[0032] The inorganic oxide particles include but are not limited to ceria, colloidal silica, high purity colloidal silica, fumed silica, colloidal ceria, alumina, titania, zirconia particles.

[0033] The metal oxide-coated inorganic oxide particles include but are not limited to the ceria-coated inorganic oxide particles, such as, ceria-coated colloidal silica, ceria-coated high purity colloidal silica, ceria-coated alumina, ceria-coated titania, ceria-coated zirconia, or any other ceria-coated inorganic oxide particles.

[0034] The organic polymer particles include, but are not limited to, polystyrene particles, polyurethane particle, polyacrylate particles, or any other organic polymer particles.

[0035] The metal oxide-coated organic polymer particles are selected from the group consisting of ceria-coated organic polymer particles, zirconia-coated organic polymer particles.

[0036] The concentration of abrasive can range from 0.01 wt.% to 30 wt.%, the preferred is from about 0.05 wt.% to about 20 wt.%, the more preferred is from about 0.01 to about 10 wt.%, and the most preferred is from 0.1 wt.% to 2 wt.%. The weight percent is relative to the composition.

[0037] The activator includes, but is not limited to (1) inorganic oxide particle with transition metal coated onto its surface; and the transition metal is selected from the group consisting of Fe, Cu, Mn, Co, Ce, and combinations thereof; (2) soluble catalyst selected from the group consisting of iron (III) nitrate, ammonium iron (III) oxalate trihydrate, iron(III) citrate tribasic monohydrate, iron(III) acetylacetonate and ethylenediamine tetraacetic acid, iron (III) sodium salt hydrate;(3) a metal compound having multiple oxidation states selected from the group consisting of Ag, Co, Cr, Cu, Fe, Mo, Mn, Nb, Ni, Os, Pd, Ru, Sn, Ti, V; and combinations thereof.

[0038] The activator ranges from 0.00001 wt.% to 5.0 wt.%, 0.0001 wt.% to 2.0 wt.%, 0.0005 wt.% to 1.0 wt.%, or 0.001 wt.% to 0.5 wt.%.

[0039] The oxidizing agent includes but is not limited to peroxy compound selected from the group consisting of hydrogen peroxide, urea peroxide, peroxyformic acid, peracetic acid, propaneperoxoic acid, substituted or unsubstituted butaneperoxoic acid, hydroperoxy-acetaldehyde, potassium periodate, ammonium peroxymonosulfate; and non-peroxy compound selected from the group consisting of ferric nitrate (iron (III) nitrate), $KClO_4$, $KBrO_4$, $KMnO_4$.

unsubstituted butaneperoxoic acid, hydroperoxy-acetaldehyde, also encompassed in this term are common complexes of peroxides, for example urea peroxide.

[00100] Suitable per-compounds containing at least one peroxy group include persulfates. As used herein, the term “persulfates” encompasses monopersulfates, di-persulfates, and acids and salts and adducts thereof. Included for example is peroxydisulfates, peroxymonosulfuric acid and/or peroxymonosulfates, Caro's acid, including for example a salt such as potassium peroxymonosulfate, but preferably a non-metallic salt such as ammonium peroxymonosulfate.

[00101] Suitable per-compounds containing at least one peroxy group include perphosphates, defined as above and including peroxydiphosphates.

[00102] Also, ozone is a suitable oxidizing agent either alone or in combination with one or more other suitable oxidizing agents.

[00103] Suitable per-compounds that do not contain a peroxy group include, but are not limited to, periodic acid and/or any periodiate salt (hereafter “periodates”), perchloric acid and/or any perchlorate salt (hereafter “perchlorates”) perbromic acid and/or any perbromate salt (hereafter “perbromates”), and perboric acid and/or any perborate salt (hereafter “perbromates”).

[00104] Other oxidizing agents are also suitable components of the composition of the present invention. Iodates are useful oxidizers.

[00105] Two and more oxidizers may also be combined to obtain synergistic performance benefits.

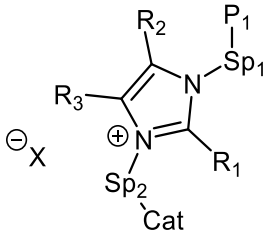
[00106] In most embodiments of the present invention, the oxidizer is selected from the group consisting of peroxy compound selected from the group consisting of hydrogen peroxide, urea peroxide, peroxyformic acid, peracetic acid, propaneperoxoic acid, substituted or unsubstituted butaneperoxoic acid, hydroperoxy-acetaldehyde, potassium periodate, ammonium peroxymonosulfate; and non-per-oxy compound selected from the group consisting of ferric nitrate (iron (III) nitrate), $KClO_4$, $KBrO_4$, $KMnO_4$.

[00107] In some embodiments, the preferred oxidizer is hydrogen peroxide.

[00108] The oxidizer concentration can range from about 0.01 wt.% to 30 wt.% while the preferred concentration of oxidizing agents is from about 0.1 wt.% to 20 wt.%, and

Claims

1. A dicationic polymer or copolymer formed by at least one dicationic monomer comprising a structure of (I):



(I);

wherein:

P_1 denotes a polymerizable group selected from groups containing C=C double bonds;

Sp_1 and Sp_2 denote independently at each occurrence a spacer group or a single bond;

R_1, R_2, and R_3 are each independently H, or substituted or unsubstituted aliphatic aromatic moiety selected from the group consisting of (1) alkyl having < 12 C atoms, or < 4 C atoms; and (2) phenyl, pyridinyl, pyrimidyl, furanyl or nitrogen-containing five-membered ring; and (3) combinations of (1) and (2);

Cat denotes in each occurrence a cationic group selected from the group consisting of ammonium-, guanidinium-, triazolium-, phosphonium-, pyridinium- and triazolium-type group;

X^- denotes an anionic counterion selected from the group consisting of halide selected from the group consisting of F-, Cl-, Br-, and I-; BF_4-; PF_6-; carboxylate; malonate; citrate; carbonate; fumarate; $MeOSO_3$-; $MeSO_3$-; CF_3COO-; CF_3SO_3-; nitrate; and sulfate; and

the dicationic polymer or copolymer is formed by a polymerization method selected from the group consisting of free radical polymerization, reversible addition-fragmentation chain-transfer polymerization (RAFT), nitroxide-mediated polymerization (NMP), atomic transfer reaction polymerization (ATRP), ring opening polymerization (ROMP) and polycondensation reaction.

2. The dicationic polymer or copolymer of claim 1, wherein the R_1, R_2, and R_3 are each independently H, or substituted or unsubstituted aliphatic aromatic moiety selected from the group consisting of CH_3 or CH_2-CH_3; pyridinylm, pyrimidyl, and combinations thereof.

3. The dicationic polymer or copolymer according to claim 1 or 2; wherein the dicationic polymer or copolymer has a block-copolymer character.

4. The dicationic polymer or copolymer according to any one of claims 1-3; wherein the dicationic polymer or copolymer is selected from the group consisting of poly(3-ethyl-1-(3-(1-vinyl-1*H*-imidazol-3-ium-3-yl)propyl)-1*H*-imidazol-3-ium dibromide), poly(3-(tributylphosphino)propyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium-co-*N*-vinyl-pyrrolidone dibromide), and combinations thereof.

5. A chemical mechanical planarization composition comprising dicationic polymer or copolymer according to any one of claims 1-4.

6. A chemical mechanical planarization composition comprising:
an abrasive selected from the group consisting of inorganic oxide particles, metal oxide-coated inorganic oxide particles, organic polymer particles, metal oxide-coated organic polymer particles, and combinations thereof;
an activator;
an oxidizing agent;
an additive comprising the dicationic polymer or copolymer according to any one of claims 1 to 4;
water; and optionally at least one
a corrosion inhibitor;
a dishing reducing agent;
a stabilizer;
a pH adjusting agent.

7. The chemical mechanical planarization composition of Claim 6, wherein the inorganic oxide particles are selected from the group consisting of ceria, colloidal silica, fumed silica, colloidal ceria, alumina, titania, zirconia, and combinations thereof; and are used in an amount ranging from 0.05 wt.% to 20 wt.%, or 0.01 wt.% to 10 wt.%;

the additive comprising the dicationic polymer or copolymer is selected from the group consisting of poly(3-ethyl-1-(3-(1-vinyl-1*H*-imidazol-3-ium-3-yl)propyl)-1*H*-imidazol-3-ium dibromide), poly(3-(tributylphosphino)propyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium-co-*N*-vinyl-pyrrolidone dibromide), and combinations thereof and the additive is used in an amount ranging from 0.00001 wt.% to 1.0 wt.%, or 0.00025 wt.% to 0.1 wt.%.

8. The chemical mechanical planarization composition of according to claim 6 or 7, wherein the additive comprising the dicationic polymer or copolymer is selected from the group consisting of poly(3-ethyl-1-(3-(1-vinyl-1*H*-imidazol-3-ium-3-yl)propyl)-1*H*-imidazol-3-ium dibromide), poly(3-(tributylphosphino)propyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium-co-*N*-vinyl-pyrrolidone dibromide), and combinations thereof and the additive is used in an amount ranging from 0.00001 wt.% to 1.0 wt.%, or 0.00025 wt.% to 0.1 wt.%.

9. The chemical mechanical planarization composition according to any one of claims 6 to 8, wherein the oxidizing agent is selected from the group consisting of peroxy compound selected from the group consisting of hydrogen peroxide, urea peroxide, peroxyformic acid, peracetic acid, propaneperoxoic acid, substituted or unsubstituted butaneperoxoic acid, hydroperoxy-acetaldehyde, potassium periodate, ammonium peroxymonosulfate; and non-per-oxy compound selected from the group consisting of iron (III) nitrate, $KClO_4$, $KBrO_4$, $KMnO_4$; and combinations thereof; and the oxidizing agent is used in an amount ranging from 0.1 wt.% to 20 wt.%, or 0.5 wt.% to 10 wt.%;
the activator is selected from the group consisting of (1) inorganic oxide particle with transition metal coated onto its surface; and the transition metal is selected from the group consisting of Fe, Cu, Mn, Co, Ce, and combinations thereof; (2) soluble catalyst selected from the group consisting of iron (III) nitrate, ammonium iron (III) oxalate trihydrate, iron(III) citrate

tribasic monohydrate, iron(III) acetylacetonate and ethylenediamine tetraacetic acid, iron (III) sodium salt hydrate;(3) a metal compound having multiple oxidation states selected from the group consisting of Ag, Co, Cr, Cu, Fe, Mo, Mn, Nb, Ni, Os, Pd, Ru, Sn, Ti, V; and combinations thereof; and the activator is used in an amount ranging from 0.00001 wt.% to 5.0 wt.%, or 0.0005 wt.% to 1.0 wt.%.

10. The chemical mechanical planarization composition according to any one of claims 6 to 9, wherein the chemical mechanical planarization composition further comprises at least one of the corrosion inhibitor selected from the group consisting of 1,2,3-triazole, 1,2,4-triazole, 1,2,3-benzotriazole, 5-methylbenzotriazole, benzotriazole, 1-hydroxybenzotriazole, 4-hydroxybenzotriazole, 3-amino-1,2,4-triazole, 4-amino-4H-1,2,4-triazole, 5 amino triazole, benzimidazole, 2,1,3-benzothiadiazole, triazinethiol, triazinedithiol, and triazinetrithiol, pyrazoles, imidazoles, isocyanurate such as 1,3,5-Tris(2-hydroxyethyl), and combinations thereof; and the corrosion inhibitor is used in an amount ranging from less than 1.0 wt.%, or less than 0.5 wt.%;
the dishing reducing agent selected from the group consisting of sarcosinate and related carboxylic compounds; hydrocarbon substituted sarcosinate; amino acids; organic polymers and copolymers having molecules containing ethylene oxide repeating units, such as polyethylene oxide (PEO); ethoxylated surfactants; nitrogen containing heterocycles without nitrogen-hydrogen bonds; sulfide; oxazolidine or mixture of functional groups in one compound; nitrogen containing compounds having three or more carbon atoms that form alkylammonium ions; amino alkyls having three or more carbon atoms; polymeric corrosion inhibitor comprising a repeating group of at least one nitrogen-containing heterocyclic ring or a tertiary or quaternary nitrogen atom; dicationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; and sulfonic acid polymer; and combinations thereof; and the dishing reducing agent is used in an amount ranging from 0.001 wt.% to 2.0 wt. %, or 0.005 wt.% to 1.5 wt. %; and

the stabilizer selected from the group consisting of adipic acid, phthalic acid, citric acid, malonic acid, orthophthalic acid; phosphoric acid; substituted or unsubstituted phosphonic acids; nitriles; and combinations thereof; and the stabilizer is used in an amount ranging from 0.0001 to 5 wt.%, 0.00025 to 2 wt.%, or 0.0005 to 1 wt.%.

11. The chemical mechanical planarization composition according to any one of claims 6 to 10, wherein pH of the composition is between 1 and 7, or 1.5 and 4; and the chemical mechanical planarization composition optionally comprises a pH adjusting agent selected from the group consisting of (a)nitric acid, sulfuric acid, tartaric acid, succinic acid, citric acid, malic acid, malonic acid, various fatty acids, various polycarboxylic acids, and mixtures thereof to lower the pH; and (b) potassium hydroxide, sodium hydroxide, ammonia, tetraethylammonium hydroxide, ethylenediamine, piperazine, polyethyleneimine, modified polyethyleneimine, and mixtures thereof to raise the pH.

12. The chemical mechanical planarization composition according to any one of claims 6 to 11, wherein the abrasive is silica particles;
the additive comprising the dicationic polymer or copolymer is selected from the group consisting of poly(3-ethyl-1-(3-(1-vinyl-1H-imidazol-3-ium-3-yl)propyl)-1*H*-imidazol-3-ium dibromide), poly(3-(tributylphosphino)propyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium-co-*N*-vinyl-pyrrolidone dibromide), and combinations thereof;
the activator is iron (III) nitrate; and
the oxidizer is hydrogen peroxide.

13. The chemical mechanical planarization composition according to any one of claims 6 to 12, wherein the chemical mechanical planarization composition comprises silica particles; poly(vinyl-3-ethyl-1*H*-imidazol-3-ium-co-tributyl-(4-vinylbenzyl)-phosphonium) bromide chloride, iron (III) nitrate, malonic acid, hydrogen peroxide, and water; the pH of the composition is between 1.5 and 4.

14. A polishing method for chemical mechanical planarization of a semiconductor substrate comprising at least one surface containing tungsten, comprising the steps of:

a) providing a polishing pad;

b) providing a chemical mechanical polishing composition comprising:
an abrasive selected from the group consisting of inorganic oxide particles, metal oxide-coated inorganic oxide particles, organic polymer particles, metal oxide-coated organic polymer particles, and combinations thereof;
an activator;
an oxidizing agent;
an additive comprising the dicationic polymer or copolymer according to any one of claims 1 to 4;
water; and optionally
a corrosion inhibitor;
a dishing reducing agent;
a stabilizer;
a pH adjusting agent;
wherein pH of the composition is between 1 and 7, or 1.5 and 4
and

c) polishing the at least one surface containing tungsten with the chemical mechanical planarization composition.

15. The polishing method of Claim 14, wherein the chemical mechanical planarization composition has the inorganic oxide particles selected from the group consisting of ceria, colloidal silica, fumed silica, colloidal ceria, alumina, titania, zirconia, and combinations thereof; and are used in an amount ranging from 0.05 wt.% to 20 wt.%, or 0.01 wt.% to 10 wt.%;
the additive comprising the dicationic polymer or copolymer selected from the group consisting of poly(3-ethyl-1-(3-(1-vinyl-1*H*-imidazol-3-ium-3-yl)propyl)-1*H*-imidazol-3-ium dibromide), poly(3-(tributylphosphino)propyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium-co-*N*-vinyl-pyrrolidone dibromide), and combinations thereof

and the additive is used in an amount ranging from 0.00001 wt.% to 1.0 wt.%, or 0.00025 wt.% to 0.1 wt.%;
the oxidizing agent selected from the group consisting of peroxy compound selected from the group consisting of hydrogen peroxide, urea peroxide, peroxyformic acid, peracetic acid, propaneperoxoic acid, substituted or unsubstituted butaneperoxoic acid, hydroperoxy-acetaldehyde, potassium periodate, ammonium peroxymonosulfate; and non-per-oxy compound selected from the group consisting of iron (III) nitrate, $KClO_4$, $KBrO_4$, $KMnO_4$; and combinations thereof; and the oxidizing agent is used in an amount ranging from 0.1 wt.% to 20 wt.%, or 0.5 wt.% to 10 wt.%; and
the activator selected from the group consisting of (1) inorganic oxide particle with transition metal coated onto its surface; and the transition metal is selected from the group consisting of Fe, Cu, Mn, Co, Ce, and combinations thereof; (2) soluble catalyst selected from the group consisting of iron (III) nitrate, ammonium iron (III) oxalate trihydrate, iron (III) citrate tribasic monohydrate, iron(III) acetylacetonate and ethylenediamine tetraacetic acid, iron (III) sodium salt hydrate;(3) a metal compound having multiple oxidation states selected from the group consisting of Ag, Co, Cr, Cu, Fe, Mo, Mn, Nb, Ni, Os, Pd, Ru, Sn, Ti, V; and combinations thereof; and the activator is used in an amount ranging from 0.00001 wt.% to 5.0 wt.%, or 0.0005 wt.% to 1.0 wt.%.

16. The polishing method according to claim 14 or 15, wherein the chemical mechanical planarization composition further comprises at least one of the corrosion inhibitor selected from the group consisting of 1,2,3-triazole, 1,2,4-triazole, 1,2,3-benzotriazole, 5-methylbenzotriazole, benzotriazole, 1-hydroxybenzotriazole, 4-hydroxybenzotriazole, 3-amino-1,2,4-triazole, 4-amino-4H-1,2,4-triazole, 5 amino triazole, benzimidazole, 2,1,3-benzothiadiazole, triazinethiol, triazinedithiol, and triazinetrithiol, pyrazoles, imidazoles, isocyanurate such as 1,3,5-Tris(2-hydroxyethyl), and combinations thereof; and the corrosion inhibitor is used in an amount ranging from less than 1.0 wt.%, or less than 0.5 wt.%;
the dishing reducing agent selected from the group consisting of sarcosinate and related carboxylic compounds; hydrocarbon substituted sarcosinate; amino acids; organic polymers and copolymers having molecules containing

ethylene oxide repeating units, such as polyethylene oxide (PEO); ethoxylated surfactants; nitrogen containing heterocycles without nitrogen-hydrogen bonds; sulfide; oxazolidine or mixture of functional groups in one compound; nitrogen containing compounds having three or more carbon atoms that form alkylammonium ions; amino alkyls having three or more carbon atoms; polymeric corrosion inhibitor comprising a repeating group of at least one nitrogen-containing heterocyclic ring or a tertiary or quaternary nitrogen atom; dicationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; and sulfonic acid polymer; and combinations thereof; and the dishing reducing agent is used in an amount ranging from 0.001 wt.% to 2.0 wt. %, or 0.005 wt.% to 1.5 wt. %; and the stabilizer selected from the group consisting of adipic acid, phthalic acid, citric acid, malonic acid, orthophthalic acid; phosphoric acid; substituted or unsubstituted phosphonic acids; nitriles; and combinations thereof; and the stabilizer is used in an amount ranging from 0.0001 to 5 wt.%, 0.00025 to 2 wt.%, or 0.0005 to 1 wt.%.

17. The polishing method according to any one of claims 14 to 16, wherein the chemical mechanical planarization composition comprises silica particles; iron (III) nitrate; malonic acid; hydrogen peroxide; poly(vinyl-3-ethyl-1*H*-imidazol-3-ium-co-tributyl-(4-vinylbenzyl)-phosphonium) bromide chloride, and water; the pH of the composition is between 1.5 and 4.

18. The polishing method according to any one of claims 14 to 17, wherein at least one surface containing tungsten comprises a dishing topography of less than 2000 or less than 1000 Angstroms and an erosion topography of less than 2000 or less than 1000 Angstroms.

19. A system for chemical mechanical planarization of a semiconductor substrate comprising at least one surface containing tungsten, comprising:
    a) a polishing pad; and
    b) a chemical mechanical polishing composition comprising:

an abrasive selected from the group consisting of inorganic oxide particles, metal oxide-coated inorganic oxide particles, organic polymer particles, metal oxide-coated organic polymer particles, and combinations thereof;
an activator;
an oxidizing agent;
an additive comprising the cationic polymer or copolymer according to any one of claims 1 to 4;
water; and optionally
a corrosion inhibitor;
a dishing reducing agent;
a stabilizer;
a pH adjusting agent; and
wherein the at least one surface containing tungsten is in contact with the polishing pad and the chemical mechanical planarization composition
polishing the at least one surface containing tungsten with the chemical mechanical planarization composition.

20. The chemical mechanical planarization composition of claim 5, wherein
the dicationic polymer or copolymer is selected from the group consisting of poly(3-ethyl-1-(3-(1-vinyl-1*H*-imidazol-3-ium-3-yl)propyl)-1*H*-imidazol-3-ium dibromide), poly(3-(tributylphosphino)propyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium dibromide), poly(3-(2-(trimethylammonio)ethyl)-1-vinyl-1*H*-imidazol-3-ium-co-*N*-vinyl-pyrrolidone dibromide), and combinations thereof;
the activator is iron (III) nitrate; and
the oxidizer is hydrogen peroxide.