Claims

1. A Chemical Mechanical Polishing(CMP) composition comprising:

abrasive particles selected from the group consisting of

ceria-coated inorganic oxide particles 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;

ceria-coated organic polymer particles selected from the group consisting of ceria-coated polystyrene particles, ceria-coated polyurethane particle, ceria-coated polyacrylate particles, and combinations thereof; and

combinations thereof;

chemical additive;

solvent selected from the group consisting of deionized (DI) water, distilled water, and alcoholic organic solvents; and

optionally

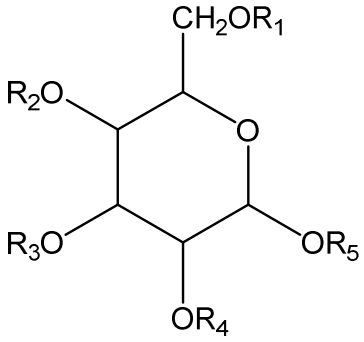
biocide; and

pH adjuster;

wherein

the composition has a pH of 2 to 12; and

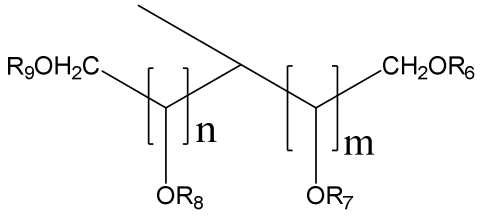
the chemical additive has at least four hydroxyl functional groups in its molecular structure as shown in (a)



(a)

wherein R1, R2, R3, R4 and R5 (Rs in group of R1 to R5) are selected from the group consisting of

(1) (i)at least one R in the group of R1 to R5 is a polyol molecular unit having a structure shown in (b):



(b);

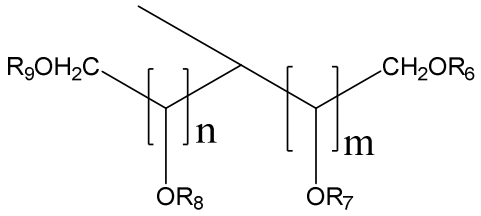
wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(ii)each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(2) (i)at least one R in the group of R1 to R5 is a polyol molecular unit having a structure shown in (b):

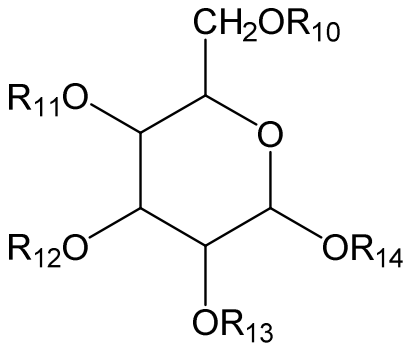


(b);

wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic

acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

(ii)at least one R in the group of R1 to R5 is a six-member ring polyol as shown in (c):



(c);

wherein one of OR in group of OR11, OR12, OR13 and OR14 will be replaced by O in structure (c); and R10 and each of other R in group of R11, R12, R13 and R14 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(iii)each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof.

2. The Chemical Mechanical Polishing(CMP) composition of Claim 1, wherein the abrasive particles range from 0.05 wt.% to 10 wt.% and have mean particle size ranging from 5nm to 500nm;

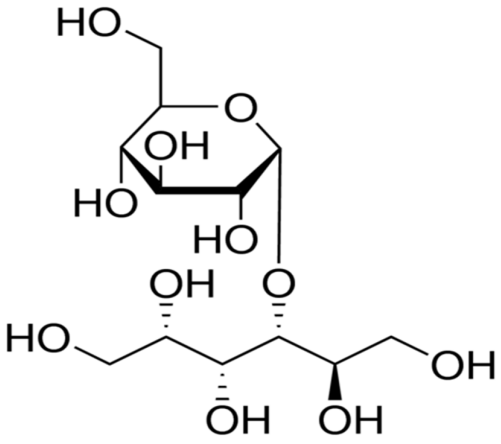
the chemical additive ranges from 0.01 wt.% to 20.0% wt.% and has at least six hydroxyl functional groups in its molecular structure; and

the composition has a pH of 3 to 10.

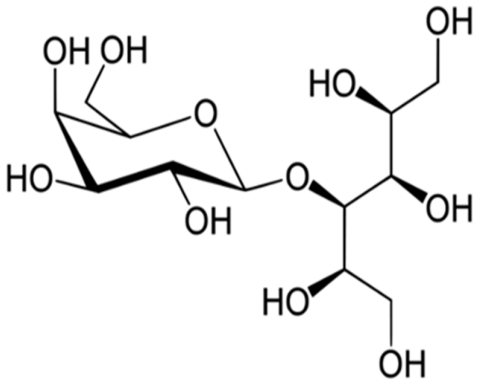
3. The Chemical Mechanical Polishing(CMP) composition of Claim 2, wherein abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 5.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under.

4. The Chemical Mechanical Polishing(CMP) composition of Claim 1, wherein
the abrasive particles having mean particle size ranging from 5nm to 500nm, and have a concentration from 0.05 wt.% to 10 wt.%;
the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (1), and ranges from 0.05 wt.% to 5 wt.%;
the composition has a pH of 3 to 10; and
the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under.

5. The Chemical Mechanical Polishing(CMP) composition of Claim 4, wherein the polyol molecular unit (b) has n = 2 and m =1; and rest of Rs in the group of R1 to R9 are all hydrogen atoms, as shown below:



Maltitol; or



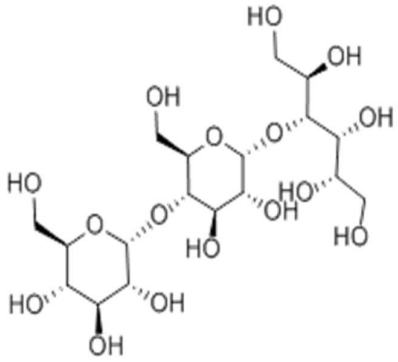
Lactitol;

the solvent is deionized (DI) water; and

the ceria-coated colloidal silica particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 2.0%.

6. The Chemical Mechanical Polishing(CMP) composition of Claim 1, wherein
the abrasive particles having mean particle size ranging from 5nm to 500nm, and have a concentration from 0.05 wt.% to 10 wt.%;
the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (2), and range from 0.05 wt.% to 5 wt.%;
the composition has a pH of 3 to 10; and
the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under.

7. The Chemical Mechanical Polishing(CMP) composition of Claim 6, wherein the polyol molecular unit (b) which has n = 2 and m =1; and rest of Rs in the group of R1 to R14 are all hydrogen atoms, as shown below:



Maltotritol;

and the solvent is deionized (DI) water, and

the ceria-coated colloidal silica particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 2.0%.

8. The chemical mechanical polishing composition of Claim 1, wherein the composition comprises ceria-coated colloidal silica particles; the chemical additive selected from the group consisting of maltitol, lactitol, maltotritol and combinations thereof; and water.

9. The chemical mechanical polishing composition of Claim 1, wherein the composition comprises one selected from the group consisting of from 0.0001 wt.% to 0.05 wt.% of the biocide having active ingredient selected from the group consisting of 5-chloro-2-methyl-4-isothiazolin-3-one, 2-methyl- -isothiazolin-3-one,and combinations thereof; from 0 wt.% to 1 wt.% of the pH adjusting agent 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; and combinations thereof.

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

(a)providing the semiconductor substrate;

(b)providing a polishing pad;

(c)providing a chemical mechanical polishing (CMP) composition comprising

abrasive particles selected from the group consisting of

ceria-coated inorganic oxide particles 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;

ceria-coated organic polymer particles selected from the group consisting of ceria-coated polystyrene particles, ceria-coated polyurethane particle, ceria-coated polyacrylate particles, and combinations thereof; and

combinations thereof;

chemical additive;

solvent selected from the group consisting of deionized (DI) water, distilled water, and alcoholic organic solvents; and

optionally

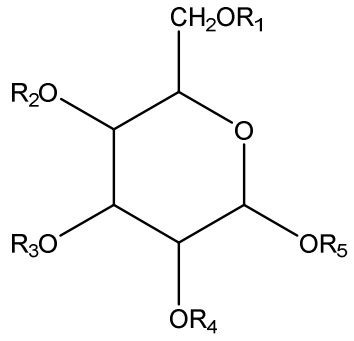
biocide; and

pH adjuster;

wherein

the composition has a pH of 2 to 12; and

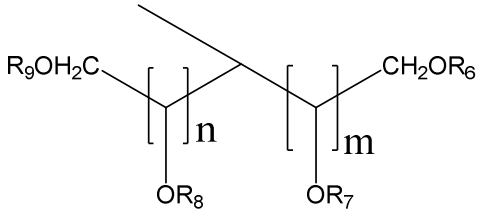
the chemical additive has at least four hydroxyl functional groups in its molecular structure as shown in (a):



(a)

wherein R1, R2, R3, R4 and R5 (Rs in group R1 to R5) are selected from the group consisting of

(1) (i)at least one R in the group of R1 to R5 is a polyol molecular unit having a structure shown in (b):



(b);

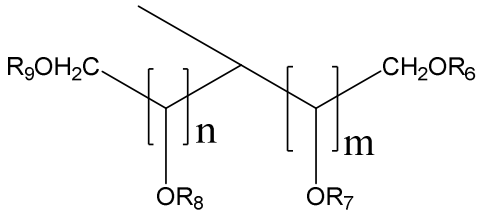
wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(ii)each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(2) (i)at least one R in group of R1 to R5 is a polyol molecular unit having a structure shown in (b):

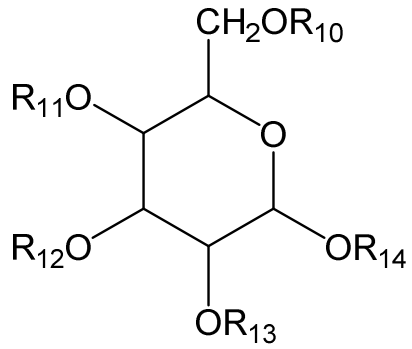


(b);

wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic

sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

(ii)at least one R in group of R1 to R5 is a six-member ring polyol as shown in (c):



(c);

wherein one of OR in group of OR11, OR12, OR13 and OR14 will be replaced by O in structure (c); and R10 and each of other R in group of R11, R12, R13 and R14 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(iii)each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

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

(e)polishing the least one surface comprising silicon dioxide film;

wherein the silicon oxide film is selected from the group consisting of Chemical vapor deposition (CVD), Plasma Enhance CVD (PECVD), High Density Deposition CVD(HDP), or spin on silicon oxide film, flowable CVD oxide film, carbon doped oxide film, nitrogen doped oxide film, and combinations thereof.

11. The method of claim 10; wherein

the chemical mechanical polishing (CMP) composition comprises

0.05 wt.% to 10 wt.% of the abrasive particles having mean particle size ranging from 5nm to 500nm;

0.01 wt.% to 20.0% wt.% of the chemical additive having at least six hydroxyl functional groups in its molecular structure;

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 5.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under; and

the chemical mechanical polishing (CMP) composition has a pH of 3 to 10.

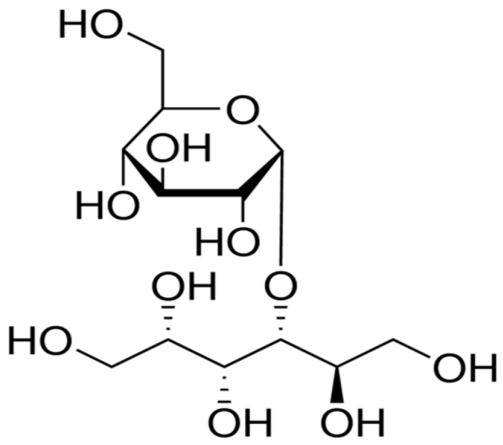
12. The method of claim 11; wherein

the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (1);

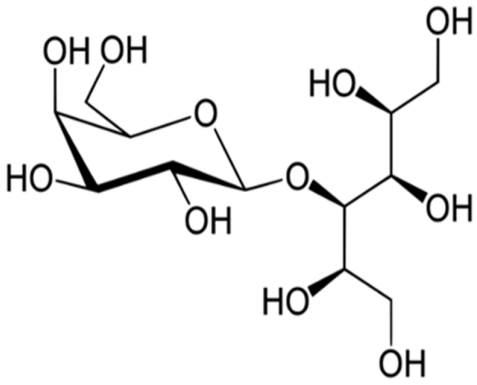
the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under; and

ratio of oxide trench dishing rate (Å/min.) vs the blanket oxide film removal rate(Å/min.) is ≤ 0.1.

13. The method of claim 12, wherein the polyol molecular unit (b) in the chemical additive has n = 2 and m =1; and rest of Rs in the group of R1 to R9 are all hydrogen atoms, as shown below:



Maltitol; or



Lactitol;

the solvent is deionized (DI) water;

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 2.0%; and

ratio of oxide trench dishing rate (Å/min.) vs the blanket oxide film removal rate(Å/min.) is ≤ 0.05.

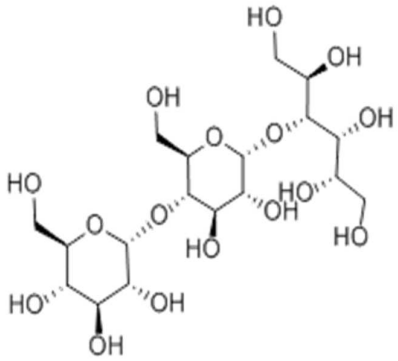
14. The method of claim 11; wherein

the abrasive particles are ceria-coated colloidal silica particles;

the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (2);

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under;
and
ratio of oxide trench dishing rate (Å/min.) vs the blanket HDP film removal rate(Å/min.) is ≤ 0.1.

15. The method of claim 14, wherein the polyol molecular unit (b) in the chemical additive has n = 2 and m =1; and rest of Rs in the group of R1 to R14 are all hydrogen atoms, as shown below:



Maltotritol;

and the solvent is deionized (DI) water;

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 2.0%; and

ratio of oxide trench dishing rate (Å/min.) vs the blanket oxide film removal rate(Å/min.) is ≤ 0.05.

16. The method of claim 11, wherein the composition comprises ceria-coated colloidal silica particles; the chemical additive selected from the group consisting of maltitol, lactitol, maltotritol and combinations thereof; and water.

17. The method of claim 11, wherein the composition comprises one selected from the group consisting of from 0.0001 wt.% to 0.05 wt.% of the biocide having active ingredient selected from the group consisting of 5-chloro-2-methyl-4-isothiazolin-3-one, 2-methyl- -isothiazolin-3-one,and combinations thereof; from 0 wt.% to 1 wt.%

of the pH adjusting agent 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; and combinations thereof.

18. The method of claim 10; wherein the semiconductor substrate further comprises a silicon nitride surface; and removal selectivity of silicon oxide: silicon nitride is greater than 20.

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

a. the semiconductor substrate;

b. a polishing pad; and

c. a chemical mechanical polishing (CMP) composition comprising

abrasive particles selected from the group consisting of

ceria-coated inorganic oxide particles 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;

ceria-coated organic polymer particles selected from the group consisting of ceria-coated polystyrene particles, ceria-coated polyurethane particle, ceria-coated polyacrylate particles, and combinations thereof; and

combinations thereof;

chemical additive;

solvent selected from the group consisting of deionized (DI) water, distilled water, and alcoholic organic solvents; and

optionally

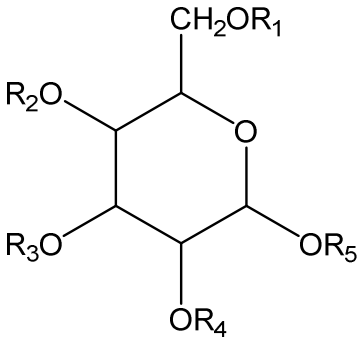
biocide; and

pH adjuster;

wherein

the composition has a pH of 2 to 12; and

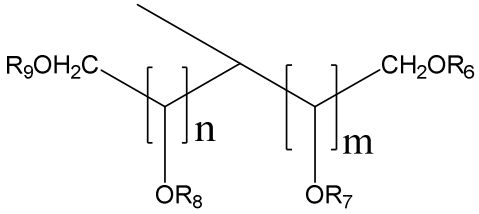
the chemical additive has at least four hydroxyl functional groups in its molecular structure as shown in (a):



(a)

wherein R1, R2, R3, R4 and R5 (Rs in group R1 to R5) are selected from the group consisting of

(1) (i)at least one R in the group of R1 to R5 is a polyol molecular unit having a structure shown in (b):



(b);

wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

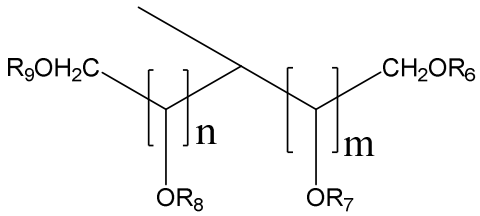
and

(ii)each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic

carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

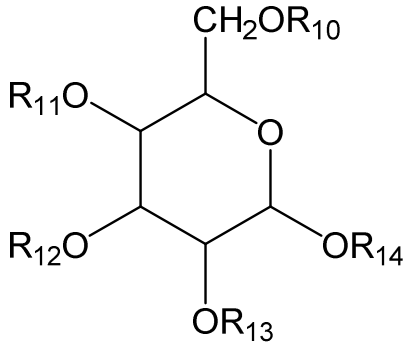
(2) (i)at least one R in group of R1 to R5 is a polyol molecular unit having a structure shown in (b):



(b);

wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

(ii)at least one R in group of R1 to R5 is a six-member ring polyol as shown in (c):



(c);

wherein one of OR in group of OR11, OR12, OR13 and OR14 will be replaced by O in structure (c); and R10 and each of other R in group of R11, R12, R13 and R14 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

and

(iii)each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

wherein

the silicon oxide film is selected from the group consisting of Chemical vapor deposition (CVD), Plasma Enhance CVD (PECVD), High Density Deposition CVD(HDP), or spin on silicon oxide film; and flowable CVD oxide film, carbon doped oxide film, nitrogen doped oxide film, and combinations thereof;

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

20. The system of claim 19; wherein

the chemical mechanical polishing (CMP) composition comprises

0.05 wt.% to 10 wt.% of the abrasive particles having mean particle size ranging from 5nm to 500nm;

0.01 wt.% to 20.0% wt.% of the chemical additive having at least six hydroxyl functional groups in its molecular structure;

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 5.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under; and

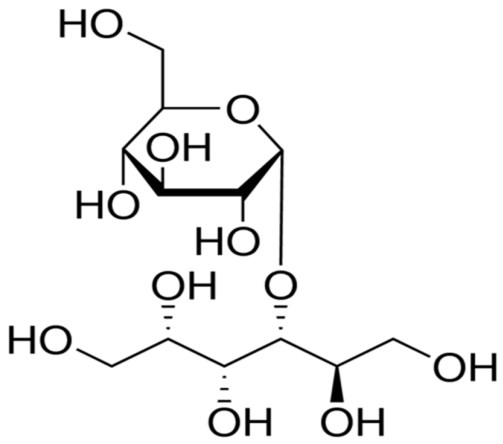
the chemical mechanical polishing (CMP) composition has a pH of 3 to 10.

21. The system of claim 19; wherein

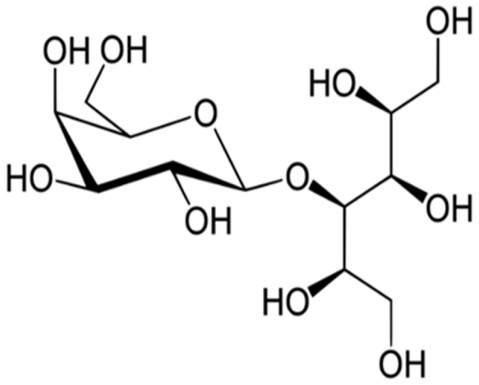
the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (1);

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under; and ratio of oxide trench dishing rate (Å/min.) vs the blanket oxide film removal rate(Å/min.) is ≤ 0.1.

22. The system of claim 21, wherein the polyol molecular unit (b) in the chemical additive has n = 2 and m =1; and rest of Rs in the group of R1 to R9 are all hydrogen atoms, as shown below:



Maltitol; or



Lactitol;

the solvent is deionized (DI) water; and

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 2.0%; and

ratio of oxide trench dishing rate (Å/min.) vs the blanket oxide film removal rate(Å/min.) is ≤ 0.05.

23. The system of claim 19; wherein

the abrasive particles are ceria-coated colloidal silica particles;

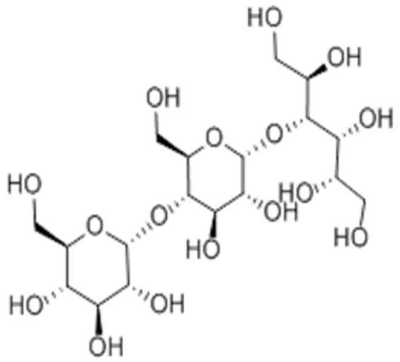
the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (2);

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 ^{0}C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under;

and

ratio of oxide trench dishing rate (Å/min.) vs the blanket HDP film removal rate(Å/min.) is ≤ 0.1.

24. The system of claim 23; wherein the polyol molecular unit (b) in the chemical additive has n = 2 and m =1; and rest of Rs in the group of R1 to R14 are all hydrogen atoms, as shown below:



Maltotritol;

and the solvent is deionized (DI) water, and

the ceria-coated colloidal silica particles have changes of mean particle size MPS(nm) and D99(nm) ≤ 2.0%; and

ratio of oxide trench dishing rate (Å/min.) vs the blanket oxide film removal rate(Å/min.) is ≤ 0.05.

25. The system of claim 19; wherein the composition comprises ceria-coated colloidal silica particles; the chemical additive selected from the group consisting of maltitol, lactitol, maltotritol and combinations thereof; and water.

26. The system of claim 19; wherein the composition comprises one selected from the group consisting of from 0.0001 wt.% to 0.05 wt.% of the biocide having active ingredient selected from the group consisting of 5-chloro-2-methyl-4-isothiazolin-3-one, 2-methyl- -isothiazolin-3-one,and combinations thereof; from 0 wt.% to 1 wt.% of the pH adjusting agent 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; and combinations thereof.