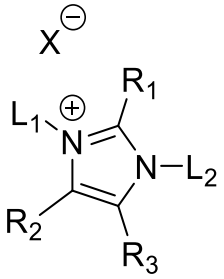
Claims

1. An imidazolium-based poly(ionic liquid) comprising at least one monomer having at least one imidazolium group with structure (I):



(I);

wherein

(a) the at least one imidazolium group with structure (I) is in a side chain or side chains of the imidazolium-based poly(ionic liquid);

wherein

one of L_1 and L_2 is a covalent bond or a spacer connecting imidazolium-ring to main chain of the imidazolium-based poly(ionic liquid), and comprises a substituted or unsubstituted aliphatic; cyclic or branched aliphatic, aromatic, heteroaromatic or siloxane moiety; wherein the main chain is formed after polymerization of a polymerizable group selected from the group consisting of vinyl, allyl, styrenic, acrylic, methacrylic, acrylamide, methacrylamide, siloxane, maleimide, norbornene, and combinations thereof;

another one of L_1 and L_2 is an alkyl group selected from the group consisting of linear, branched, and cyclic alkyl group; wherein CH_2 thereof can be replaced by O, S or N in a way that no heteroatoms are connected to each other;

hydrogen can be replaced by F, Cl or CN;

each of R_1, R_2, R_3 can be independently H or an alkyl group selected from the group consisting of linear, branched, and cyclic alkyl group; where CH_2 thereof can be replaced by O, S or N in a way that no heteroatoms are connected to each other; and hydrogen can be replaced by F, Cl or CN; R_2 and R_3 can also be connected to a cyclic unit; preferably, $R_1 = R_2 = H$;

and

anion X^- is selected from the group consisting of halide (F-, Cl-, Br-, I-), BF_4-, PF_6-, $[C_2F_5BF_3]$-, carboxylate RCOO- with R = H, alkyl or aryl; malonate,

citrate, fumarate, $MeOSO_3$-, $MeSO_3$-, CF_3COO-, CF_3SO_3-, nitrate, and sulfate; wherein Me is methyl;

(b) the at least one imidazolium group with structure (I) is in main chain of the imidazolium-based poly(ionic liquid);

wherein

L_1 and L_2 each independently comprises a substituted or unsubstituted aliphatic, cyclic or branched aliphatic, aromatic, heteroaromatic, and siloxane moiety; wherein CH_2 thereof can be replaced by O, S or N in a way that no heteroatoms are connected to each other; hydrogen can be replaced by F, Cl or CN;

L_1, L_2 or both L_1 and L_2 can connect the at least one imidazolium group via suitable functional group to the main chain to form the imidazolium-based poly(ionic liquid); wherein the suitable functional group is selected from group consisting of esters, amides, urethanes, ethers, thioethers, imides, and combinations thereof;

each of R_1, R_2, R_3 can be independently H or an alkyl group selected from the group consisting of linear, branched, and cyclic alkyl group; where CH_2 can be replaced by O, S or N in a way that no heteroatoms are connected to each other; and hydrogen can be replaced by F, Cl or CN; R_2 and R_3 can also be connected to a cyclic unit; preferably, $R_1 = R_2 = H$;

and

anion X^- is selected from the group consisting of halide (F-, Cl-, Br-, I-), BF_4-, PF_6-, $[C_2F_5BF_3]$-, carboxylate RCOO- with R = H, alkyl or aryl; malonate, citrate, fumarate, $MeOSO_3$-, $MeSO_3$-, CF_3COO-, CF_3SO_3-, nitrate, and sulfate, wherein Me is methyl;

and

(c) the at least one imidazolium group with structure (I) are in both the side chain or the side chains of the imidazolium-based poly(ionic liquid) as defined in above (a) and in the main chain of the imidazolium-based poly(ionic liquid) as defined in above (b).

2. The imidazolium-based poly(ionic liquid) of Claim 1, wherein the imidazolium-based poly(ionic liquid) comprises a cross-linkable monomer with polymerizable groups for L_1 and L_2 of (a).

3. The imidazolium-based poly(ionic liquid) of Claim 1, wherein the imidazolium-based poly(ionic liquid) is a copolymer comprising at least two different monomers selected from (a), (b), and (e)a non-ionic monomer which can form copolymers with the monomer in (a) or the monomer in (b) and is selected from the group consisting of acrylate or methacrylate, acrylamide or methacrylamide, maleimide, vinyl benzene, ~~vinyl-type monomer,~~ ethylene glycol, siloxane, norbornene, and combinations thereof.

4. The imidazolium-based poly(ionic liquid) of Claim 1, wherein the imidazolium-based poly(ionic liquid) is a block-copolymer.

5. The imidazolium-based poly(ionic liquid) of Claim 1, wherein the imidazolium-based poly(ionic liquid) comprises at least one of a functional anion as a reducing agent or complexation agent.

6. The imidazolium-based poly(ionic liquid) of Claim 1, wherein polymerization of the imidazolium-based poly(ionic liquid) is 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), polycondensation reaction, and combinations thereof.

7. The imidazolium-based poly(ionic liquid) of Claim 1, wherein the imidazolium-based poly(ionic liquid) is selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylamide) chloride, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, and poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-

co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.

8. A chemical mechanical planarization composition comprising
an additive comprising the imidazolium-based poly(ionic liquid) according to any one of claims 1 to 7;
an abrasive;
water;
and optionally
~~an abrasive;~~
an activator;
an oxidizing agent;
a corrosion inhibitor;
a dishing reducing agent;
a stabilizer;
a pH adjusting agent.

9. The chemical mechanical planarization composition of Claim 8, wherein
the additive ranges from 0.0005 wt.% to 0.01 wt.%;
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 0.5 wt.% to 20 wt.%;
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 ferric nitrite, $KClO_4$, $KBrO_4$, $KMnO_4$; and combinations thereof and the oxidizing agent ranges from 0.1 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 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 ranges from 0.00001 wt.% to 5.0 wt.%;

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 and the corrosion inhibitor ranges less than 1.0 wt.%;

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, 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; polycationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; phosphonium compound; and sulfonic acid polymer; and combinations thereof and the dishing reducing agent ranges from 0.001 wt.% to 2.0 wt. %; ~~and~~

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 stabilizer ranges from 0.0001 wt.% to 5 wt.%; 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, other fatty acids, 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; and pH of the composition is between 1 and 14, or 1 and 6.

~~10. The chemical mechanical planarization composition of Claim 8, wherein~~
~~the abrasive ranges from 0.01 wt.% to 30 wt.%, 0.05 wt.% to 20 wt.%, 0.01 wt.% to 10 wt.%, or from 0.1 wt.% to 2 wt.%;~~
~~the additive comprising an imidazolium-based cationic polymer ranges from 0.00001 wt.% to 1 wt.%, 0.0001 wt.% to 0.5 wt., or 0.0005 wt.% to 0.1 wt.%;~~
~~the oxidizing agent ranges from 0.01 wt.% to 30 wt.%, 0.1 wt.% to 20 wt.%, or 0.5 wt.% to 10 wt.%;~~
~~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.%;~~
~~the corrosion inhibitor ranges from less than 1.0 wt.%, less than 0.5 wt.%, or less than 0.25 wt.%;~~
~~the dishing reducing agent ranges from 0.001 wt.% to 2.0 wt. %, 0.005 wt.% to 1.5 wt. %, or 0.01 wt.% to 1.0 wt. %;~~
~~and~~
~~the stabilizer ranges from 0.0001 to 5 wt.%, 0.0005 to 2 wt.%, or 0.001 to 1 wt.%.~~

~~11. The chemical mechanical planarization composition of Claim 8, wherein 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; and pH of the composition is between 1 and 14, 1 and 7, 1 and 6, or 1 and 4.~~

~~12.~~10. The chemical mechanical planarization composition of Claim 8, wherein the chemical mechanical planarization composition comprises
silica particles; and the imidazolium-based poly(ionic liquid) selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-

acrylamide) chloride, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, and poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.

~~13.~~11. The chemical mechanical planarization composition of Claim 8, wherein the chemical mechanical planarization composition comprises silica particles; ferric nitrate, malonic acid, hydrogen peroxide, the imidazolium-based poly(ionic liquid) selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylamide) chloride, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, and poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.

~~14.~~12. 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 additive comprising the imidazolium-based poly(ionic liquid) according to any one of claims 1 to 7;

an abrasive;

water; and optionally

~~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;

a corrosion inhibitor;

a dishing reducing agent;

a stabilizer;

a pH adjusting agent; and

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

~~15. The polishing method of Claim 14, wherein in the chemical mechanical polishing composition:~~

~~the abrasive ranges from 0.01 wt.% to 30 wt.%, 0.05 wt.% to 20 wt.%, 0.01 wt.% to 10 wt.%, or from 0.1 wt.% to 2 wt.%;~~

~~the additive comprising an imidazolium-based cationic polymer ranges from 0.00001 wt.% to 1 wt.%, 0.0001 wt.% to 0.5 wt., or 0.0005 wt.% to 0.1 wt.%;~~

~~the oxidizing agent ranges from 0.01 wt.% to 30 wt.%, 0.1 wt.% to 20 wt.%, or 0.5 wt.% to 10 wt.%;~~

~~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.%;~~

~~the corrosion inhibitor ranges from less than 1.0 wt.%, less than 0.5 wt.%, or less than 0.25 wt.%;~~

~~the dishing reducing agent ranges from 0.001 wt.% to 2.0 wt. %, 0.005 wt.% to 1.5 wt. %, or 0.01 wt.% to 1.0 wt. %;~~

~~and~~

~~the stabilizer ranges from 0.0001 to 5 wt.%, 0.0005 to 2 wt.%, or 0.001 to 1 wt.%.~~

~~16.~~13. The polishing method of Claim ~~14~~12, wherein in ~~the~~ chemical mechanical polishing composition:

the additive ranges from 0.0005 wt.% to 0.01 wt.%;

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 0.5 wt.% to 20 wt.%;

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 ferric nitrite, $KClO_4$, $KBrO_4$, $KMnO_4$; and combinations thereof and the oxidizing agent ranges from 0.1 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 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 ranges from 0.00001 wt.% to 5.0 wt.%;

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 and the corrosion inhibitor ranges less than 1.0 wt.%;

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, 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; polycationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; phosphonium compound; and sulfonic acid polymer; and combinations thereof and the dishing reducing agent ranges from 0.001 wt.% to 2.0 wt. %; ~~and~~

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 stabilizer ranges from 0.0001 wt.% to 5 wt.%; 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, other fatty acids, 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; and pH of the composition is between 1 and 14, or 1 and 6.

~~17. The polishing method of Claim 14, wherein in the chemical mechanical polishing composition:~~

~~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; and pH of the composition is between 1 and 14, 1 and 7, 1 and 6, or 1 and 4.~~

~~18.~~14. The polishing method of Claim ~~14~~12, wherein the chemical mechanical planarization composition comprises the abrasive; and
the imidazolium-based poly(ionic liquid) selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylamide) chloride, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, and poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.

~~19.~~15. The polishing method of Claim ~~14~~12, wherein the chemical mechanical planarization composition comprises silica particles; ferric nitrate, malonic acid, hydrogen peroxide, the imidazolium-based poly(ionic liquid) selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylamide) chloride, poly (vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly (vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-

1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.

~~20.~~16. The polishing method of Claim ~~14~~12, 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.

~~21.~~17. 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 additive comprising the imidazolium-based poly(ionic liquid) of any one of claims 1 to 7;

an abrasive;

water; and optionally

~~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;

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.

~~22. The system of Claim 21, wherein in the chemical mechanical polishing composition:~~

~~the abrasive ranges from 0.01 wt.% to 30 wt.%, 0.05 wt.% to 20 wt.%, 0.01 wt.% to 10 wt.%, or from 0.1 wt.% to 2 wt.%;~~

~~the additive comprising an imidazolium-based cationic polymer ranges from 0.00001 wt.% to 1 wt.%, 0.0001 wt.% to 0.5 wt., or 0.0005 wt.% to 0.1 wt.%;~~

~~the oxidizing agent ranges from 0.01 wt.% to 30 wt.%, 0.1 wt.% to 20 wt.%, or 0.5 wt.% to 10 wt.%;~~

~~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.%;~~

~~the corrosion inhibitor ranges from less than 1.0 wt.%, less than 0.5 wt.%, or less than 0.25 wt.%;~~

~~the dishing reducing agent ranges from 0.001 wt.% to 2.0 wt. %, 0.005 wt.% to 1.5 wt. %, or 0.01 wt.% to 1.0 wt. %;~~

~~and~~

~~the stabilizer ranges from 0.0001 to 5 wt.%, 0.0005 to 2 wt.%, or 0.001 to 1 wt.%.~~

~~23.~~18. The system of Claim ~~21~~17, wherein in the chemical mechanical polishing composition:

the additive ranges from 0.0005 wt.% to 0.01 wt.%;

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 0.5 wt.% to 20 wt.%;

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 ferric nitrite, $KClO_4$, $KBrO_4$, $KMnO_4$; and combinations thereof and the oxidizing agent ranges from 0.1 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 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 ranges from 0.00001 wt.% to 5.0 wt.%;

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 and the corrosion inhibitor ranges less than 1.0 wt.%;

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~~, 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; polycationic amine compound; cyclodextrin compound; polyethyleneimine compound; glycolic acid; chitosan; sugar alcohols; polysaccharides; alginate compound; phosphonium compound; and sulfonic acid polymer; and combinations thereof and the dishing reducing agent ranges from 0.001 wt.% to 2.0 wt. %; ~~and~~

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 stabilizer ranges from 0.0001 wt.% to 5 wt.%; 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, other fatty acids, 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; and pH of the composition is between 1 and 14, or 1 and 6.

~~24. The system of Claim 21, wherein in the chemical mechanical polishing composition: 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; and pH of the composition is between 1 and 14, 1 and 7, 1 and 6, or 1 and 4.~~

~~25.~~19. The system of Claim ~~21~~17, wherein the chemical mechanical planarization composition comprises

silica particles; and

the imidazolium-based poly(ionic liquid) selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylamide) chloride, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, and poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.

~~26.~~20. The system of Claim ~~21~~17, wherein the chemical mechanical planarization composition comprises silica particles; ferric nitrate, malonic acid, hydrogen peroxide,

the imidazolium-based poly(ionic liquid) selected from the group consisting of poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylamide) chloride,, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-acrylomorpholine) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl benzyl 1-butyl-1*H*-imidazol-3-ium-co-*N*-methyl maleimide) chloride, poly 3-butyl-1*H*-imidazol-3-ium acetate, poly 3-(2,2'-(ethane-1,2-diylbis(oxy))bis(ethane)-1*H*-imidazol-3-ium acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium) chloride, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium-co-vinyl 3,3'-butane-1*H*-imidazol-3-ium) bromide, poly(vinylbenzyl-1-ethyl-1*H*-imidazol-3-ium-co-vinyl-3-ethyl-1*H*-imidazol-3-ium) bromide chloride, poly(1-ethyl-3-propyl-1H-imidazol-3-ium acrylate) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium) bromide, poly(vinyl 3-isopropyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) acetate, poly(vinyl 3-butyl-1*H*-imidazol-3-ium-co-*N*-vinylpyrrolidone) bromide, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) malonate, poly(vinyl 3-ethyl-1*H*-imidazol-3-ium) nitrate, and combinations thereof.