferably, the alkali metal ion is present in the polishing composition in a concentration of 0.25 M or more, 0.3 M or more, 0.35 M or more, 0.4 M or more, or even 0.45 M or more. Generally, the alkali metal ion is present in the polishing composition in an amount that does not exceed 1.5 M, preferably an amount that does not exceed 0.75 M (e.g., 0.15-0.75 M, or more preferably, 0.2 M-0.5 M).

[0021] Any suitable film-forming agent (i.e., corrosion-inhibitor) can be used in conjunction with the polishing system. For example, in STI polishing methods, suitable film-forming agents generally include surface-active agents (i.e., surfactants) that preferentially adsorb to and prevent polishing of silicon nitride. Therefore, suitable film-forming agents include, for example, alkylamines, alkanolamines, hydroxylamines, phosphate esters, sodium laurylsulfate, fatty acids, polyacrylates, polymethacrylates, polyvinylphosphonates, polymalate, polystyrenesulfonate, and polyvinylsulfonate. Other film-forming agents include, for example, benzotriazole, triazole, benzimidazole, and mixtures thereof.

[0022] Any suitable complexing agent (i.e., chelating agent or selectivity enhancer) can be used in conjunction with the polishing system. Suitable complexing agents 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), and carboxylates containing one or more sulfonic and/or phosphonic groups. 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 phosphate-containing compounds (e.g., phosphonium salts and phosphonic acids).

[0023] Any suitable surfactant and/or rheological control agent can be used in conjunction with the polishing system, including viscosity enhancing agents and coagulants. Suitable rheological control agents include polymeric rheological control agents, such as, for example, urethane polymers (e.g., urethane polymers with a molecular weight greater than 100,000 Daltons), acrylates comprising one or more acrylic subunits (e.g., vinyl acrylates and styrene acrylates), and polymers, copolymers, and oligomers thereof, and salts thereof. Preferably, the rheological control agent is a low molecular weight carboxylate base or a high molecular weight polyacrylamide agent. Suitable surfactants include, for example, cationic surfactants, anionic surfactants, anionic polyelectrolytes, nonionic surfactants, amphoteric surfactants, fluorinated surfactants, mixtures thereof, and the like.

[0024] The polishing system can contain any suitable polymeric stabilizer or other surface-active dispersing agent. Suitable stabilizers include, for example, phosphoric acid, organic acids, tin oxides, organic phosphonates, mixtures thereof, and the like.

[0025] The compounds recited herein have been classified for illustrative purposes, and there is no intent to limit the uses of these compounds to their noted classifications. As those of skill in the art will recognize, certain compounds may perform differently in different contexts and/or perform more than one function.

[0026] The substrate can be polished (e.g., planarized) by contacting the surface of the substrate with the polishing system using any suitable technique. For example, in one typical CMP process, a wafer is pressed against a polishing pad using the inventive polishing system under controlled chemical, pressure, velocity, and temperature conditions and the pad and the wafer are moved with respect to each other. Material is then removed from the surface of the wafer. The substrate comprises polysilicon in combination with silicon oxide and/or silicon nitride. The polysilicon can be any suitable polysilicon, many of which are know in the art. The polysilicon can have any suitable phase, and can be amorphous, crystalline, or a combination thereof. The silicon oxide similarly can be any suitable silicon oxide, many of which are known in the art. Suitable types of silicon oxide include but are not limited to borophosphosilicate glass (BPSG), plasma-enhanced tetraethyl ortho silicate (PETEOS), thermal oxide, undoped silicate glass, and high density plasma (HDP) oxide.

[0027] The substrate can be polished with the polishing system 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, and coformed products thereof, and mixtures thereof. As discussed above, the abrasive of the polishing system can be fixed (e.g., embedded) in whole or in part, in or on the polishing pad. Such fixation of the abrasive on the polishing pad can be accomplished, for example, by blending the abrasive into the aforementioned polymers during the formation of the polishing pad or by adhering the abrasive to the pad after the pad is formed using such adherents as are known.

[0028] Desirably, the polishing removal rate of polysilicon is substantially the same as the removal rate of polysilicon would be under the same conditions except for the absence of the polyethylene oxide/polypropylene oxide copolymer. Accordingly preferred formulations of the polishing system can provide selective polishing of silicon oxide and/or silicon nitride surfaces relative to polysilicon surfaces. The selectivity can be controlled, to some extent, by altering the relative concentrations of the components of the polishing system. When desirable, the method of the invention can be used to polish a substrate with a silicon nitride to polysilicon polishing selectivity of 2:1 or more (e.g., 4:1 or more, or 6:1 or more). Also, the method of the invention can be used to polish a substrate with a silicon dioxide to polysilicon polishing selectivity of 5:1 or more (e.g., 10:1 or more, or 15:1 or more). Certain formulations can exhibit even higher silicon dioxide to polysilicon selectivities, such as 20:1 or more, or even 30:1 or more. In a preferred embodiment, the method of the invention simultaneously provides selective polishing of silicon dioxide and silicon nitride relative to polysilicon.

[0029] The following examples further illustrate the invention but, of course, should not be construed as in any way limiting its scope.

EXAMPLE 1

[0030] This example demonstrates the effect of polyethylene oxide/polypropylene oxide copolymers having an HLB of 15 or less on the polishing removal rate of polysilicon and other silicon-containing layers.

[0031] Six polishing compositions (Composition 1A-1F) comprising 12 wt.% fumed silica and water having a pH of 8 were used to polish a substrate comprising polysilicon, silicon nitride, and borophosphosilicate glass (BPSG). Compositions 1A-1F contained 50 ppm of Pluronic® L121 (invention), Pluronic® L31 (invention), Pluronic® 17R2 (invention), Pluronic® P84 (invention), Pluronic® F127 (comparative), or Pluronic® F38 (comparative) copolymer, respectively. The polishing removal rates (RR) for the polysilicon, BPSG, and silicon nitride layers were determined for each of the polishing compositions at 10 ppm and 50 ppm Pluronic® copolymer. The polishing removal rates were also determined for the polysilicon, BPSG, and silicon nitride layers in the absence of any Pluronic® copolymer. The percent change in the removal rates for each of the three materials is shown in Tables 1 (50 ppm v. 0 ppm surfactant) and 2 (50 ppm v. 10 ppm surfactant).

Table 1. Percent Change in Removal Rate (50 ppm v. 0 ppm) for Polysilicon, BPSG, and Silicon Nitride Layers.

Composition	Surfactant	HLB	% Change Polysilicon	% Change BPSG	% Change Silicon Nitride
1A (invention)	Pluronic® L121	1	-22%	+8%	+1%
1B (invention)	Pluronic® L31	5	-59%	-23%	---
1C (invention)	Pluronic® 17R2	6	-11%	+16%	-5%
1D (invention)	Pluronic® P84	14	-8%	+11%	---
1E (comparative)	Pluronic® F127	22	+2%	+9%	-24%
1F (comparative)	Pluronic® F38	31	-6%	+9%	---

Table 2. Percent Change in Removal Rate (50 ppm v. 10 ppm) for Polysilicon, BPSG, and Silicon Nitride Layers at pH = 8.

Composition	Surfactant	HLB	% Change Polysilicon	% Change BPSG	% Change Silicon Nitride
1A (invention)	Pluronic® L121	1	-26%	-8%	-5%
1B (invention)	Pluronic® L31	5	-33%	-24%	---
1C (invention)	Pluronic® 17R2	6	-20%	-4%	+2%
1D (invention)	Pluronic® P84	14	+3%	+2%	---
1F (comparative)	Pluronic® F38	31	+17%	+26%	---

[0032] The data shown in Tables 1 and 2 illustrate that small amounts of Pluronic® surfactants having an HLB value of 8 or less are effective at inhibiting polysilicon removal without significantly inhibiting polishing of other silicon-containing substrate layers. Contrastingly, Pluronic® surfactants having an HLB value greater than 8 are not significantly effective for inhibiting removal of polysilicon.

EXAMPLE 2

[0033] This example demonstrates the selectivity of silicon nitride to polysilicon polishing that can be achieved using the method of the invention.

[0034] Three polishing compositions (Composition 2A-2C) comprising 10 wt.% fumed silica and water having a pH of 8 were used to polish a substrate comprising polysilicon, silicon nitride, and borophosphosilicate glass (BPSG). Composition 2A (control) contained no copolymer. Compositions 2B and 2C (invention) further comprised 100 ppm and 1000 ppm Pluronic® L31 copolymer (which has an HLB of 5), respectively. The polishing removal rates (RR) for the polysilicon, silicon nitride, and BPSG were determined for each of the polishing compositions. The removal rates and selectivities for each composition are shown in Table 3.

Table 3. Removal Rates and Selectivity of Silicon Nitride and BPSG to Polysilicon.

Composition	Surfactant Concentration (ppm)	Polysilicon RR (Å/min)	Nitride RR (Å/min)	BPSG RR (Å/min)	Nitride: Polysilicon Selectivity	BPSG: Polysilicon Selectivity
2A (control)	0	700-1000	150-300	700-1000	--	--
2B (invention)	100	33	145	749	4:1	23:1
2C (invention)	1000	22	135	703	6:1	32:1

[0035] The data shown in Table 3 illustrate that low concentrations (i.e., 1000 ppm or less) of a polyethylene oxide/polypropylene oxide copolymer having an HLB of 8 or less are effective at inhibiting polishing of polysilicon without any detrimental effect on the polishing rates of other substrate layers.

CLAIMS

1. A method of chemically-mechanically polishing a substrate, which method comprises:

(i) contacting a substrate comprising polysilicon and a material selected from silicon oxide and silicon nitride with a chemical-mechanical polishing system comprising:

(a) an abrasive,

(b) a liquid carrier,

(c) 1 ppm to 1000 ppm, based on the weight of the liquid carrier and any components dissolved or suspended therein, of a polyethylene oxide/polypropylene oxide copolymer having an HLB of 15 or less, and

(d) a polishing pad,

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

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

2. The method of claim 1, wherein the amount of copolymer is 100 ppm to 800 ppm.

3. The method of claim 1, wherein the copolymer has a molecular weight of 4000 g/mol or less.

4. The method of claim 1, wherein the copolymer has an HLB of 8 or less.

5. The method of claim 1, wherein the copolymer is terminated with a hydroxyl group.

6. The method of claim 1, wherein the abrasive is selected from the group consisting of alumina, ceria, silica, zirconia, and combinations thereof.

7. The method of claim 6, wherein the abrasive is fumed silica.

8. The method of claim 6, wherein the abrasive is ceria.

9. The method of claim 1, wherein the abrasive is suspended in the liquid carrier.

10. The method of claim 9, wherein the amount of abrasive is 5 wt.% to 20 wt.%, based on the weight of the liquid carrier and any components dissolved or suspended therein.

11. The method of claim 10, wherein the amount of abrasive is 8 wt.% to 15 wt.%.

12. The method of claim 9, wherein the liquid carrier comprises water.

13. The method of claim 12, wherein the pH is 5 to 12.

14. The method of claim 13, wherein the pH is 7 to 9.

15. The method of claim 1, wherein the polishing system further comprises a complexing agent dissolved or suspended in the liquid carrier.

16. The method of claim 1, wherein the polishing system further comprises an amine dissolved or suspended in the liquid carrier.

17. The method of claim 1, wherein the substrate comprises both silicon oxide and silicon nitride.

18. The method of claim 1, wherein the polishing removal rate of the polysilicon is substantially the same as the removal rate under the same conditions except for the absence of the copolymer.