removal rate tuning and oxide trench dishing reducing and more uniform oxide trench dishing on the polished patterned wafers along with the tunable oxide vs nitride selectivity.

[0015] Therefore, it should be readily apparent from the foregoing that there remains a need within the art for compositions, methods and systems of STI chemical mechanical polishing that can afford the tunable oxide film removal rates, the tunable SiN film removal rates and the reduced oxide trench dishing and more uniformed oxide trench dishing across various sized oxide trench features on polishing patterned wafers in a STI chemical and mechanical polishing (CMP) process.

SUMMARY OF THE INVENTION

[0016] The present invention provides STI CMP polishing compositions for the tunable oxide film removal rates with the use of relative low concentrations of ceria-coated inorganic oxide abrasives, the tunable SiN film removal rates and the tunable TEOS: SiN selectivity and the reduced oxide trench dishing on the polished patterned wafers.

[0017] The present invented STI CMP polishing compositions provides tunable oxide vs nitride selectivity by introducing dual chemical additives for tuning oxide and SiN film removal rates and reducing oxide trenching dishing in the chemical mechanical polishing (CMP) compositions for Shallow Trench Isolation (STI) CMP applications at wide pH range including acidic, neutral and alkaline pH conditions.

[0018] The disclosed chemical mechanical polishing (CMP) compositions for Shallow Trench Isolation (STI) CMP applications have a unique combination of using ceria-coated inorganic oxide abrasive particles and the suitable dual chemical additives as oxide film and nitride film removal rate tuning agents, and oxide trench dishing reducing agents.

[0019] In one aspect, there is provided 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; 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.

DETAILED DESCRIPTION OF THE INVENTION

[0024] In the global planarization of patterned STI structures, tuning SiN removal rates, reducing oxide trench dishing across various sized oxide trench features, tuning oxide film removal rates, and using relative low concentrations of ceria-coated inorganic oxide particles as abrasives are the key factors to be considered.

[0025] The lower trench oxide loss will prevent electrical current leaking between adjacent transistors. Non-uniform trench oxide loss across die (within die) will affect transistor performance and device fabrication yields. Severe trench oxide loss (high oxide trench dishing) will cause poor isolation of transistor resulting in device failure. Therefore, it is important to reduce trench oxide loss by reducing oxide trench dishing in STI CMP polishing compositions.

[0026] This development relates to Chemical Mechanical Polishing (CMP) compositions using chemical additives and ceria-coated composite particles as abrasives for Shallow Trench Isolation (STI) CMP applications.

[0027] More specifically, the disclosed chemical mechanical polishing (CMP) composition for Shallow Trench Isolation (STI) CMP applications have a unique combination of using ceria-coated inorganic oxide abrasive particles and two types of chemical additives as dual chemical additives for oxide film removal rate tuning, oxide trench dishing reducing and nitride removal rate tuning.

[0028] Dual chemical additives used in the same STI CMP polishing compositions provide the benefits of achieving desirable oxide film removal rates, tunable SiN film removal rates, and tunable Oxide: SiN selectivity, and more importantly, providing significantly reduced oxide trench dishing and improving over polishing window stability on polishing patterned wafers.

[0029] The first chemical additive (also referred to herein as Type I) comprises at least one nitrogen-containing aromatic heterocyclic compound such as, for example, benzotriazole and its derivatives, 2-aminobenzimidazole and its derivatives, amitrole and its derivatives, and triazole and its derivatives.

[0030] The second chemical additive (also referred to herein as Type II) comprises at least one non-ionic organic molecule having more than one hydroxyl functional group.

[0031] In one aspect, there is provided a STI CMP polishing composition comprises 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; 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

[0032] The ceria-coated inorganic oxide particles include, but are not limited to, ceria-coated colloidal silica, ceria-coated alumina, ceria-coated titania, ceria-coated zirconia, or any other ceria-coated inorganic oxide particles.

[0033] The particle sizes of these ceria-coated inorganic oxide particles in the disclosed invention herein are ranged from 10 nm to 1,000 nm, the preferred mean particle sized are ranged from 20 nm to 500 nm, the more preferred mean particle sizes are ranged from 50 nm to 250 nm.

[0034] In some embodiments, the concentrations of these ceria-coated inorganic oxide particles range from 0.01 wt.% to 20 wt.%, the preferred concentrations range from 0.05 wt.% to 10 wt.%, and the more preferred concentrations range from 0.1 wt.% to 5 wt.%.

[0035] In some other embodiments, the concentrations of these ceria-coated inorganic oxide particles range from 0.01 wt.% to 2wt.%, the preferred concentrations range from 0.025 wt.% to 1.0 wt.%, the more preferred concentrations range from 0.05 wt.% to 0.5 wt.%.

[0036] The preferred ceria-coated inorganic oxide particles are ceria-coated colloidal silica particles.

[0037] The solvent includes but is not limited to deionized (DI) water, distilled water, and alcoholic organic solvents.

[0038] The preferred solvent is DI water.

[0039] The STI CMP composition may contain a biocide from 0.0001 wt.% to 0.05 wt.%; preferably from 0.0005 wt.% to 0.025 wt.%, and more preferably from 0.001 wt.% to 0.01 wt.%.

[0040] The biocide includes, but is not limited to, Kathon™, Kathon™ CG/ICP II, from Dupont/Dow Chemical Co. Bioban from Dupont/Dow Chemical Co. They have active ingredients of 5-chloro-2-methyl-4-isothiazolin-3-one and 2-methyl-4-isothiazolin-3-one.

[0041] The STI CMP composition may contain a pH adjusting agent.

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;
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.%.

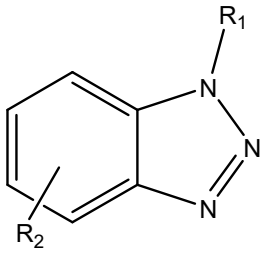
6. The chemical mechanical polishing composition of claim 5, wherein the ceria-coated inorganic oxide particles are present in the composition at range of from 0.1 wt.% to 5 wt.%.

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)



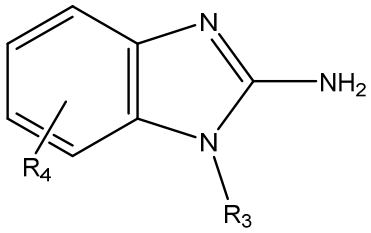
wherein

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)



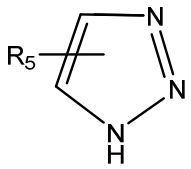
wherein

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;

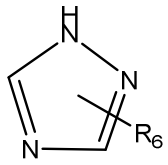
(c)



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;

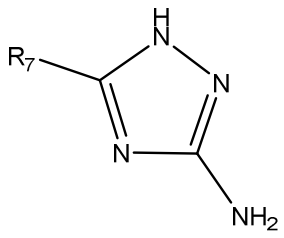
(d)



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

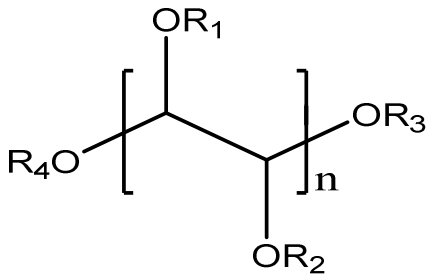
a derivative molecule of 1,2,4-triazole when R_6 is an organic function group attached at any positions of -3, or -5 on 1,2,4-triazole ring; and

(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.%; and have the general molecular structures selected from a group comprising:

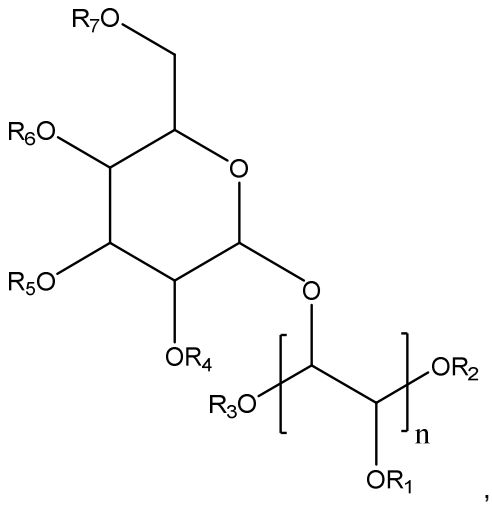
(a)



,

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)



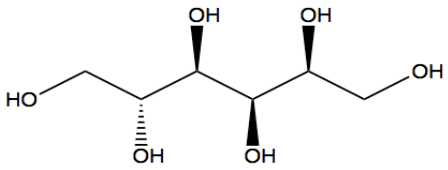
,

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

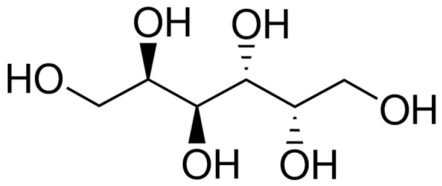
(c) combinations of (a) and (b) thereof;

and the non-ionic organic molecule has a concentration range 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 11, wherein R_1, R_2, R_3 and R_4 are all hydrogen atoms in structure (a), the non-ionic organic molecule is:

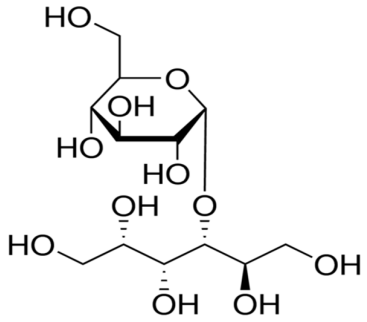


D-sorbitol; or

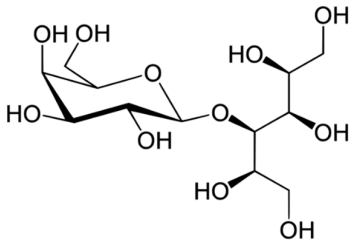


Dulcitol.

13. The chemical mechanical polishing composition of claim 11, 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.