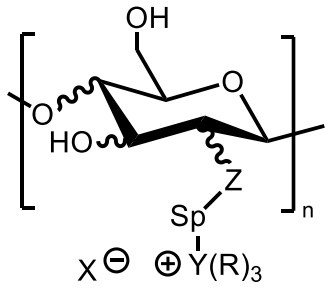
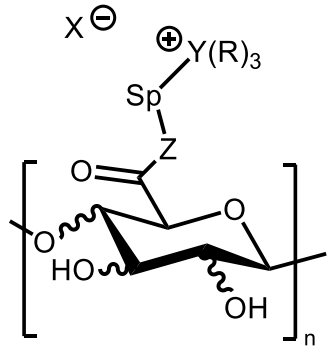
CLAIMS

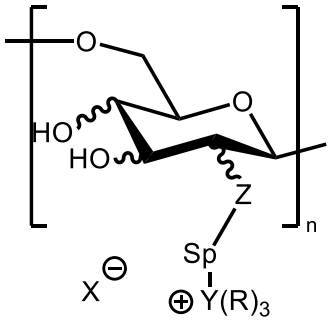
1. A cationic-modified water-soluble polysaccharide comprising cationic repeating unit having a structure selected from the group consisting of



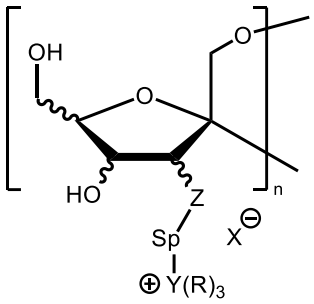
(1);



(2);



(3); and



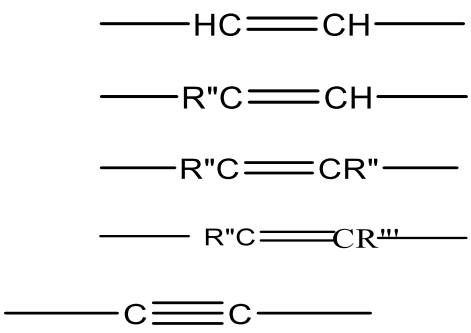
(4);

wherein

the water-soluble polysaccharide is selected from the group consisting of chitosan, pectin, dextran, pullulan, and inulin;

pentagon or hexagon denotes the backbone of the water-soluble polysaccharide;

Z is selected from the group consisting of NH, -O-, -S-, -O-(C=O)-, -NH-(C=O)-, -O-(C=O)-, -NH-(C=O)-, NR' herein R' is alkyl having C_1 to C_6, and carbon to carbon double-bond or triple-bond as shown below:



wherein two carbon atoms in the double bond structure can be connected to two protons, one proton and one alkyl group R" wherein R" is alkyl having C_1 to C_6, two same alkyl groups as in R", or two different alkyl groups as in R" and R"' wherein R"' is alkyl having C_1 to C_6;

preferably Z denotes NH or -O-;

Sp denotes at each occurrence a spacer group having single bond or double bond structure; preferably single bond structure;

Y^+ denotes a cation function selected from the group consisting of N^+, P^+, and S^+; wherein the cationic-modified water-soluble polysaccharides comprises repeating unit containing no ion or at least one ion;

X^- denotes the counter ion selected from the group consisting of F^-, Cl^-, Br^-, I^-, BF_4^-, $CF_3BF_3^-$, OH^-, PF_6^-, carboxylate, malonate, citrate, carbonate, fumarate, $MeOSO_3^-$, $MeSO_3^-$, CF_3COO^-, $CF_3SO_3^-$, cyanate, isothiocyanate, nitrate, phosphate, and sulfate, wherein Me is methyl;

R denotes a cation side group selected from the group consisting of H; CH_3; saturated or unsaturated, branched or aliphatic alkyl chain; cyclic ring, and other functional group selected from the group consisting of amine, carboxylic acid, sulfonate, siloxane, ether, and alcohol; wherein $(R)_3$ can be alkyl or form a ring selected from the group consisting of imidazolium, triazolium, and tetrazolium; tris-alkyl phosphonium, tris-phenyl phosphonium, tris-alkyl sulfonium, and tris-phenyl sulfonium;

n denotes the number of the repeating units, wherein $1<n<2000$, or $75<n<1000$.

2. The cationic-modified water-soluble polysaccharide of claim 1, wherein the water-soluble polysaccharide is modified by a method selected from the group consisting of etherification; esterification; amidation; and amination; and the cationic-modified water-soluble polysaccharide has an ion density between 5-200%, or between 10% - 100%.

3. The cationic-modified water-soluble polysaccharide according to claim 1or 2, wherein the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl- triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof.

4. A chemical mechanical planarization composition comprising 0.00001 wt.% to 1.0 wt.% or 0.00025 wt.% to 0.1 wt.% of the cationic-modified water-soluble polysaccharide

according to any one of claims 1 to 3; and the cationic-modified water-soluble polysaccharide has an ion density between 5-200%, or between 10% - 100%.

5. The chemical mechanical planarization composition of claim 4 further comprising at least one of:
   an abrasive;
   an activator;
   an oxidizing agent;
   a corrosion inhibitor;
   a dishing reducing agent;
   a stabilizer;
   a pH adjusting agent.

6. The chemical mechanical planarization composition of claim 5, wherein the abrasive is 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; and the abrasive ranges from 0.01 wt.% to 30 wt.%, or from 0.1 wt.% to 2 wt.%.

7. The chemical mechanical planarization composition according to claim 5 or 6, wherein the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl- triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof.

8. The chemical mechanical planarization composition according to any one of claims 5 to 7, wherein 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, and 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, and V; and combinations thereof;
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, and ammonium peroxymonosulfate; and non-peroxy compound selected from the group consisting of ferric nitrite, $KClO_4$, $KBrO_4$, and $KMnO_4$; and combinations thereof;
the corrosion inhibitor is 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;
the dishing reducing agent is 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, 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; polycationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; and sulfonic acid polymer; and combinations thereof;

the stabilizer is 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 pH adjusting agent is 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.

9. The chemical mechanical planarization composition according to any one of claims 5 to 8, wherein the chemical mechanical planarization composition comprises silica particles or surface modified silica particles; the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl- triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof; iron (III) nitrate, malonic acid, hydrogen peroxide, and water; the pH of the composition is between 1 and 14 or 1 and 7.

10. 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 planarization composition comprising:
an abrasive;
an additive comprising 0.00001 wt.% to 1.0 wt.% or 0.00025 wt.% to 0.1 wt.% of the cationic-modified water-soluble polysaccharide according to any one of claims 1 to 3;
water; and optionally at least one of
an activator;

an oxidizing agent;

a corrosion inhibitor;

a dishing reducing agent;

a stabilizer;

a pH adjusting agent;

wherein the cationic-modified water-soluble polysaccharide has an ion density between 5-200%, or between 10% - 100%; and

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

11. The polishing method of claim 10, wherein the chemical mechanical planarization composition has the 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; and the abrasive ranges from 0.01 wt.% to 30 wt.%, or from 0.1 wt.% to 2 wt.%.

12. The polishing method according to claim 10 or 11, wherein the additive comprising the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl- triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof.

13. (Currently Amended) The polishing method according to any one of claims 10 to 12, wherein 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, and 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, and V; and combinations thereof;
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, and ammonium peroxymonosulfate; and non-peroxy compound selected from the group consisting of ferric nitrite, $KClO_4$, $KBrO_4$, and $KMnO_4$; and combinations thereof;
the corrosion inhibitor is 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;
the dishing reducing agent is 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, 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; polycationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; and sulfonic acid polymer; and combinations thereof;
the stabilizer is 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 pH adjusting agent is 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.

14. The polishing method according to any one of claims 10 to 13, wherein the chemical mechanical planarization composition comprises silica particles or surface modified silica particles; the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl-triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof; 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 and 7 or 1.5 and 4.

15. 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 planarization composition comprising:
        an abrasive;
        0.00001 wt.% to 1.0 wt.% or 0.00025 wt.% to 0.1 wt.% of the cationic-modified water-soluble polysaccharide according to any one of claims 1 to 3;
        water; and optionally at least one of
        an activator;
        an oxidizing agent;
        a corrosion inhibitor;
        a dishing reducing agent;
        a stabilizer;
        a pH adjusting agent;

wherein the cationic-modified water-soluble polysaccharide has an ion density between 5-200%, or between 10% - 100%; and
wherein the at least one surface containing tungsten is in contact with the polishing pad and the chemical mechanical planarization composition, thereby polishing the at least one surface containing tungsten with the chemical mechanical planarization composition.

16. The system of claim 15, wherein the chemical mechanical planarization composition has the 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; and the abrasive ranges from 0.01 wt.% to 30 wt.%, or from 0.1 wt.% to 2 wt.%.

17. The system according to claim 15 or 16, wherein the additive comprising the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl- triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof.

18. The system according to any one of claims 15 to 17, wherein 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, and 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, and V; and combinations thereof;

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, and ammonium peroxymonosulfate; and non-peroxy compound selected from the group consisting of ferric nitrite, $KClO_4$, $KBrO_4$, and $KMnO_4$; and combinations thereof;

the corrosion inhibitor is 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;

the dishing reducing agent is 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, 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; polycationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; and sulfonic acid polymer; and combinations thereof;

the stabilizer is 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 pH adjusting agent is 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.

19. The system according to any one of claims 15 to 18, wherein the chemical mechanical planarization composition comprises silica particles or surface modified silica particles; the cationic-modified water-soluble polysaccharide is selected from the group consisting of chitosan-triphenylphosphonium bromide salt, dextran-triphenylphosphonium bromide salt, chitosan-imidazolium chloride salt, dextran-(2-hydroxy)propyl- triphenylphosphonium chloride salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-trialkylphosphonium bromide salt, dextran-trialkylphosphonium bromide salt, pectin-ethylene diamine triphenylphosphonium bromide salt, chitosan-ethylene guanidinium bromide salt, dextran-imidazolium chloride salt, dextran-ethylene guanidinium bromide salt, chitosan-triazolium iodide salt, dextran-triazolium iodide salt, chitosan-guanidinium-triazolium salt, dextran-phosphonium-triazolium iodide salt, chitosan-trialkylphosphonium/triphenylphosphonium mix bromide, dextran-trialkylphosphonium/triphenylphosphonium mix bromide, and combinations thereof; 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 and 7 or 1.5 and 4.

20. The chemical mechanical planarization composition according to claim 14, wherein the pH of the composition is between 1.5 and 4.