CLAIMS

1. A chemical mechanical polishing composition comprising:

at least one ceria-coated inorganic oxide particles;

at least one silicone-containing compound comprising at least one selected from the group consisting of at least one ethylene oxide and propylene oxide (EO-PO) group, and at least one substituted ethylene diamine group;

at least one non-ionic organic molecule having at least two hydroxyl functional groups;

solvent;

optionally,

a biocide; and

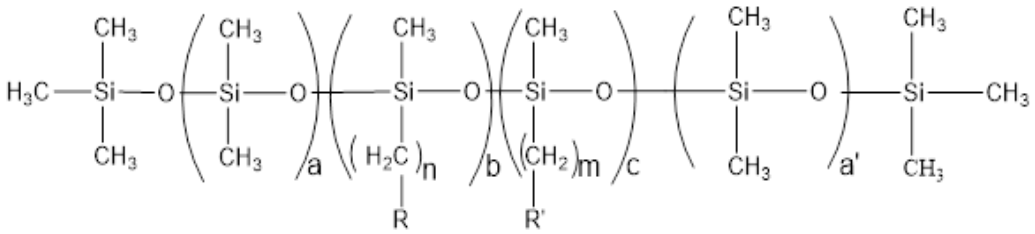
pH adjuster,

wherein

the composition has a pH ~~selected from the group consisting~~ of ~~2 to 12,~~ 3 to 10, or 4 to 9~~, and 5 to 7~~; and

the at least one silicone-containing compound has a general molecular structure selected from the group comprising of:

(1)



,

wherein

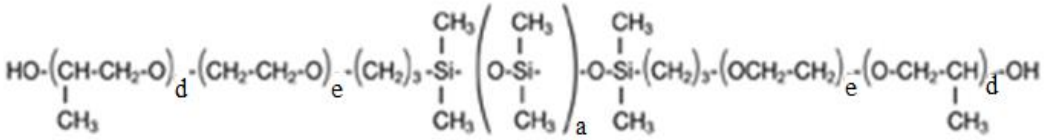
a and a' each is independently ranged from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~; wherein at least one of a and a' is not 0;

b and c each is independently ranged from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~; wherein at least one of b and c is not 0;

n and m can be the same or different, and each is independently ranged from 1 to 12, ~~1 to 8,~~ or 1 to 5~~, or 2 to 4~~;

R and R' can be the same or different, and each is independently selected from the group consisting of hydrogen; $–(CH_2)_pCH_3$ with p ranged from 1 to 12 or 2 to 5; $-NH_2$; $-NH(CH_2)_q-NH_2$ with q ranged from 1 to 12 or from 2 to 5; ethylene oxide(EO) and propylene oxide (PO) repeating group $-(EO)_e-(PO)_d-OH$ with d and e each independently selected from the group consisting of from 1 to 50, 1 to 40, 1 to 30, 1 to 20, 1 to 10, and 1 to 5; -COOH; -COOM; $-COOR^1$; $-R^1COOH$; $-R^1COOM$; $-R^1COOR^2$; $-SO_3H$; $-SO_3M$; $-R^1SO_3H$; phosphonic acid; phosphate salt selected from sodium, potassium or ammonium salts; benzyl; di-benzyl; wherein R^1 and R^2 each is independently selected from the group consisting of $–(CH_2)_m$ with m ranged from 1 to 12, and $–(C_6H_4)_n$ with n ranged from 1 to 4; and M is selected from the group consisting of sodium, potassium, and ammonium;

(2)



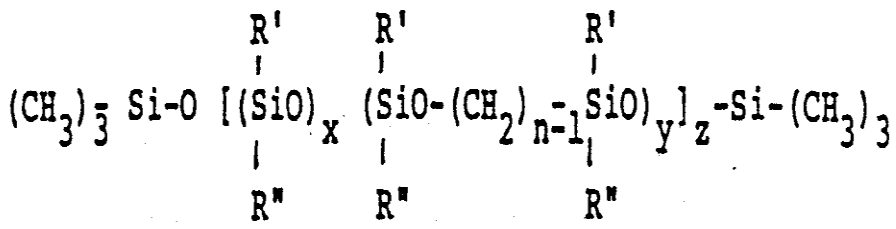
,

wherein

a is ~~selected~~ from 0 to 50~~, 0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

e and d can be the same or different, and each is independently ranged from 1 to 12;

(3)



,

wherein

R' and R" can be the same or different, and each is independently selected from the group consisting of hydrogen; $–(CH_2)_pCH_3$ with p ranged from 1 to 12 or 2 to 5; $-NH_2$; $-NH(CH_2)_q-NH_2$ with q ranged from 1 to 12 or from 2 to 5; ethylene oxide(EO) and

propylene oxide (PO) repeating group -$(EO)_e$-$(PO)_d$-OH with d and e each independently selected from the group consisting of from 1 to 50, 1 to 40, 1 to 30, 1 to 20, 1 to 10, and 1 to 5; -COOH; -COOM; -$COOR^1$; -R^1COOH; -R^1COOM; -R^1COOR^2; -SO_3H; -SO_3M; -R^1SO_3H; phosphonic acid; phosphate salt selected from sodium, potassium or ammonium salts; benzyl; di-benzyl; wherein R^1 and R^2 each is independently selected from the group consisting of –$(CH_2)_m$ with m ranged from 1 to 12, and –$(C_6H_4)_n$ with n ranged from 1 to 4; and M is selected from the group consisting of sodium, potassium, and ammonium; and

x, y, and z can be the same or different, and each is independently selected from 1 to 12; n-1 is from 2 to 13;

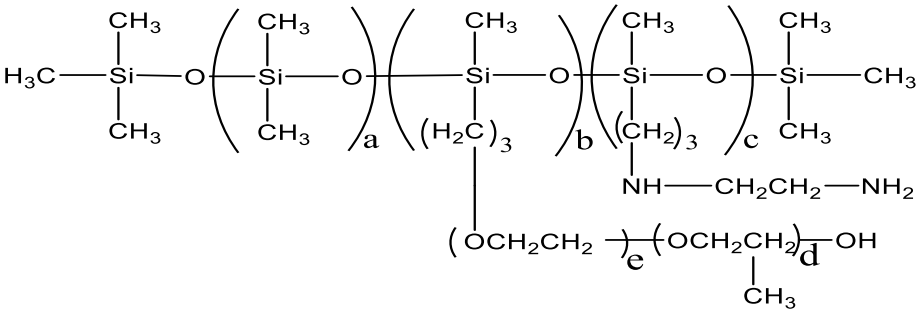
and

(4)combinations of (1), (2) and (3).

2. The chemical mechanical polishing composition of claim 1, wherein the ceria-coated inorganic metal oxide particles are selected from the group consisting of ceria-coated colloidal silica, ceria-coated alumina, ceria-coated titania, ceria-coated zirconia particles and combinations thereof, wherein the particles are present in the composition at a range ~~selected~~ from 0.01 wt.% to 20 wt.%, or 0.025 wt.% to 10 wt.%~~, or 0.05 wt.% to 5 wt.%~~.

3. The chemical mechanical polishing composition of claim 1, wherein the at least one silicone-containing compound having a general molecular structure (1) is selected from the group comprising of:

(a)



,

wherein

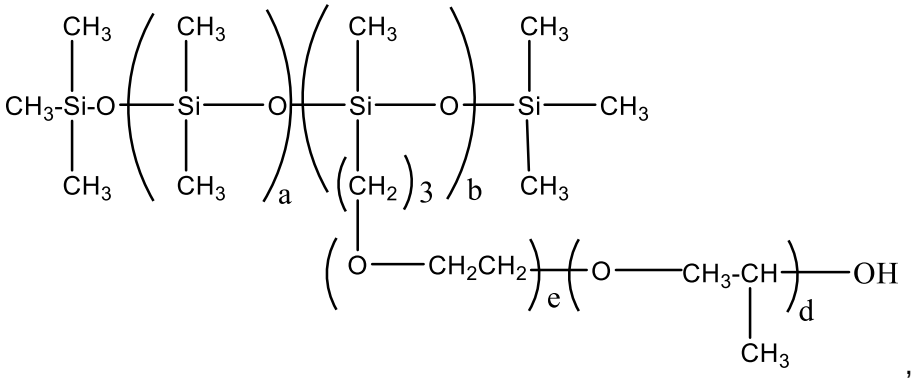
a is ~~selected~~ from 0 to 50~~, 0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

b and c can be the same or different, and each is independently ~~selected~~ from ~~f~~ 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or0 to 5~~; wherein at least one of b and c is not 0;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(b)



,

wherein

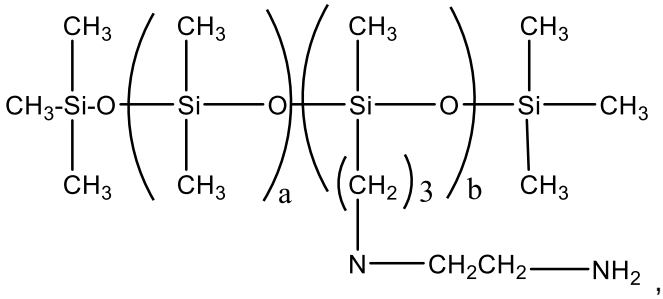
a is ~~selected~~ from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, and 0 to 5~~;

b is ~~selected~~ from 1 to 50, ~~1 to 40, 1 to 30,~~ or 1 to 20~~, 1 to 10, or 1 to 5~~;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(c)



,

wherein

a is ~~selected from~~ 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

b is ~~selected from~~ 1 to 50~~, 1 to 40, 1 to 30,~~ or 1 to 20~~, 1 to 10, or 1 to 5~~;

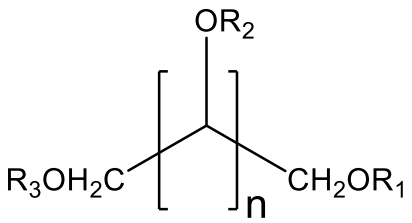
and

(d)combinations thereof.

4. The chemical mechanical polishing composition of claim 1, wherein the at least one silicone-containing compound is present in the composition at a concentration ~~selected~~ of from 0.0001 wt.% to 2.0% wt.%, or from 0.001 wt.% to 1.0 wt~~.%, or from 0.0025 wt.% to 0.25 wt.%~~**.**

5. The chemical mechanical polishing composition of claim 1, wherein the at least one non-ionic organic molecule having at least two hydroxyl functional groups has a general molecular structure selected from a group comprising:

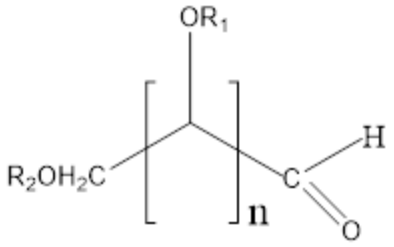
(a)



,

wherein n is selected from of 2 to 5,000, or 3 to 12~~, or 4 to 6~~; R_1, R_2, and R_3 groups can be the same or different and each is independently selected from the group consisting of hydrogen, an alkyl group C_nH_{2n+1}, n is ~~selected from the group consisting of~~ from 1 to 12, or 1 to 6~~, and 1 to 3~~; 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 them are hydrogen atoms;

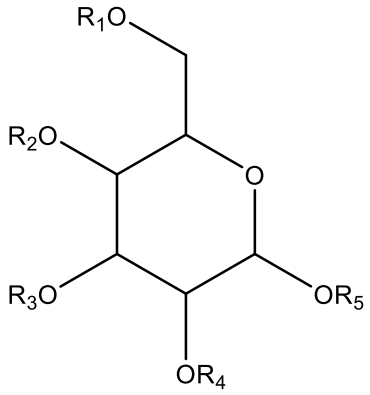
(b)



,

wherein n is selected from 2 to 5,000, or 3 to 12, or 4 to 7; each of R_1 and R_2 can be independently selected 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;

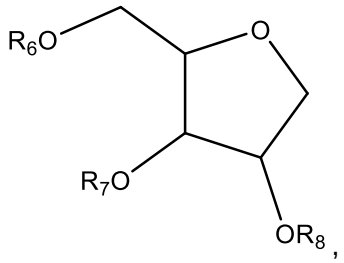
(c)



,

wherein R_1, R_2, R_3, R_4, and R_5 can be the same or different and can be independently selected 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, preferably four or more of them are hydrogen atoms;

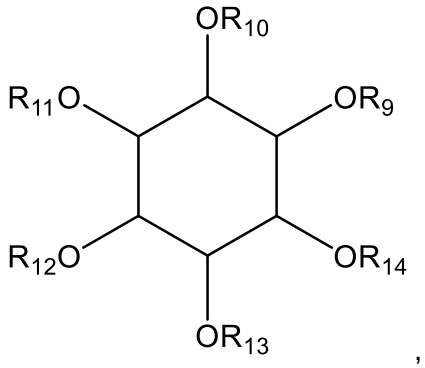
(d)



(d)

wherein R_6, R_7, and R_8 can be the same or different and can be independently selected 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, preferably four or more of them are hydrogen atoms;

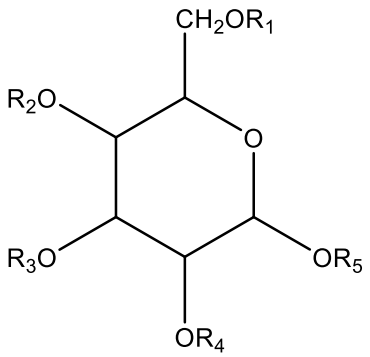
(e)



,

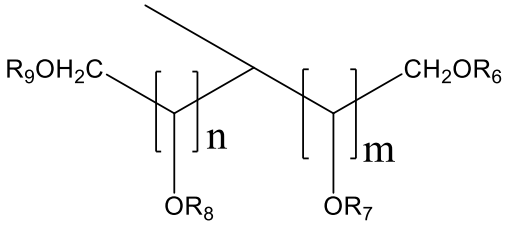
wherein R_9, R_{10}, R_{11}, R_{12}, R_{13}, and R_{14} can be the same or different and can be independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid, substituted organic sulfonic acid salt, substituted organic carboxylic acid, substituted organic carboxylic acid salt, organic carboxylic ester, organic amine groups, and combinations thereof; wherein, at least two, preferably four or more of them are hydrogen atoms;

(f)



,

wherein at least one R in the group of R_1 to R_5 in the general molecular structure (f) is a polyol molecular unit having a structure shown in (i):

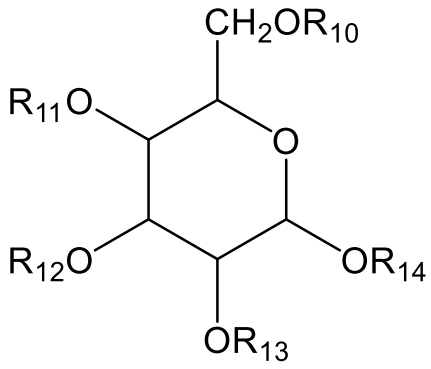


(i);

wherein n and m can be the same or different and is independently ~~selected~~ from 1 to 5, or ~~1 to 4,~~ 1 to 3~~, or 1 to 2~~; R_6 to R_9 can be the same or different and are independently selected 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, and combinations thereof; and at least two of them are hydrogen atoms;

and

the rest of each R in the group of R_1 to R_5 can be 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, a six-member ring polyol having a structure shown in (ii):



(ii);

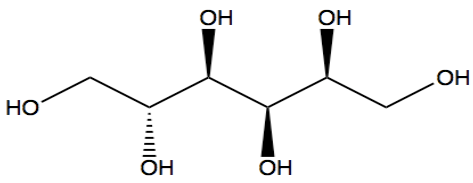
wherein the structure (ii) is connected through oxygen carbon bond in structure (f) by removing one R from R_{11} to R_{14} in (ii) and each of the rest R_{10} to R_{14} is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof;

(g) combinations thereof;

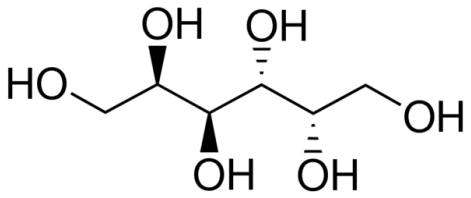
and the non-ionic organic molecule has a concentration range from 0.001 wt.% to 2.0% wt.%, or from 0.0025 wt.% to 1.0 wt.%~~, or from 0.05 wt.% to 0.5 wt.%~~**.**

6. The chemical mechanical polishing composition of claim 1, wherein the at least one non-ionic organic molecule has at least four hydroxyl functional groups.

7. The chemical mechanical polishing composition of claim 1, wherein the at least one non-ionic organic molecule is:

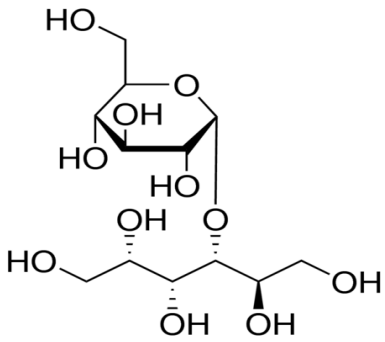


D-sorbitol; or

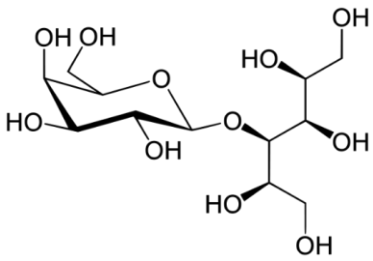


Dulcitol.

8. The chemical mechanical polishing composition of claim 1, wherein the non-ionic organic molecule is:



Maltitol, or



Lactitol.

9. The chemical mechanical polishing composition of claim 1, wherein the solvent is selected from the group consisting of deionized water, distilled water, and an alcohol-containing organic solvent.

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

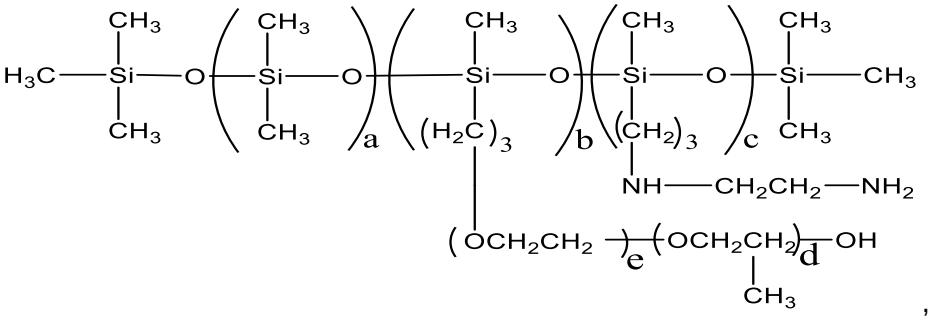
11. The chemical mechanical polishing composition of claim 1, wherein the composition comprises from 0 wt.% to 1 wt.% pH adjusting agent selected from the group consisting of nitric acid, sulfuric acid, tartaric acid, succinic acid, citric acid, malic acid, malonic acid, various fatty acids, hydrochloric acid, phosphoric acid various polycarboxylic acids, and mixtures thereof for acidic pH conditions; or selected from the group consisting of potassium hydroxide, sodium hydroxide, ammonia hydroxide, tetraethylammonium hydroxide, organic quaternary ammonium hydroxide compounds; ethylenediamine, piperazine, polyethyleneimine, modified polyethyleneimine, and combinations thereof for alkaline pH conditions.

12. The chemical mechanical polishing composition of claim 1, wherein the chemical mechanical polishing composition comprises

ceria-coated colloidal silica;

at least one selected from the group comprising of:

(a)



,

wherein

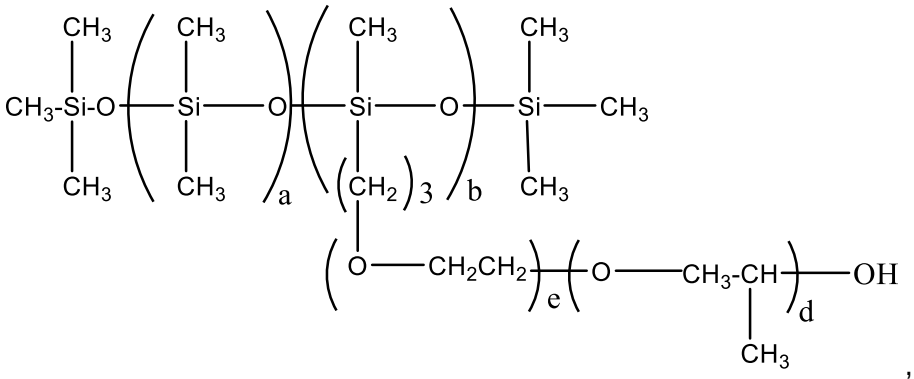
a is ~~selected~~ from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

b and c can be the same or different, and each is independently selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~; wherein at least one of b and c is not 0;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(b)



,

wherein

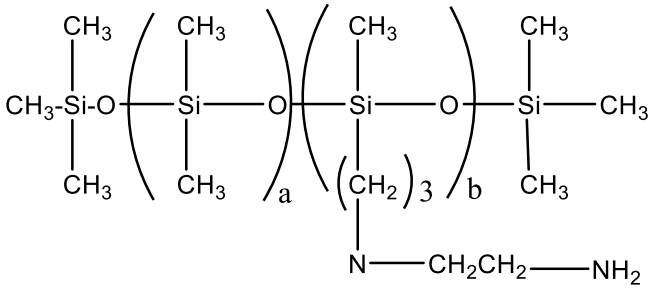
a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, and 0 to 5~~;

b is selected from 1 to 50, ~~1 to 40, 1 to 30,~~ or 1 to 20~~, 1 to 10, or 1 to 5~~;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(c)



,

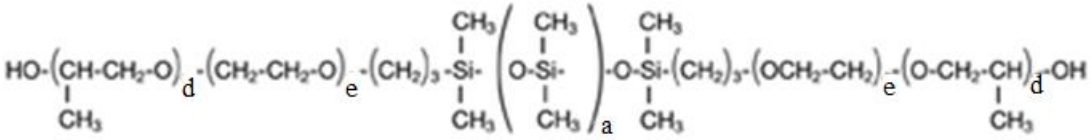
wherein

a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

b is selected from 1 to 50, ~~1 to 40, 1 to 30,~~ or 1 to 20~~, 1 to 10, or 1 to 5~~;

and

(d)



;

wherein

a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

e and d can be the same or different, and each is independently ranged from 1 to 12;

and

(e)combinations thereof;

at least one selected from the group consisting of Dulcitol, D-sorbitol, Maltitol, Lactitol, and combinations thereof;

deionized water;

and

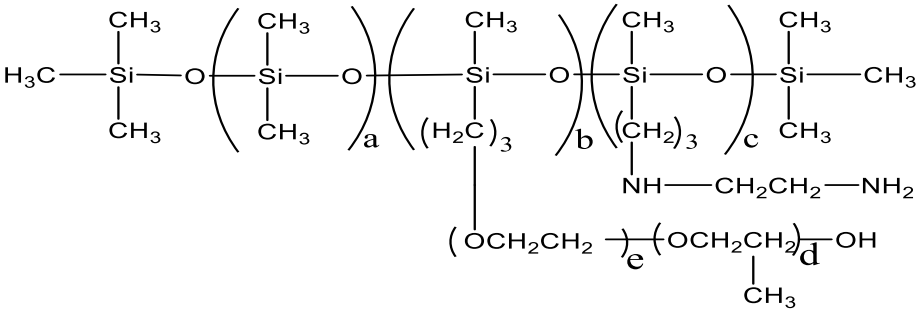
the pH is from 4 to 9.

13. The chemical mechanical polishing composition of claim 1, wherein the chemical mechanical polishing composition comprises

ceria-coated colloidal silica;

at least one selected from the group comprising of:

(a)



,

wherein

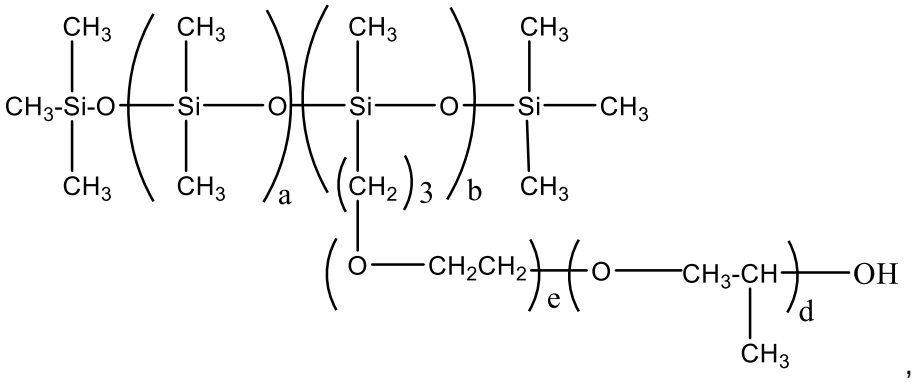
a is selected from 0 to 10, or 0 to 5;

b and c can be the same or different, and each is independently selected from 0 to 10, or 0 to 5; wherein at least one of b and c is not 0;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(b)



,

wherein

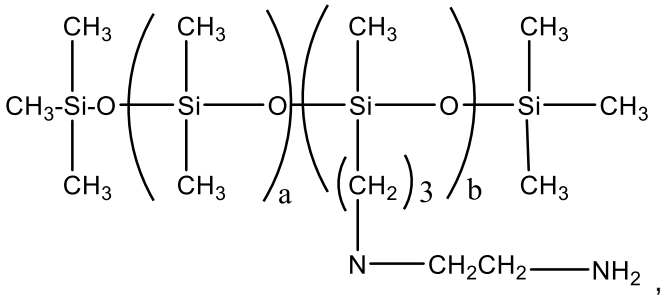
a is selected from 0 to 10, and 0 to 5;

b is selected from 1 to 10, or 1 to 5;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(c)



,

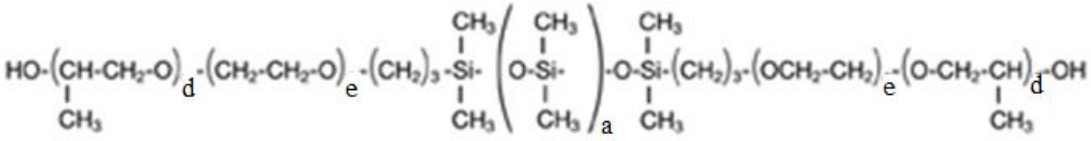
wherein

a is selected from 0 to 10, or 0 to 5;

b is selected from 1 to 10, or 1 to 5;

and

(d)



;

wherein

a is selected from 0 to 10, or 0 to 5;

e and d can be the same or different, and each is independently ranged from 1 to 12;

and

(e)combinations thereof;

at least one selected from the group consisting of Dulcitol, D-sorbitol, Maltitol, Lactitol, and combinations thereof;

deionized water;

and

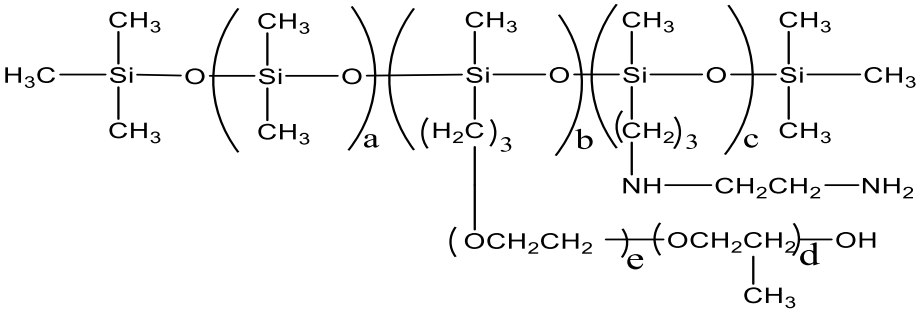
the pH is from 4 to 9.

14. The chemical mechanical polishing composition of claim 1, wherein the chemical mechanical polishing composition comprises

ceria-coated colloidal silica;

at least one selected from the group comprising of:

(a)



,

wherein

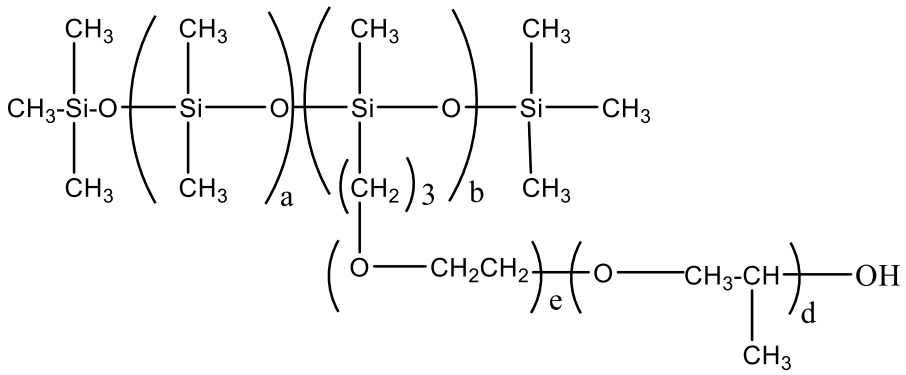
a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

b and c can be the same or different, and each is independently selected from f 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or0 to 5~~; wherein at least one of b and c is not 0;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(b)



,

wherein

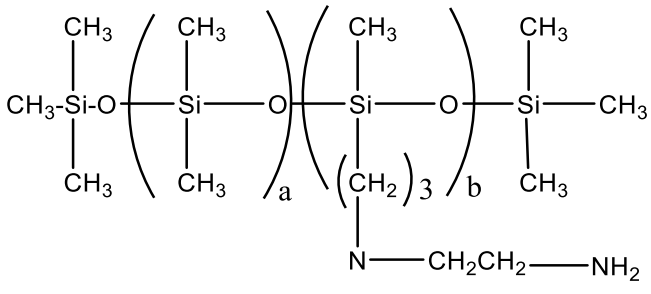
a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, and 0 to 5~~;

b is selected from 1 to 50, ~~1 to 40, 1 to 30,~~ or 1 to 20~~, 1 to 10, or 1 to 5~~;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(c)



,

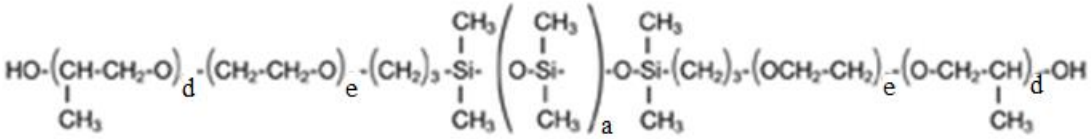
wherein

a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

b is selected from 1 to 50, ~~1 to 40, 1 to 30,~~ or 1 to 20~~, 1 to 10, or 1 to 5~~;

and

(d)



;

wherein

a is selected from 0 to 50, ~~0 to 40, 0 to 30,~~ or 0 to 20~~, 0 to 10, or 0 to 5~~;

e and d can be the same or different, and each is independently ranged from 1 to 12;

and

(e)combinations thereof;

at least one selected from the group consisting of Dulcitol, D-sorbitol, Maltitol, Lactitol, and combinations thereof;

a biocide comprising s 5-chloro-2-methyl-4-isothiazolin-3-one or 2-methyl- -isothiazolin-3-one;

deionized water;

and

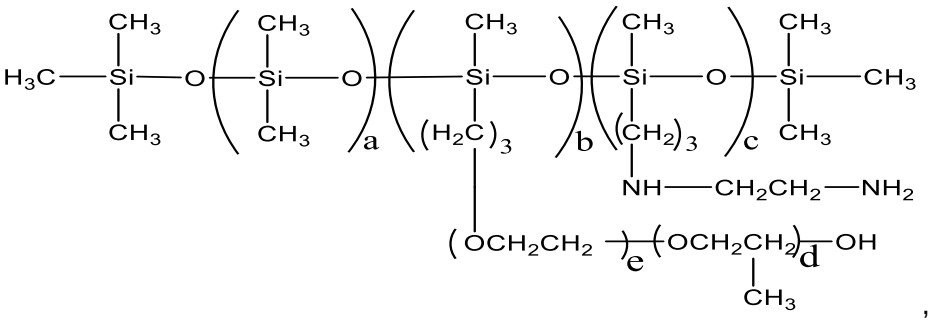
the pH is from 5 to 7.

15. The chemical mechanical polishing composition of claim 1, wherein the chemical mechanical polishing composition comprises

ceria-coated colloidal silica;

at least one selected from the group comprising of:

(a)



,

wherein

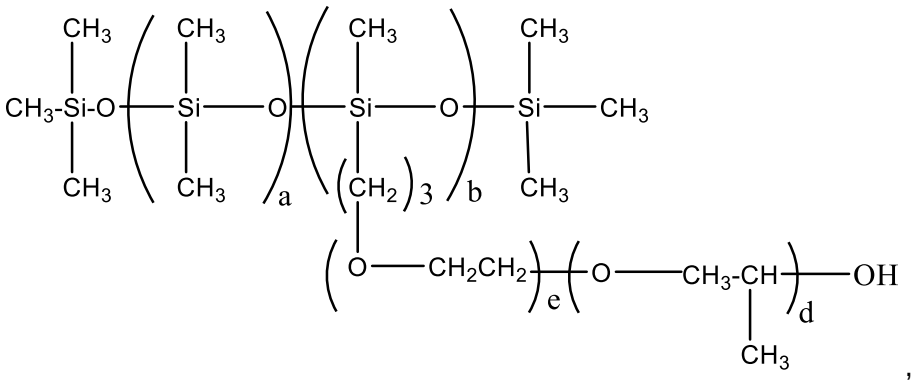
a is selected from 0 to 10, or 0 to 5;

b and c can be the same or different, and each is independently selected from 0 to 10, or 0 to 5; wherein at least one of b and c is not 0;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(b)



,

wherein

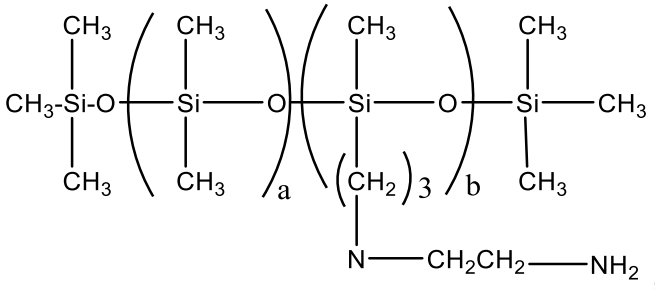
a is selected from 0 to 10, and 0 to 5;

b is selected from 1 to 10, or 1 to 5;

and

e and d can be the same or different, and each is independently ranged from 1 to 12;

(c)



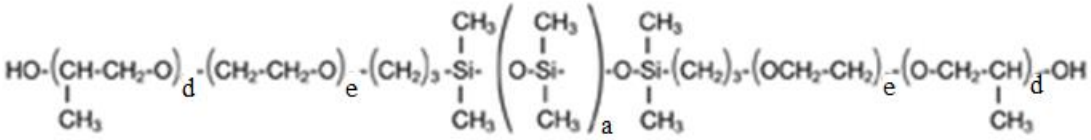
wherein

a is selected from 0 to 10, or 0 to 5;

b is selected from 1 to 10, or 1 to 5;

and

(d)



;

wherein

a is selected from 0 to 10, or 0 to 5;

e and d can be the same or different, and each is independently ranged from 1 to 12;

and

(e)combinations thereof;

at least one selected from the group consisting of Dulcitol, D-sorbitol, Maltitol, Lactitol, and combinations thereof;

a biocide comprising s 5-chloro-2-methyl-4-isothiazolin-3-one or 2-methyl- -isothiazolin-3-one;

deionized water;

and

the pH is from 5 to 7.

16. 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 in ~~any one of claims~~ claim 1 ~~to 15~~;

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.

17. The method of claim 16, wherein the silicon oxide film is high density plasma deposited tetraethyl orthosilicate(TEOS) (HDP) film.

~~18. The method of claim 16, wherein the semiconductor substrate further comprises a silicon nitride (SiN) surface.~~

~~19.~~18. The method of claim 16, wherein the silicon oxide film is high density plasma deposited tetraethyl orthosilicate(TEOS) (HDP) film; the semiconductor substrate further comprises a silicon nitride surface; and removal rate of HDP / removal rate of SiN is ≥ 70, ~~80, 90, 100, 110,~~ or 120.

~~20.~~19. 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 in ~~any one of claims~~ claim 1 ~~to 15~~;

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 high density plasma deposited tetraethyl orthosilicate(TEOS) (HDP) film.~~

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

~~23.~~20. The system of claim ~~20~~19; wherein the silicon oxide film is high density plasma deposited tetraethyl orthosilicate(TEOS) (HDP) film; the semiconductor substrate further comprises a silicon nitride surface; and removal rate of HDP / removal rate of SiN is ≥ 70, ~~80, 90, 100, 110,~~ or 120.