CLAIMS

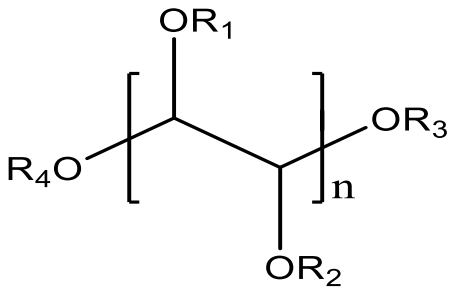
1. A chemical mechanical polishing composition comprising:

at least one ceria-coated inorganic oxide particles;

at least one nitrogen-containing aromatic heterocyclic compound;

at least one non-ionic organic molecule having more than one hydroxyl functional group selected from a group comprising:

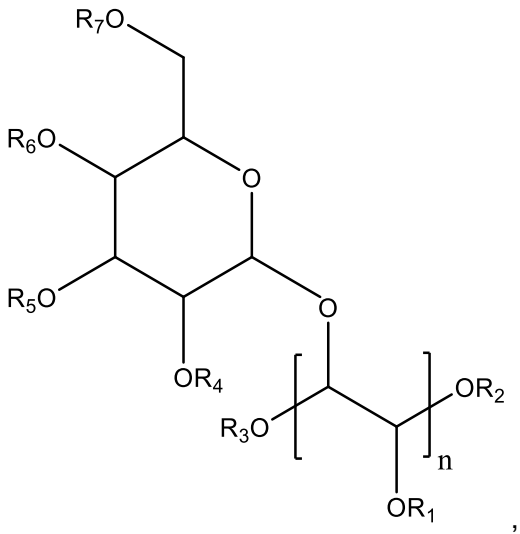
(a)



,

wherein n is selected from the group consisting of from 1 to 5,000, from 2 to 12, and from 3 to 6; R_1, R_2, R_3, and R_4 can be the same or different atoms or functional groups selected independently from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid, substituted organic sulfonic acid salt, substituted organic carboxylic acid, substituted organic carboxylic acid salt, organic carboxylic ester, organic amine groups, and combinations thereof; wherein, at least two of R_1, R_2, R_3, and R_4, are a hydrogen atom;

(b)



,

wherein n is selected from the group consisting of from 1 to 5,000, from 1 to 100, from 1 to 12, and from 2 to 6; R_1, R_2, R_3, R_4, R_5, R_6, and R_7 can be the same or different atoms or functional groups selected independently from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid, substituted organic sulfonic acid salt, substituted organic carboxylic acid, substituted organic carboxylic acid salt, organic carboxylic ester, organic amine groups, and combinations thereof; wherein, at least two of R_1, R_2, R_3, R_4, R_5, R_6, and R_7 are hydrogen atoms; and

(c) combinations of (a) and (b) thereof;

at least one solvent; and

optionally, a biocide; and

optionally, at least one a pH adjuster,

wherein the composition has a pH of from 2 to 12.

2. The chemical mechanical polishing composition of claim 1 wherein the pH is from 3 to 10.

3. The chemical mechanical polishing composition of claim 2 wherein the pH is from 4 to 9.

4. The chemical mechanical polishing composition of claim 1, wherein the ceria-coated inorganic oxide particles are at least one selected from the group consisting of ceria-coated colloidal silica, ceria-coated high purity colloidal silica, ceria-coated alumina,

ceria-coated titania, ceria-coated zirconia particles and combinations thereof, wherein the particles are present in the composition at range selected from the group consisting of from 0.01 wt.% to 20 wt.%., from 0.05 wt.% to 10 wt.%, and from 0.1 wt.% to 5 wt.%.

5. The chemical mechanical polishing composition of claim 4, wherein the ceria-coated inorganic oxide particles are present in the composition at range of from 0.05 wt.% to 10 wt.%.

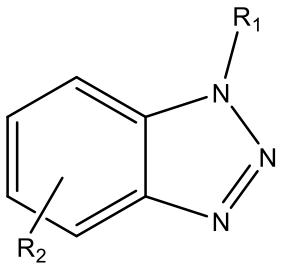
6. The chemical mechanical polishing composition of claim 5, wherein the ceria-coated inorganic oxide particles are present in the composition at range of from 0.1 wt.% to 5 wt.%.

7. The chemical mechanical polishing composition of claim 1, wherein the ceria-coated inorganic oxide particles are at least one selected from the group consisting of ceria-coated colloidal silica, ceria-coated high purity colloidal silica, ceria-coated alumina, ceria-coated titania, ceria-coated zirconia particles and combinations thereof, wherein the concentration of the particles are present at a concentration range selected from the group consisting of from 0.01 wt.% to 2.00 wt.%, from 0.025 wt.% to 1.0 wt.%, and from 0.05 wt.% to 0.5 wt.%.

8. The chemical mechanical polishing composition of claim 1, wherein the at least one solvent is selected from the group consisting of deionized (DI) water, distilled water, and an alcohol-containing organic solvent.

9. The chemical mechanical polishing composition of claim 1, wherein the at least one nitrogen-containing aromatic heterocyclic compound is present in the composition at a concentration selected from the group consisting of from 0.0001 wt.% to 2.0% wt.%, from 0.001 wt.% to 1.0 wt.%, and from 0.0025 wt.% to 0.25 wt.%**,** wherein the at least one nitrogen-containing aromatic heterocyclic compound has a general molecular structure selected from a group comprising:

(a)



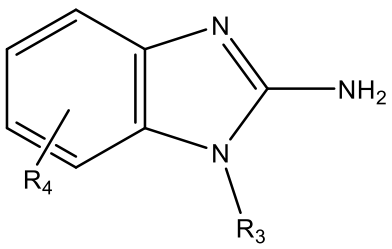
wherein

R_1 is selected from the group consisting of hydrogen, alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH_4+), $-HPO_4M$ (M= Na+, K+ or NH4+), $-PO_4M_2$ (M= Na+, K+ or NH4+), and combinations thereof;

and

R_2 can be present or not present; R_2 is selected from the group consisting of alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH_4+), $-HPO_4M$ (M= Na+, K+ or NH_4+), $-PO_4M_2$ (M= Na+, K+ or NH_4+), and combinations thereof;

(b)



wherein

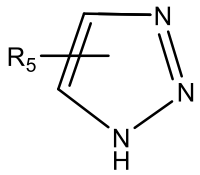
R_3 is selected from the group consisting of hydrogen, alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with

single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH_4+), $-HPO_4M$ (M= Na+, K+ or NH_4+), $-PO_4M_2$ (M= Na+, K+ or NH_4+), and combinations thereof;

and

R_4 can be present or not present and, when present, R_4 is selected from the group consisting of alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH_4+), $-HPO_4M$ (M= Na+, K+ or NH_4+), $-PO_4M_2$ (M= Na+, K+ or NH_4+), and combinations thereof;

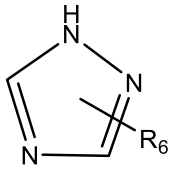
(c)



wherein

R_5 can be present or not present; R_5 is selected from the group consisting of alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH4+), $-HPO_4M$ (M= Na+, K+ or NH_4+), $-PO_4M_2$ (M= Na+, K+ or NH_4+), and combinations thereof;

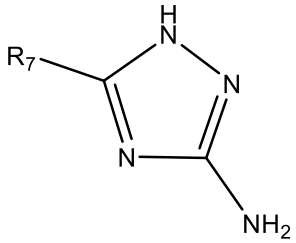
(d)



wherein

R_6 can be present or not present; R_6 is selected from the group consisting of alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH_4+), $-HPO_4M$ (M= Na+, K+ or NH_4+), $-PO_4M_2$ (M= Na+, K+ or NH_4+), and combinations thereof;

(e)



wherein

R_7 can be present or not present; R_7 is selected from the group consisting of alkyl groups with straight chain or branched chain, alkoxy groups with straight chain or branched chain, alkene groups with single or multi carbon to carbon double bonds, alkyne groups with single or multi carbon to carbon triple bonds, primary amine groups, secondary amino groups, tertiary amino groups, cationic organic quaternary ammonium groups, -COOH, $-SO_3H$, $-H_2PO_4$, -COOR', -COOM (M= Na+, K+ or NH_4+), $-SO_3M$ (M= Na+, K+ or NH_4+), $-HPO_4M$ (M= Na+, K+ or NH_4+), $-PO_4M_2$ (M= Na+, K+ or NH_4+), and combinations thereof;

and

(f) combinations thereof.

10. The chemical mechanical polishing composition of claim 9, wherein the at least one nitrogen-containing aromatic heterocyclic compound is selected from the group consisting of

(1) benzotriazole when R_1 is a hydrogen atom and R_2 is not present; or

a derivative molecule of benzotriazole when R_1 is an organic function group other than hydrogen atom, and R_2 is another organic functional group attached at any positions of -4, -5, 6, or -7 on benzene ring;

(2) 2-aminobenzimidazole when R_3 is a hydrogen atom and R_4 is not present; or

a derivative molecule of 2-aminobenzimidazole when R_3 is an organic function group other than hydrogen atom, and R_4 is another organic functional group attached at any positions of -4, -5, 6, or -7 on benzene ring;

(3) 1,2,3-triazole when R_5 is not present; or

a derivative molecule of 1,2,3-triazole when R_5 is an organic function group attached at any positions of -4 or -5 on 1,2,3-triazole ring;

(4) 1,2,4-triazole when R_6 is not present; or

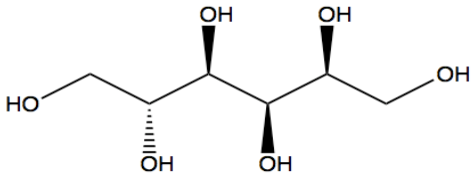
a derivative molecule of 1,2,4-triazole when R_6 is an organic function group attached at any positions of -3, or -5 on 1,2,4-triazole ring; and

(5) 3-amino-1,2,4-triazole or amitrole when R_7 is not present; or

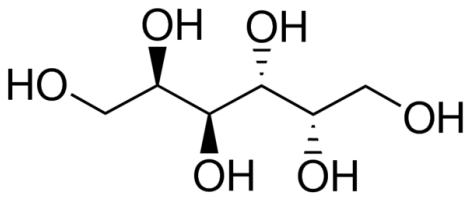
a derivative molecule of 3-amino-1,2,4-triazole when R_7 is an organic function group attached at position -5 on 3-amino-1,2,4-trizole ring.

11. The chemical mechanical polishing composition of claim 1, wherein the at least one non-ionic organic molecule having more than one hydroxyl functional group is present in the composition at a concentration ranging selected from the group consisting of from 0.001 wt.% to 2.0% wt.%, from 0.0025 wt.% to 1.0 wt.%, and from 0.05 wt.% to 0.5 wt.%.

12. The chemical mechanical polishing composition of claim 1, wherein R_1, R_2, R_3 and R_4 are all hydrogen atoms in structure (a), the non-ionic organic molecule is:

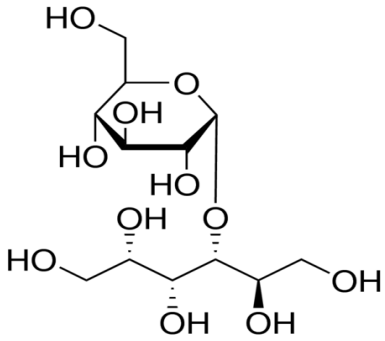


D-sorbitol; or

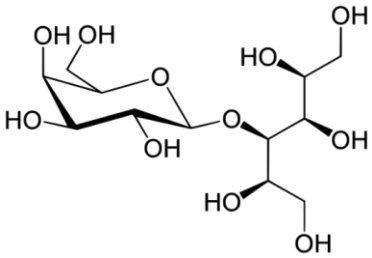


Dulcitol.

13. The chemical mechanical polishing composition of claim 1, wherein R_1, R_2, R_3, R_4, R_5, R_6, and R_7 are all hydrogen atoms in structure (b), the non-ionic organic molecule is:



Maltitol, or



Lactitol.

14. The chemical mechanical polishing composition of claim 1, wherein the composition further comprises from 0.0001 wt.% to 0.05 wt.% of the biocide, wherein the biocide comprises 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl- -isothiazolin-3-one.

15. The chemical mechanical polishing composition of claim 1, wherein the composition further comprises from 0 wt.% to 1 wt.% of the pH adjusting agent wherein the Ph adjusting agent is selected from the group consisting of nitric acid, hydrochloric acid, sulfuric acid, phosphoric acid, other inorganic or organic acids, and mixtures thereof for acidic pH conditions; or selected from the group consisting of sodium hydride, potassium hydroxide, ammonium hydroxide, tetraalkyl ammonium hydroxide, organic quaternary ammonium hydroxide compounds, organic amines, and combinations thereof for alkaline pH conditions.

16. The chemical mechanical polishing composition of claim 1, comprising ceria-coated colloidal silica, the at least one nitrogen-containing aromatic heterocyclic compound is selected from the group consisting of benzotriazole and its derivatives, 2-aminobenzimidazole and its derivatives, amitrole and its derivatives, triazole and its derivatives, and combinations thereof; and the at least one non-ionic organic molecule having more than one hydroxyl functional group is selected from the group consisting of Dulcitol, D-sorbitol, Maltitol, Lactitol, and combinations thereof.

17. A method of chemical mechanical polishing (CMP) a semiconductor substrate having at least one surface comprising a silicon oxide film, the method comprising the steps of:

providing the semiconductor substrate;

providing a polishing pad;

providing the chemical mechanical polishing (CMP) composition of claim 1;

contacting the surface of the semiconductor substrate with the polishing pad and the chemical mechanical polishing composition; and

polishing the least one surface comprising silicon dioxide.

18. The method of claim 17, wherein the silicon oxide film is SiO_2.

19. The method of claim 17, wherein the semiconductor substrate further comprises a silicon nitride surface.

20. A system of chemical mechanical polishing (CMP) a semiconductor substrate having at least one surface comprising silicon oxide, the system comprising:

    a. a semiconductor substrate;

    b. the chemical mechanical polishing (CMP) composition of claim 1;

    c. a polishing pad,

    wherein the at least one surface comprising silicon oxide film is in contact with the polishing pad and the chemical mechanical polishing composition.

21. The system of claim 20; wherein the silicon oxide film is SiO_2.

22. The system of claim 20; wherein the semiconductor substrate further comprises a silicon nitride surface.