

TITLE OF THE INVENTION:

Low Oxide Trench Dishing Chemical Mechanical Polishing

CROSS REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C. § 119(e) to earlier filed U.S. patent applications Serial Numbers 62/692,633, and 62/692,639 filed on June 5 29, 2018, which are entirely incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] This invention relates to the chemical mechanical planarization (CMP) for polishing oxide and doped oxide films.

10 **[0003]** In the fabrication of microelectronics devices, an important step involved is polishing, especially surfaces for chemical-mechanical polishing for the purpose of recovering a selected material and/or planarizing the structure.

[0004] For example, a SiN layer is deposited under a SiO₂ layer to serve as a polish stop. The role of such polish stop is particularly important in Shallow Trench Isolation (STI) structures. Selectivity is characteristically expressed as the ratio of the oxide polish 15 rate to the nitride polish rate. An example is an increased polishing selectivity rate of silicon dioxide(SiO₂) as compared to silicon nitride(SiN).

[0005] In the global planarization of patterned structures, reducing oxide trench dishing is a key factor to be considered. The lower trench oxide loss will prevent 20 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 CMP polishing compositions.

25 **[0006]** US Patent 5,876,490 discloses the polishing compositions containing abrasive particles and exhibiting normal stress effects. The slurry further contains non-polishing particles resulting in reduced polishing rate at recesses, while the abrasive

particles maintain high polish rates at elevations. This leads to improved planarization. More specifically, the slurry comprises cerium oxide particles and polymeric electrolyte, and can be used for Shallow Trench Isolation (STI) polishing applications.

5 **[0007]** US Patent 6,964,923 teaches the polishing compositions containing cerium oxide particles and polymeric electrolyte for Shallow Trench Isolation (STI) polishing applications. Polymeric electrolyte being used includes the salts of polyacrylic acid, similar as those in US Patent 5,876,490. Ceria, alumina, silica & zirconia are used as abrasives. Molecular weight for such listed polyelectrolyte is from 300 to 20,000, but in overall, <100,000.

10 **[0008]** US Patent 6,616,514 discloses a chemical mechanical polishing slurry for use in removing a first substance from a surface of an article in preference to silicon nitride by chemical mechanical polishing. The chemical mechanical polishing slurry according to the invention includes an abrasive, an aqueous medium, and an organic polyol that does not dissociate protons, said organic polyol including a compound having at least three
15 hydroxyl groups that are not dissociable in the aqueous medium, or a polymer formed from at least one monomer having at least three hydroxyl groups that are not dissociable in the aqueous medium.

[0009] However, the importance of oxide trench dishing reducing has not been addressed in the STI CMP polishing process.

20 **[0010]** It should be readily apparent from the foregoing that there remains a need within the art for compositions, methods and systems of chemical mechanical polishing that can afford the reduced oxide trench dishing and improved over polishing window stability in a chemical and mechanical polishing (CMP) process, in addition to high removal rate of silicon dioxide as well as high selectivity for silicon dioxide to silicon
25 nitride.

BRIEF SUMMARY OF THE INVENTION

[0011] The present invention provides Chemical mechanical polishing(CMP) compositions, methods and systems in CMP applications for polishing oxide.

30 **[0012]** The present invention provides the benefits of achieving high oxide film removal rates, low SiN film removal rates, high and tunable Oxide: SiN selectivity, lower total

defect counts post-polishing, excellent mean particle size(nm) stability, and importantly, significantly reducing oxide trench dishing and improving over polishing window stability.

[0013] In one aspect, there is provided a CMP polishing composition comprises:

abrasive particles selected from the group consisting of ceria-coated inorganic oxide

5 particles, ceria-coated organic polymer particles, and combinations thereof;

chemical additive as oxide trenching dishing reducer,

a solvent; and

optionally

biocide; and

10 pH adjuster;

wherein the composition has a pH of 2 to 12, preferably 3 to 10, and more preferably 4 to 9.

[0014] The ceria-coated inorganic oxide particles include, but are not limited to,

ceria-coated colloidal silica, ceria-coated high purity colloidal silica, ceria-coated alumina,

15 ceria-coated titania, ceria-coated zirconia, or any other ceria-coated inorganic oxide particles.

[0015] The ceria-coated organic polymer particles include, but are not limited to, ceria-coated polystyrene particles, ceria-coated polyurethane particle, ceria-coated polyacrylate particles, or any other ceria-coated organic polymer particles.

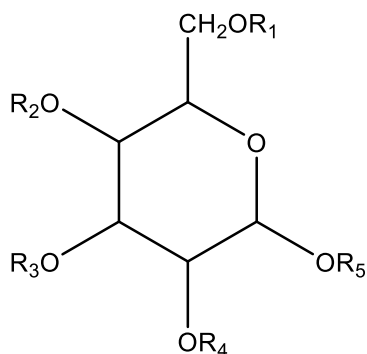
20 **[0016]** The preferred abrasive particles are ceria-coated inorganic oxide particles; more preferred abrasive particles are ceria-coated silica particles.

[0017] The solvent includes but is not limited to deionized (DI) water, distilled water, and alcoholic organic solvents.

[0018] The chemical additives contain at least one six-member ring structure motif
25 ether bonded with at least one polyol molecular unit containing multiple hydroxyl functional groups in the molecular unit structures or at least one polyol molecular unit containing multiple hydroxyl functional groups in the molecular unit structures and at least one six-member ring polyol. A polyol is an organic compound containing hydroxyl groups.

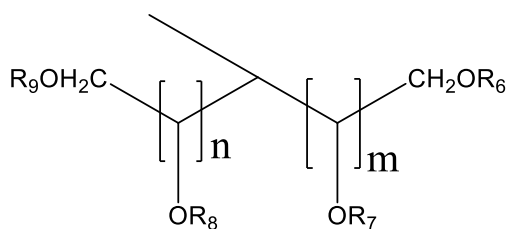
30 **[0019]** The chemical additives as oxide trenching dishing reducers contain at least two, at least four, or at least six hydroxyl functional groups in their molecular structures.

[0020] The general molecular structure for the chemical additives is shown in (a):



(a).

- 5 **[0021]** In one embodiment, at least one R in the group of R1 to R5 in the general molecular structure is a polyol molecular unit having a structure shown in (b):



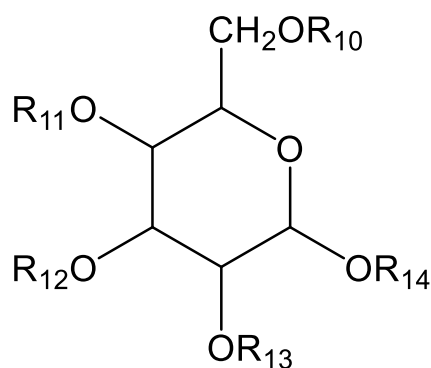
(b);

- wherein n and m can be the same or different. m or n is independently selected from 1 to 5, preferably from 1 to 4, more preferably from 1 to 3, and most preferably from 1 to 2. R6 to R9 can be the same or different atoms or functional groups and each 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 the rest of Rs in the group of R1 to R5 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, and combinations thereof.

- 20 **[0022]** In another embodiment, at least one R in the group of R1 to R5 in the general molecular structure is a polyol molecular unit having a structure shown in (b); at least

one R in the group of R1 to R5 in the general molecular structure is a six-member ring polyol as shown in (c):



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(c);

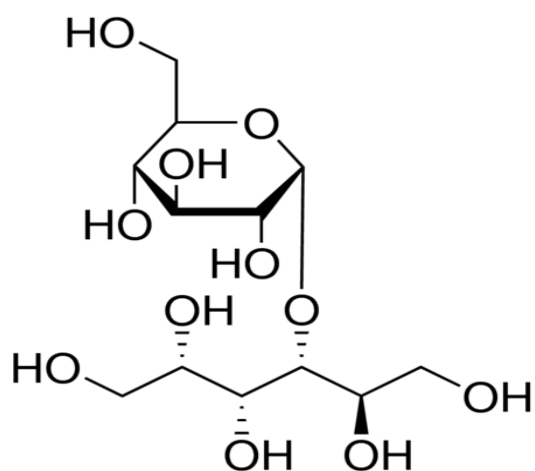
wherein

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;

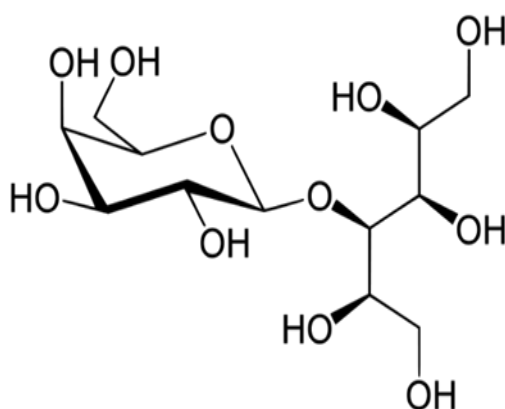
and the rest of Rs in the group of R1 to R5 can be independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof.

[0023] In the general molecular structure, at least two, preferably four, more preferably six of the Rs in the group of R1 to R9 are hydrogen atoms.

[0024] When only one R, such as R5 in the group of R1 to R5 in the general molecular structure is a polyol molecular unit (b) having $n = 2$ and $m = 1$; and all rest of Rs in the group of R1 to R9 are all hydrogen atoms, the following two chemical additives are obtained:

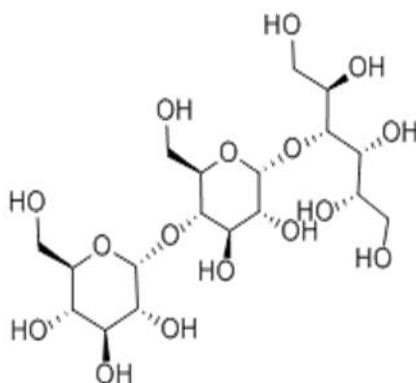


Maltitol



Lactitol

- 5 **[0025]** When one R, such as R5 is a polyol molecular unit (b) having $n = 2$ and $m = 1$; and one R, such as R2 is a six-member ring polyol; and all rest of Rs in the group of R1 to R14 are all hydrogen atoms, the following chemical additive is obtained:



Maltotrititol

[0026] The preferred chemical additive comprises maltitol, lactitol, maltotritol, and combinations.

[0027] In some embodiments, the CMP polishing composition can be made into two or more parts and mixed at the point of use.

5 **[0028]** In another aspect, there is provided a method of chemical mechanical polishing (CMP) a substrate having at least one surface comprising silicon dioxide (such as tetraethyl orthosilicate or TEOS) using the chemical mechanical polishing (CMP) composition described above.

10 **[0029]** In yet another aspect, there is provided a system of chemical mechanical polishing (CMP) a substrate having at least one surface comprising silicon dioxide using the chemical mechanical polishing (CMP) composition described.

[0030] The polished oxide films can be Chemical vapor deposition (CVD), Plasma Enhance CVD (PECVD), High Density Deposition CVD(HDP), or spin on oxide films.

15 **[0031]** The substrate disclosed above can further comprise a silicon nitride(SiN) surface. The removal selectivity of SiO₂: SiN is greater than 10, preferably greater than 20, and more preferably greater than 30.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

20 **[0032]** Figure 1 depicts the effects of Maltitol or Lactitol on Film RR (Å /min.) & TEOS: SiN Selectivity

[0033] Figure 2 depicts the effects of Maltitol or Lactitol on Oxide Trench Dishing vs OP Times (Sec.)

[0034] Figure 3 depicts the effects of Maltitol or Lactitol on Slopes of Dishing vs OP Removal Amount

25 **[0035]** Figure 4 depicts the effects of Maltitol or Lactitol on Trench Loss Rates (Å/min.)

[0036] Figure 5 depicts the effects of pH on Film RR (Å /min) & Selectivity of Oxide: SiN

30 **[0037]** Figure 6 depicts the effects of lactitol at different pH Conditions on Oxide Trench Dishing vs over polishing(OP) times (Sec.)

[0038] Figure 7 depicts the effects of lactitol at different pH on Slopes of Dishing vs OP Removal Amount

[0039] Figure 8 depicts the of lactitol at different pH conditions on Trench Loss Rates ($\text{\AA}/\text{min.}$)

5 **[0040]** Figure 9 depicts mean particle size and size distribution stability test Results@50 °C

[0041] Figure 10 depicts mean particle size and size distribution stability test Results@50 °C

10 **[0042]** Figure 11 depicts mean particle size and size distribution stability test Results@50 °C

[0043] Figure 12 depicts the effect of different polishing compositions on TEOS & SiN total defect counts

15 DETAILED DESCRIPTION OF THE INVENTION

[0044] This invention relates to the Chemical mechanical polishing(CMP) compositions, methods and systems for CMP applications polishing oxide and doped oxide films.

20 **[0045]** In the global planarization of patterned structures, reducing oxide trench dishing is a key factor to be considered. The lower trench oxide loss will prevent electrical current leaking between adjacent transistors. Non-uniform trench oxide loss across die or/and 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
25 by reducing oxide trench dishing in CMP polishing compositions.

[0046] The CMP compositions comprise the unique combination of abrasive and the suitable chemical additives.

[0047] This invention provides a reduced oxide trench dishing and thus improved over polishing window stability by introducing chemical additives as oxide trench dishing

reducing additives in the Chemical mechanical polishing(CMP) compositions at wide pH range including acidic, neutral and alkaline pH conditions.

[0048] The Chemical Mechanical Polishing (CMP) compositions provide high oxide film removal rates, low SiN film removal rates and high SiO₂: SiN selectivity.

- 5 **[0049]** The Chemical Mechanical Polishing (CMP) composition also further provides excellent mean particle size and size distribution stability for the abrasive particles which is very important in maintaining robust CMP polishing performances with minimized polishing performance variations.

[0050] In one aspect, there is provided a CMP polishing composition comprises:

- 10 abrasive particles selected from the group consisting of ceria-coated inorganic oxide particles, ceria-coated organic polymer particles, and combinations thereof;
chemical additives as oxide trenching dishing and total defect count reducers;
a solvent; and
optionally
15 biocide; and
pH adjuster;
wherein the composition has a pH of 2 to 12, preferably 3 to 10, and more preferably 4 to 9.

- [0051]** The ceria-coated inorganic oxide particles include, but are not limited to,
20 ceria-coated colloidal silica, ceria-coated high purity colloidal silica, ceria-coated alumina, ceria-coated titania, ceria-coated zirconia, or any other ceria-coated inorganic oxide particles.

- [0052]** The ceria-coated organic polymer particles include, but are not limited to, ceria-coated polystyrene particles, ceria-coated polyurethane particle, ceria-coated
25 polyacrylate particles, or any other ceria-coated organic polymer particles.

[0053] The average mean particle sizes or mean particle sizes (MPS) abrasive particles in the disclosed invention herein are ranged from 2 to 1,000nm, 5 to 500nm, 15 to 400 nm or 25 to 250nm. MPS refers to diameter of the particles and is measured using dynamic light scattering (DLS) technology.

- 30 **[0054]** The concentrations of abrasive particles range from 0.01 wt.% to 20 wt.%, 0.05 wt.% to 10 wt.%, or 0.1 wt.% to 5 wt.%.

[0055] The preferred abrasive particles are ceria-coated inorganic oxide particles; more preferred abrasive particles are ceria-coated silica particles.

[0056] The solvent includes but is not limited to deionized (DI) water, distilled water, and alcoholic organic solvents.

5 **[0057]** The preferred solvent is DI water.

[0058] The CMP slurry may contain biocide from 0.0001 wt.% to 0.05 wt.%; 0.0005 wt.% to 0.025 wt.%, or 0.001 wt.% to 0.01 wt.%.

10 **[0059]** 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 or 2-methyl-4-isothiazolin-3-one.

[0060] The CMP slurry may contain a pH adjusting agent.

[0061] An acidic or basic pH adjusting agent can be used to adjust the polishing compositions to the optimized pH value.

15 **[0062]** The acidic pH adjusting agents include, but are not limited to nitric acid, hydrochloric acid, sulfuric acid, phosphoric acid, other inorganic or organic acids, and mixtures thereof.

20 **[0063]** pH adjusting agents also include the basic pH adjusting agents, such as sodium hydride, potassium hydroxide, ammonium hydroxide, tetraalkyl ammonium hydroxide, organic quaternary ammonium hydroxide compounds, organic amines, and other chemical reagents that can be used to adjust pH towards the more alkaline direction.

[0064] The CMP slurry contains 0 wt.% to 1 wt.%; 0.01 wt.% to 0.5 wt.%; or 0.1 wt.% to 0.25 wt.% pH adjusting agent.

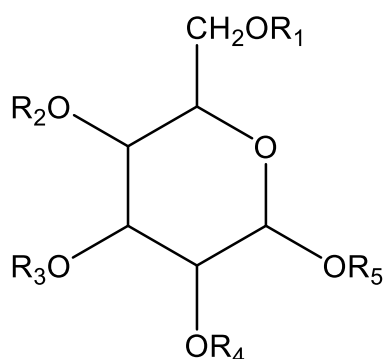
25 **[0065]** The CMP slurry contains 0.01 wt.% to 20 wt.%, 0.025 wt.% to 10 wt.%, 0.05 wt.% to 5 wt.%, or 0.1 to 3.0% wt.% of the chemical additives as oxide trenching dishing and total defect count reducers.

30 **[0066]** The chemical additives contain at least one six-member ring structure motif ether bonded with at least one polyol molecular unit containing multiple hydroxyl functional groups in the molecular unit structures or at least one polyol molecular unit containing multiple hydroxyl functional groups in the molecular unit structures and at

least one six-member ring polyol. A polyol is an organic compound containing hydroxyl groups.

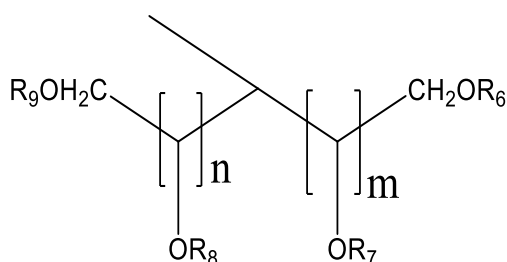
[0067] The chemical additives as oxide trenching dishing reducers contain at least two, at least four, or at least six hydroxyl functional groups in their molecular structures.

5 **[0068]** The general molecular structure for the chemical additives is shown in (a):



(a).

[0069] In one embodiment, at least one R in the group of R1 to R5 in the general molecular structure is a polyol molecular unit having a structure shown in (b):



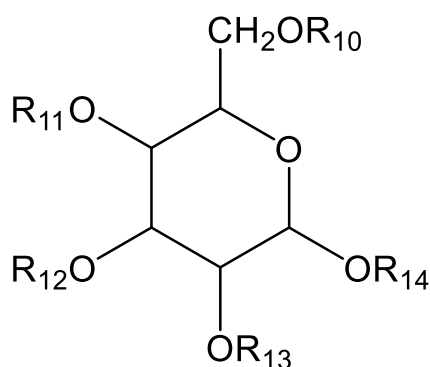
(b);

wherein n and m can be the same or different. m or n is independently selected from 1 to 5, preferably from 1 to 4, more preferably from 1 to 3, and most preferably from 1 to 2; R6 to R9 can be the same or different atoms or functional groups; and

15 the rest of Rs in the group of R1 to R5 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, and combinations thereof.

20 **[0070]** In another embodiment, at least one R in the group of R1 to R5 in the general molecular structure is a polyol molecular unit having a structure shown in (b); at least

one R in the group of R1 to R5 in the general molecular structure is a six-member ring polyol as shown in (c):



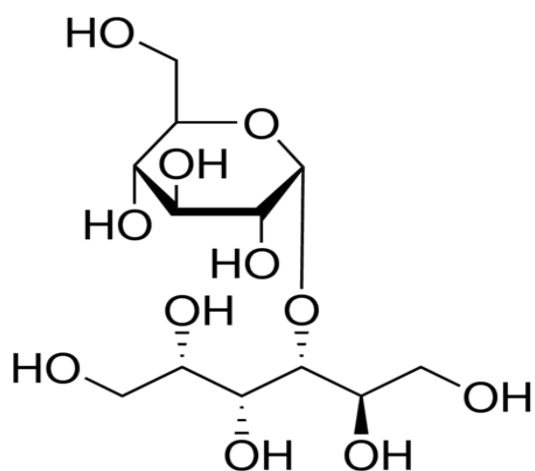
(c);

- 5 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;
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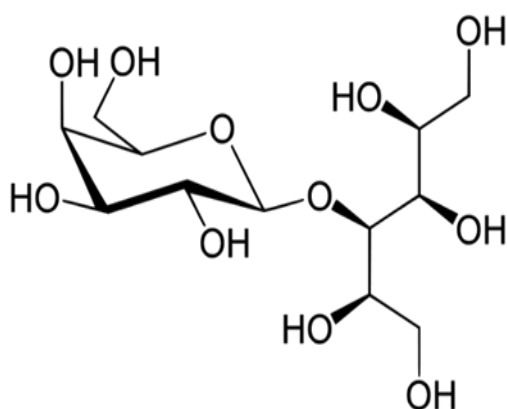
and the rest of Rs in the group of R1 to R5 can be independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine, and combinations thereof.

- 15 **[0071]** In the general molecular structure, at least two, preferably four, more preferably six of the Rs in the group of R1 to R9 are hydrogen atoms.

- [0072]** When only one R, such as R5 in the group of R1 to R5 in the general molecular structure is a polyol molecular unit (b) having $n = 2$ and $m = 1$; and all rest of Rs in the group of R1 to R9 are all hydrogen atoms, the following two chemical additives are
- 20 obtained:

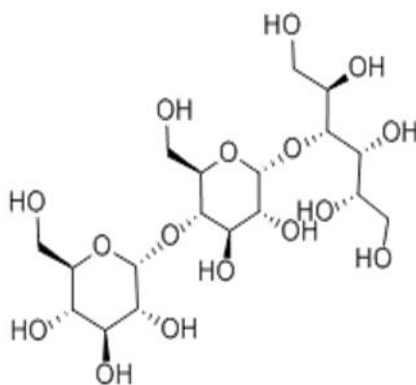


Maltitol



Lactitol

- 5 **[0073]** When one R, such as R5 is a polyol molecular unit (b) having $n = 2$ and $m = 1$; and one R, such as R2 is a six-member ring polyol; and all rest of Rs in the group of R1 to R14 are all hydrogen atoms, the following chemical additive is obtained:



Maltotrititol

[0074] The preferred chemical additive comprises maltitol, lactitol, maltotritol, and combinations.

[0075] In some embodiments, the CMP polishing compositions can be made into two or more parts and mixed at the point of use.

5 **[0076]** In another aspect, there is provided a method of chemical mechanical polishing (CMP) a substrate having at least one surface comprising silicon dioxide using the chemical mechanical polishing (CMP) composition described.

[0077] In yet another aspect, there is provided a system of chemical mechanical polishing (CMP) a substrate having at least one surface comprising silicon dioxide using
10 the chemical mechanical polishing (CMP) composition described.

[0078] The polished oxide films can be Chemical vapor deposition (CVD), Plasma Enhance CVD (PECVD), High Density Deposition CVD(HDP), spin on oxide films, flowable CVD oxide film, carbon doped oxide film, or nitrogen doped oxide film.

[0079] The substrate disclosed above can further comprises a silicon nitride surface.
15 The removal selectivity of SiO₂: SiN is greater than 10, preferably greater than 20, and more preferably greater than 30.

[0080] Dishing performance of the CMP compositions can also be characterized by the ratio of oxide trench dishing rate (Å/min.) vs the blanket HDP film removal rate(Å/min.).

20 **[0081]** The smaller of this ratio is, the lower oxide trench dishing is. The CMP compositions having the ratio of ≤ 0.1 , 0.08, 0.06, 0.05, 0.03, or 0.02 provide good oxide dishing performance.

[0082] In CMP polishing compositions, it is very important to keep abrasive particles stable to assure consistent desired CMP polishing performance.

25 **[0083]** When using the chemical additives in the CMP polishing compositions, these chemical additives can have some impacts on the stability of abrasive particles in the compositions.

[0084] For example, when maltitol, lactitol or their derivatives, are used as oxide trench reducing agents in polishing compositions, these chemical additives can have
30 some impacts on the stability of ceria-coated inorganic oxide abrasives in the CMP polishing compositions.

[0085] Typically, the abrasive particle stability is tested by monitoring the mean particle size (MPS) (nm) and particle size distribution parameter D99(nm) changes vs the times or at elevated temperatures.

5 **[0086]** Particle size distribution may be quantified as a weight percentage of particles that has a size lower than a specified size. For example, parameter D99(nm) represents a particle size (diameter) where 99 wt.% of all the slurry particles would have particle diameter equal to or smaller than the D99(nm). That is, D99(nm) is a particle size that 99 wt.% of the particles fall on and under.

10 **[0087]** The smaller of MPS (nm) and D99(nm) changes, the more stable of the abrasive particles are and thus the CMP polishing compositions are.

[0088] Particle size distribution can be measured by any suitable techniques such as imaging, dynamic light scattering, hydrodynamic fluid fractionation, disc centrifuge etc. .

[0089] MPS(nm) and D99 (nm) are both measured by dynamic light scattering in this application.

15 **[0090]** CMP compositions providing abrasive particle stability have the changes for MPS (nm) and D99(nm) $\leq$ 6.0%, 5.0%, 3.0%, 2.0%, 1.0%, 0.5 %, 0.3% or 0.1% for a shelf time of at least 30 days, 40 days, 50 days, 60 days, 70 days or 100 days at a temperature ranging from 20 to 60 °C, 25 to 50 °C.

20 **[0091]** The following non-limiting examples are presented to further illustrate the present invention.

CMP Methodology

[0092] In the examples presented below, CMP experiments were run using the procedures and experimental conditions given below.

25

GLOSSARY

COMPONENTS

30 **[0093]** Ceria-coated Silica: used as abrasive having a mean particle size ranged from approximately 20 nanometers (nm) to 500 nanometers (nm).

[0094] Ceria-coated Silica particles (with varied sizes) were supplied by JGC Inc. in Japan.

[0095] Chemical additives, such as maltitol, lactitol and other chemical raw materials were supplied by Sigma-Aldrich, St. Louis, MO

5 **[0096]** TEOS: tetraethyl orthosilicate

[0097] Polishing Pad: Polishing pad, IC1010 and other pads were used during CMP, supplied by DOW, Inc.

PARAMETERS

10 General

[0098] Å or A: angstrom(s) – a unit of length

[0099] BP: back pressure, in psi units

[00100] CMP: chemical mechanical planarization = chemical mechanical polishing

[00101] CS: carrier speed

15 **[00102]** DF: Down force: pressure applied during CMP, units psi

[00103] min: minute(s)

[00104] ml: milliliter(s)

[00105] mV: millivolt(s)

[00106] psi: pounds per square inch

20 **[00107]** PS: platen rotational speed of polishing tool, in rpm (revolution(s) per minute)

[00108] SF: slurry flow, ml/min

[00109] Wt. %: weight percentage (of a listed component)

[00110] TEOS: SiN Selectivity: (removal rate of TEOS)/ (removal rate of SiN)

[00111] HDP: high density plasma deposited TEOS

25 **[00112]** TEOS or HDP Removal Rates: Measured TEOS or HDP removal rate at a given down pressure. The down pressure of the CMP tool was 2.0, 3.0 or 4.0 psi in the examples.

[00113] SiN Removal Rates: Measured SiN removal rate at a given down pressure. The down pressure of the CMP tool was 3.0 psi in the examples.

Metrology

- 5 **[00114]** Films were measured with a ResMap CDE, model 168, manufactured by Creative Design Engineering, Inc, 20565 Alves Dr., Cupertino, CA, 95014. The ResMap tool is a four-point probe sheet resistance tool. Forty-nine-point diameter scan at 5mm edge exclusion for film was taken.

10

CMP Tool

- [00115]** The CMP tool that was used is a 200mm Mirra, or 300mm Reflexion manufactured by Applied Materials, 3050 Boweres Avenue, Santa Clara, California, 95054. An IC1000 pad supplied by DOW, Inc, 451 Bellevue Rd., Newark, DE 19713 was used on platen 1 for blanket and pattern wafer studies.
- 15 **[00116]** The IC1010 pad or other pad was broken in by conditioning the pad for 18 mins. At 7 lbs. down force on the conditioner. To qualify the tool settings and the pad break-in two tungsten monitors and two TEOS monitors were polished with Versum® STI2305 slurry, supplied by Versum Materials Inc. at baseline conditions.

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Wafers

[00117] Polishing experiments were conducted using PECVD or LECVD or HD TEOS wafers. These blanket wafers were purchased from Silicon Valley Microelectronics, 2985 Kifer Rd., Santa Clara, CA 95051.

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Polishing Experiments

[00118] In blanket wafer studies, oxide blanket wafers, and SiN blanket wafers were polished at baseline conditions. The tool baseline conditions were: table speed; 87 rpm; head speed: 93 rpm; membrane pressure: 3.0 psi; inter-tube pressure: 3.1 psi; retaining ring pressure: 5.1psi; slurry flow speed: 200 ml/min.

5 **[00119]** The slurry was used to polish the patterned wafers (MIT860), supplied by SWK Associates, Inc. 2920 Scott Blvd. Santa Clara, CA 95054). These wafers were measured on the Veeco VX300 profiler/AFM instrument. The 3 different sized pitch structures were used for oxide dishing measurement. The wafer was measured at center, middle, and edge die positions.

[00120] TEOS: SiN Selectivity: (removal rate of TEOS)/ (removal rate of SiN) obtained from the CMP polishing compositions were tunable.

Working Examples

10 **[00121]** In the following working examples, a reference (ref.)polishing composition comprising 0.2 wt.% ceria-coated silica, a biocide ranging from 0.0001 wt.% to 0.05 wt.%, and deionized water was prepared.

[00122] The polishing compositions were prepared with the reference (0.2 wt.% ceria-coated silica, a biocide ranging from 0.0001 wt.% to 0.05 wt.%, and deionized
15 water) and a chemical additive ranging from 0.01 wt.% to 2.0% wt.%.

[00123] All compositions in the examples, except compositions used in different pH condition example had a pH at 5.35. ,

[00124] pH adjusting agent used for acidic pH condition and alkaline pH condition were nitric acid and ammonium hydroxide respectively.

20

Example 1

[00125] In Example 1, the polishing compositions were prepared as shown in Table 1. The chemical additives, maltitol or lactitol were used at 0.28 wt.% respectively.

[00126] The removal rates (RR at Å/min) for different films were tested. The effects of
25 two selected chemical additives, maltitol and lactitol on the film removal rates and selectivity were observed.

[00127] The test results were listed in Table 1 and shown in Figure 1.

Table 1. Effects of Maltitol or Lactitol on Film RR (Å /min.) & TEOS: SiN Selectivity

Compositions	TEOS Film RR (Å/min.)	HDP Film RR (Å/min.)	SiN Film RR (Å/min.)	TEOS: SiN Selectivity
0.2% Ceria-coated Silica pH 5.35	3279	2718	349	9.4
0.2% Ceria-coated Silica + 0.28% Maltitol pH 5.35	2623	2639	46	57.0
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	2630	2547	55	47.8

[00128] As the results shown in Table 1 and Figure 1, the addition of the chemical additives, maltitol or lactitol, in the polishing compositions, significantly suppressed SiN removal rates while still afforded high TEOS and HDP film removal rates, thus, significantly increased Oxide: SiN film polishing selectivity.

Example 2

[00129] In Example 2, the polishing composition were prepared as shown in Table 2. The chemical additives, maltitol or lactitol were used at 0.28 wt.% respectively. All samples had a pH at 5.35.

[00130] Oxide trenching dishing for without/or with different over polishing times were tested.

[00131] The effects of maltitol or lactitol on the oxide trenching dishing vs over polishing times were observed.

[00132] The test results were listed in Table 2 and shown in Figure 2.

[00133] As the results shown in Table 2 and Figure 2, the polishing compositions with the addition of the chemical additives, maltitol or lactitol, afforded low oxide trench dishing on 100um pitch, and 200um pitch respectively when 60 second or 120 second over polishing(OP) times were applied.

[00134] The compositions provided significant oxide trench dishing reductions comparing to the reference polishing composition which did not have the chemical additives, maltitol or lactitol.

Table 2. Effects of Maltitol or Lactitol on Oxide Trench Dishing vs OP Times (Sec.)

Compositions	OP Times (Sec.)	100um pitch dishing	200um pitch dishing
0.2% Ceria-coated Silica pH 5.35 Ref.	0	165	291
	60	857	1096
	120	1207	1531
0.2% Ceria-coated Silica + 0.28% Maltitol pH 5.35	0	408	616
	60	480	713
	120	542	803
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	0	349	563
	60	438	702
	120	510	779

[00135] Table 3 listed the ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket HDP film removal rate($\text{\AA}/\text{min.}$).

5

Table 3

Compositions	P100 Dishing Rate ($\text{\AA}/\text{min.}$) /Blanket HDP RR (A/min.)	P200 Dishing Rate ($\text{\AA}/\text{min.}$) /Blanket HDP RR (A/min.)
0.2% Ceria-coated Silica pH 5.35	0.13	0.16
0.2% Ceria-coated Silica + 0.28% Maltitol pH 5.35	0.02	0.03
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	0.03	0.03

[00136] As the results shown in Table 3, the addition of either maltitol or lactitol as oxide trench dishing reducer in polishing compositions significantly reduced the ratio of trench dishing rate vs the blanket HDP film removal rates. The lower of this ratio is, the lower of oxide trench dishing is.

10

[00137] The slopes of oxide trench dishing vs the OP removal amount was showed in Table 4 and Figure 3.

15

[00138] The results listed in Table 4 and Figure 3 indicated that the compositions with chemical additives, maltitol or lactitol provided lower slopes which indicated good over polishing window for maintaining low oxide trench dishing even more oxide film removed in over polishing steps.

Table 4. Effects of Maltitol or Lactitol on Slopes of Dishing vs OP Removal Amount

Compositions	P100 dishing/OP Amt Slope	P200 dishing/OP Amt Slope	P1000 dishing/OP Amt Slope
0.2% Ceria-coated Silica pH 5.35 Ref.	0.19	0.23	0.25
0.2% Ceria-coated Silica + 0.28% Maltitol pH 5.35	0.04	0.05	0.08
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	0.04	0.06	0.09

- [00139] As showing in Table 4 and Figure 3, the CMP polishing compositions comprising chemical additives such as maltitol or lactitol, and ceria-coated silica again showed much lower slope values comparing to those slope values obtained for the ceria-coated silica abrasive based reference sample.

Example 3

- 10 [00140] In Example 3, the trench oxide loss rates were compared for the polishing compositions using reference and working compositions comprising maltitol or lactitol

[00141] The results were listed in Table 5 and depicted in Figure 4.

Table 5. Effects of Maltitol or Lactitol on Trench Loss Rates (Å/min.)

Compositions	P100Trench Loss Rate (Å/sec.)	P200Trench Loss Rate (Å/sec.)
0.2% Ceria-coated Silica pH 5.35 Ref.	18.5	19.3
0.2% Ceria-coated Silica + 0.28% Maltitol pH 5.35	2.0	2.5
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	2.3	2.6

- 15 [00142] As the results shown in Table 4 and Figure 4, the addition of maltitol or lactitol as oxide trench dishing reducing agent into the polishing compositions, the trench loss rates were significantly reduced vs the reference sample without using such chemical additives.

Example 4

[00143] The compositions were prepared as shown in Table 6. The reference composition did not use any chemical additives. The working compositions comprised 0.2 wt.% ceria-coated silica as abrasives, 0.28 wt.% lactitol as chemical additive, biocide, DI water, and a pH adjusting agent to provide different pH conditions.

[00144] The removal rates (RR at Å/min) for different films were tested. The effects of pH conditions on the film removal rates and selectivity were observed.

[00145] The test results were listed in Table 6 and shown in Figure 5.

[00146] As the results shown in Table 6 and Figure 5, the working compositions having lactitol as oxide trench dishing reducing agent provided similar high TEOS and HDP film removal rates, and similarly suppressed SiN film removal rates at three different pH conditions: acidic, neutral and alkaline. High TEOS: SiN selectivity were also maintained.

Table 6. Effects of pH on Film RR (Å /min) & Selectivity of Oxide: SiN

Compositions	TEOS Film RR (Å/min.)	HDP Film RR (Å/min.)	SiN Film RR (Å/min.)	TEOS: SiN Selectivity
0.2% Ceria-coated Silica pH 5.35	3279	2718	349	9.4
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	2623	2639	46	57.0
0.2% Ceria-coated Silica + 0.28% Lactitol pH 7.0	2524	2517	56	45.1
0.2% Ceria-coated Silica + 0.28% Lactitol pH 8.0	2401	2417	52	46.2

[00147] As the results shown in Table 6 and Figure 5, the working compositions having lactitol as oxide trench dishing reducing agent provided similar high TEOS and HDP film removal rates, and similarly suppressed SiN film removal rates at three different pH conditions: acidic, neutral and alkaline. High TEOS: SiN selectivity were also maintained.

[00148] Oxide trenching dishing using compositions without/or with lactitol as chemical additive over polishing times were also tested.

[00149] The effects of lactitol containing polishing composition at different pH conditions on the oxide trenching dishing vs over polishing times were observed.

[00150] The test results were listed in Table 7 and shown in Figure 6.

[00151] As the results shown in Table 7 and Figure 6, the polishing compositions with the chemical additive lactitol, provided low oxide trench dishing on 100um pitch, and 200um pitch respectively when 60 second or 120 second over polishing times were applied at three different tested pH conditions

[00152] The compositions with lactitol as oxide trench dishing reducing agent provided significant oxide trench dishing reductions comparing to the reference polishing composition which did not use the chemical additive, lactitol.

10 Table 7. Effects of Lactitol at Different pH Conditions on Oxide Trench Dishing vs OP Times (Sec.)

Compositions	OP Times (Sec.)	100um pitch dishing	200um pitch dishing
0.2% Ceria-coated Silica pH 5.35 Ref.	0	165	291
	60	857	1096
	120	1207	1531
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	0	349	563
	60	438	702
	120	510	779
0.2% Ceria-coated Silica + 0.28% Lactitol pH 7.0	0	73	182
	60	222	390
	120	346	532
0.2% Ceria-coated Silica + 0.28% Lactitol pH 8.0	0	269	386
	60	425	576
	120	568	766

[00153] The Ratio of oxide Trench Dishing Rate ($\text{\AA}/\text{min.}$) vs Blanket HDP film RR (A/min.) at different pH was listed in Table 8.

[00154] As the results shown in Table 8, the addition of lactitol as oxide trench dishing reducer in polishing composition significantly reduced the ratio of trench dishing rate vs the blanket HDP film removal rates at different pH conditions than that ratio obtained for reference sample at pH 5.35.

Table 8

Compositions	P100 Dishing Rate (Å/min.) /Blanket HDP RR (Å/min.)	P200 Dishing Rate (Å/min.) /Blanket HDP RR (Å/min.)
0.2% Ceria-coated Silica pH 5.35	0.13	0.16
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	0.03	0.03
0.2% Ceria-coated Silica + 0.28% Lactitol pH 7.0	0.05	0.06
0.2% Ceria-coated Silica + 0.28% Lactitol pH 8.0	0.06	0.08

- 5 [00155] The slopes of oxide trench dishing vs the OP removal amount was showed in Table 9 and Figure 7.

Table 9. Effects of Lactitol at Different pH on Slopes of Dishing vs OP Removal Amount

Compositions	P100 dishing/OP Amt Slope	P200 dishing/OP Amt Slope
0.2% Ceria-coated Silica pH 5.35	0.19	0.23
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	0.04	0.06
0.2% Ceria-coated Silica + 0.28% Lactitol pH 7.0	0.06	0.08
0.2% Ceria-coated Silica + 0.28% Lactitol pH 8.0	0.06	0.08

- 10 [00156] The results listed in Table 9 and Figure 7 indicated that the compositions with chemical additive lactitol provided lower slopes of trench dishing vs the over polishing removal amounts which indicated good over polishing window for maintaining low oxide trench dishing even more oxide film removed in over polishing steps at all three tested pH conditions.

[00157] The trench oxide loss rates were compared between the polishing compositions using lactitol (at different pH conditions) and the reference without using lactitol at pH 5.35.

5 Table 10. Effects of Lactitol at Different pH Conditions on Trench Loss Rates (Å/min.)

Compositions	P100Trench Loss Rate (Å/sec.)	P200Trench Loss Rate (Å/sec.)
0.2% Ceria-coated Silica pH 5.35 Ref.	18.5	19.3
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	2.3	2.6
0.2% Ceria-coated Silica + 0.28% Lactitol pH 7.0	3.3	4.0
0.2% Ceria-coated Silica + 0.28% Lactitol pH 8.0	3.7	4.2

[00158] The results were listed in Table 10 and depicted in Figure 8.

[00159] As the results shown in Table 10 and Figure 8, the trench loss rates were significantly reduced for the polishing compositions comprising lactitol at different pH conditions comparing with the reference sample without using lactitol.

[00160] The polishing test results obtained at different pH conditions indicates that the disclosed CMP polishing compositions comprising the chemical additives can be used for wide pH range; for acidic, neutral or alkaline pH conditions.

Example 5

[00161] In this example, the stability of ceria-coated silica abrasive particles in the compositions having chemical additives was monitored by measuring the change of the mean particles size and the change of particle size distribution D99.

[00162] The reference composition was prepared using 0.2 wt.% ceria-coated silica abrasive and very low concentration of biocide, and pH was adjusted to 5.35.

[00163] The working compositions were made using 0.2 wt.% or other wt.% ceria-coated silica abrasive, very low concentration of biocide, and varied concentrations of maltitol or lactitol as oxide trench dishing reducer and with pH adjusted to 5.35.

[00164] The abrasive particle stability tests on the polishing compositions were carried out at 50 °C for at least 10 days.

[00165] The MPS (nm) and D99(nm) of the abrasive particles were measured using dynamic light scattering (DLS) technology.

5 **[00166]** The stability test results were listed in Table 11 and depicted in Figure 9.

Table 11. Particle Size Stability Test Results@50 °C – MPS (nm) & D99(nm)

Compositions	Particle Sizes (nm)	Day 0	Day 1	Day 2	Day 3	Day 4	Day 8	Day 15	Day 18	Day 22	Day 32
0.2% Ceria-coated Silica pH 5.35	MPS(nm)	121.1	121.1			121.4	122.0	121.8		121.0	
	D99(nm)	177.4	179.6			177.6	178.8	178.8		176.7	
0.2% Ceria-coated Silica + 0.15% Maltitol pH 5.35	MPS(nm)	115.8	116.6	114.5	116.3	115.9			116.7		116.9
	D99(nm)	179.6	179.6	178.4	179.6	180.0			183.2		182.8
0.2% Ceria-coated Silica + 0.15% Lactitol pH 5.35	MPS(nm)	117.2	115.5	113.8	116.2	115.6			119.4		120.3
	D99(nm)	180.0	178.8	178.4	180.9	180.6			185.9		182.3

[00167] Data showed that 0.2 wt. % ceria-coated silica particles had a mean particle size changes of less than 8.26×10^{-4} and 0.4 % by day 22 at 50 °C.

10 **[00168]** 0.2 wt. % of the ceria-coated silica particles had a mean particle size changes of less than 0.1 % and 2.7 % by day 32 at 50 °C in the composition having 0.15 wt. % of maltitol and 0.15 wt.% lactitol respectively.

[00169] Data also showed that 0.2 wt. % of the ceria-coated silica particles had a D99 changes of less than 1.8 % and 1.3 % by day 32 at 50 °C in the composition having 0.15 wt. % of maltitol and 0.15 wt.% lactitol respectively.

15

[00170] Additional stability tests were performed using abrasive particles with different MPS (120nm) and were performed longer (day 62) using compositions comprising maltitol. The results were listed in Table 12 and depicted in Figure 10.

Table 12. Particle Size Stability Test Results@50 °C – MPS (nm) & D99(nm)

Compositions	Particle Sizes (nm)	Day 0	Day 1	Day 4	Day 8	Day 15	Day 22	Day 33	Day 40	Day 62
0.2% Ceria-coated Silica + 0.15% Maltitol pH 5.35	MPS(nm)	120	121.1	122.8	123	123.2	121.5	121.9	120.6	119.9
	D99(nm)	176.3	178	180.9	180.4	180	172.4	178.3	176.2	177.4

20

[00171] Data also showed that 0.2 wt. % of the ceria-coated silica particles had MPS and D99 changes of less than 8.5×10^{-4} and less than 0.63 % by day 62 at 50 °C respectively .

[00172] Furthermore, the particle stability tests were also conducted at 50 °C on

25 polishing compositions comprised more concentrated ceria-coated silica abrasives (

more than 0.2 wt. %) and more concentrated maltitol (more than 0.15 wt. %) as oxide trench dishing reducer.

[00173] The test results were listed in Table 13 and depicted in Figure 11.

Table 13. Particle Size Stability Test Results@50 °C – MPS (nm) & D99(nm)

Compositions	Particle Sizes (nm)	Day 0	Day 3	Day 5	Day 7	Day 14	Day 19	Day 25	Day 42
0.8% Ceria-coated Silica + 0.6% Maltitol pH 5.35	MPS(nm)	122	122	121.9	122	121	121	121.4	122.5
	D99(nm)	180.5	179.5	180	179.6	185.3	185.3	179.6	180.9
1.6% Ceria-coated Silica + 1.2% Maltitol pH 5.35	MPS(nm)	121.2	122.1	122.1	121.5	121.3	121.2	121.4	122.6
	D99(nm)	179.5	180	180	179.2	179.6	179.6	180.5	182.3
2.4% Ceria-coated Silica + 1.8% Maltitol pH 5.35	MPS(nm)	122.1	121.9	121.5	121.1	121	121	122	122.5
	D99(nm)	180.5	180	179.2	178	180.1	180.1	180.5	180.9

[00174] Data also showed that 0.8 wt. % of the ceria-coated silica particles had MPS and D99 changes of less than 0.41 % and less than 0.23 % respectively by day 42 at 50 °C in the composition having 0.6 wt. % of maltitol respectively.

[00175] 1.6 wt. % of the ceria-coated silica particles had MPS and D99 changes of less than 1.2% and less than 1.6 % respectively by day 42 at 50 °C in the composition having 1.2 wt. % of maltitol respectively..

[00176] 2.4 wt. % of the ceria-coated silica particles had MPS and D99 changes of less than 0.33 % and less than 0.23 % respectively by day 42 at 50 °C in the composition having 1.8 wt. % of maltitol respectively.

[00177] As the results shown in Table 9, 10, and 11 and Figure 9, 10 and 11, when maltitol or lactitol used as oxide trench dishing reducer with ceria-coated silica particles as abrasives, the polishing compositions showed very good abrasive particle size stability as the changes of particle MPS(nm) and particle size distribution D99(nm) were less than 1.8 % and less than 2.7 % respectively even at elevated testing temperatures.

[00178] Thus, the abrasive particles were stable in the disclosed CMP polishing compositions.

Example 6

[00179] The following three polishing compositions were prepared for defect count testing.

[00180] The first sample was prepared using 0.5 wt.% calcinated ceria abrasives, 0.05 wt.% polyacrylate salt and low concentration of biocide. The first sample was picked since it is a known polishing CMP composition comprised of calcinated ceria abrasives and polyacrylate salt as chemical additive for dispersing and trench dishing reducer.

- 5 **[00181]** The second sample was prepared using 0.2 wt.% ceria-coated silica abrasives, 0.28 wt.% maltitol and low concentration of biocide; the third sample was prepared using 0.2 wt.% ceria-coated silica abrasives, 0.28 wt.% lactitol and low concentration of biocide; all three formulations have pH valued at 5.35.

- 10 **[00182]** In order to obtain similar dielectric film removal rates used for comparison, higher concentration of calcinated ceria abrasive was used in sample 1.

[00183] The total defect counts on polished TEOS and SiN wafers were compared by using three afore listed polishing compositions. The total defect count results were listed in Table 14 and depicted in Figure 12.

Table 14. Effects of Different Polishing Compositions on TEOS & SiN Total Defect Counts

Compositions	TEOS Total Defect Count@0.13 μ m LPD	SiN Total Defect Count@0.13 μ m LPD
0.5% Calcinated Ceria + 0.05% Polyacrylate Salt pH	3847	498
0.2% Ceria-coated Silica + 0.28% Maltitol pH 5.35	438	73
0.2% Ceria-coated Silica + 0.28% Lactitol pH 5.35	493	73

- 15 **[00184]** As the total defect count results shown in Table 12 and Figure 12, the polishing compositions using ceria-coated silica particles as abrasives and either maltitol or lactitol as trench dishing reducing agent afforded significantly lower total defect counts on the polished TEOS and SiN wafers than the total defect counts obtained using a well-
- 20 known polishing composition comprised of calcinated ceria abrasives and polyacrylate salt as chemical additive.

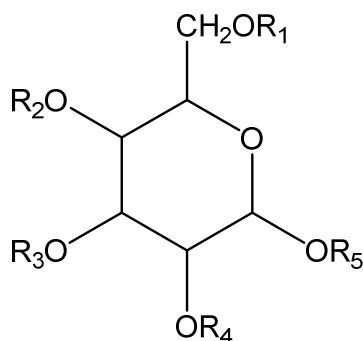
[00185] Thus, the CMP polishing compositions in the present invention provide reduced total defect counts through and post-polishing.

[00186] The embodiments of this invention listed above, including the working example, are exemplary of numerous embodiments that may be made of this invention. It is contemplated that numerous other configurations of the process may be used, and the materials used in the process may be elected from numerous materials other than
5 those specifically disclosed.

Claims

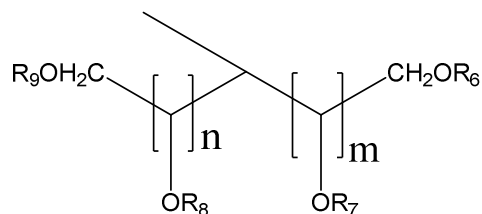
1. A Chemical Mechanical Polishing(CMP) composition consisting essentially of:

- 5 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
10 polyacrylate particles, and combinations thereof; and
combinations thereof;
chemical additive;
solvent selected from the group consisting of deionized (DI) water, distilled water,
15 and alcoholic organic solvents; and
optionally
biocide; and
pH adjuster;
wherein
20 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)

- 25 wherein R_1 , R_2 , R_3 , R_4 and R_5 (R s in group of R_1 to R_5) are selected from the group consisting of
(1) (i) at least one R in the group of R_1 to R_5 is a polyol molecular unit having a structure shown in (b):



(b);

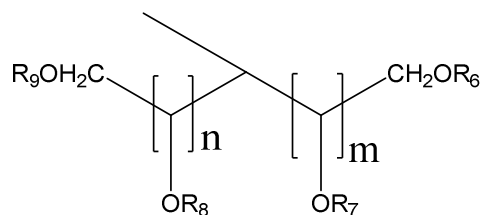
wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic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

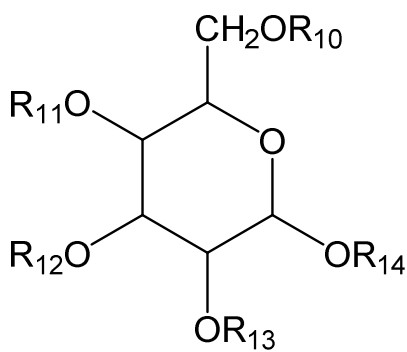


(b);

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

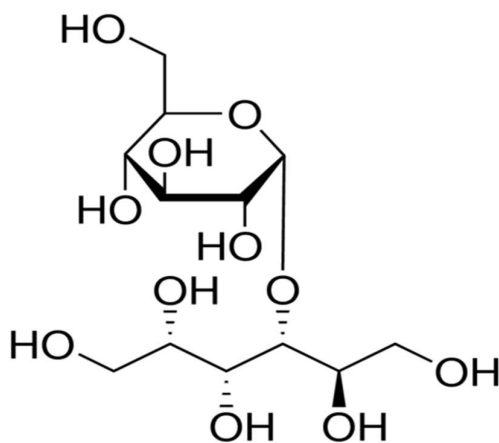
(iii) each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic carboxylic ester, organic amine,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

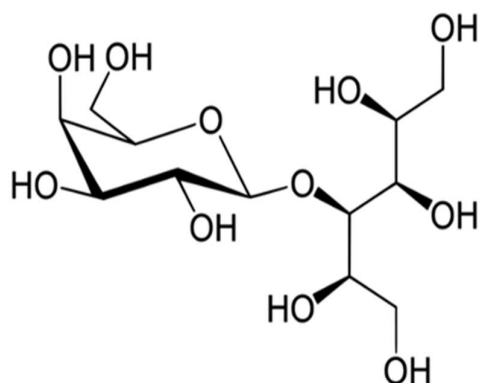
the chemical additive ranges from 0.01 wt.% to 20.0% wt.% and has at least six hydroxyl functional groups in its molecular structure; and

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) $\leq$
5 5.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 °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
10 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) $\leq$
15 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 °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
20 hydrogen atoms, as shown below:



Maltitol; or

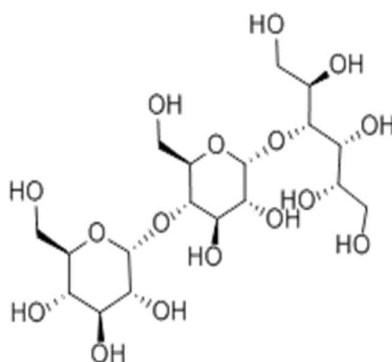


Lactitol;

the solvent is deionized (DI) water; and

the ceria-coated colloidal silica particles have changes of mean particle size MPS(nm)
 5 and $D_{99}(\text{nm}) \leq 2.0\%$.

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.%;
 10 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 $D_{99}(\text{nm}) \leq$
 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 °C; wherein
 15 $D_{99}(\text{nm})$ 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)
 5 and $D_{99}(\text{nm}) \leq 2.0\%$.

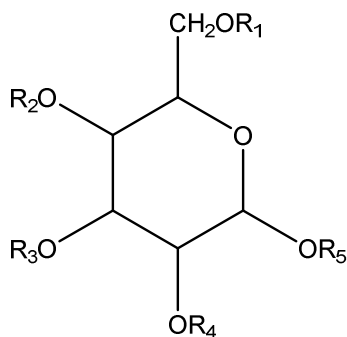
8. The chemical mechanical polishing composition of Claim 1, wherein the composition
 10 comprises ceria-coated colloidal silica particles; the chemical additive selected from
 the group consisting of maltitol, lactitol, maltotritol and combinations thereof; and
 water.

9. The chemical mechanical polishing composition of Claim 1, wherein the composition
 15 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
 20 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.

25 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 consisting essentially of

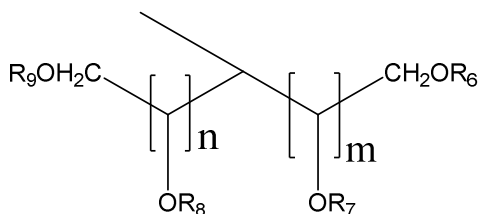
5 abrasive particles selected from the group consisting of
 ceria-coated inorganic oxide particles selected from the group consisting of
 ceria-coated colloidal silica, ceria-coated high purity colloidal silica, ceria-
 coated alumina, ceria-coated titania, ceria-coated zirconia particles and
 combinations thereof;
10 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;
15 solvent selected from the group consisting of deionized (DI) water, distilled water,
 and alcoholic organic solvents; and
 optionally
 biocide; and
 pH adjuster;
20 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):



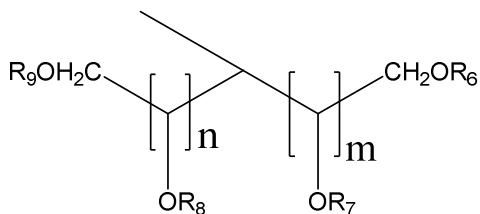
wherein m or n is independently selected from 1 to 5; and each of R6, R7, R8 and R9 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic carboxylic acid or salt, organic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

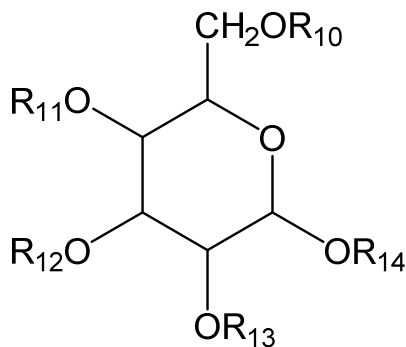
and

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



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

- 5 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;
- 10 the abrasive particles have changes of mean particle size MPS(nm) and D99(nm)
 $\leq 5.0\%$ over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 °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.

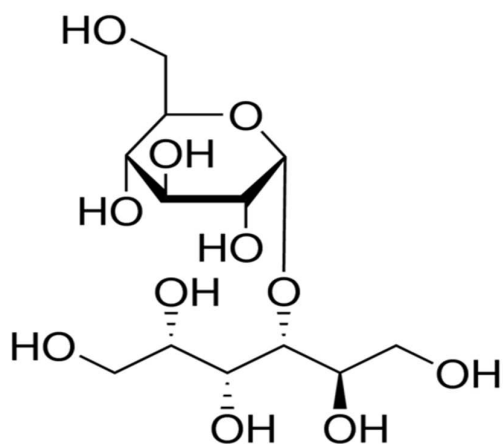
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12. The method of claim 11; wherein

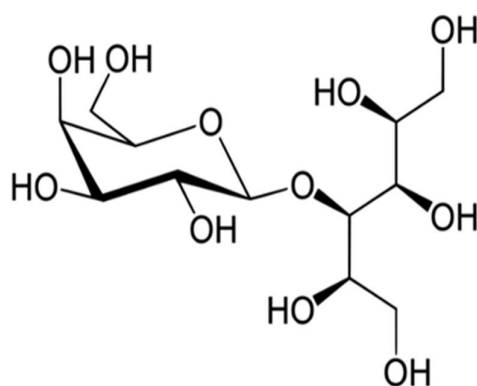
- the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected
 from (1);
- 20 the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) $\leq$
 3.0% over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 °C; wherein
 D99(nm) is a particle size that 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 .

25

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;

- 5 the solvent is deionized (DI) water;
- the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) $\leq$ 2.0%; and
- ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket oxide film removal rate($\text{\AA}/\text{min.}$) is $\leq$ 0.05.

10

14. The method of claim 11; wherein

the abrasive particles are ceria-coated colloidal silica particles;

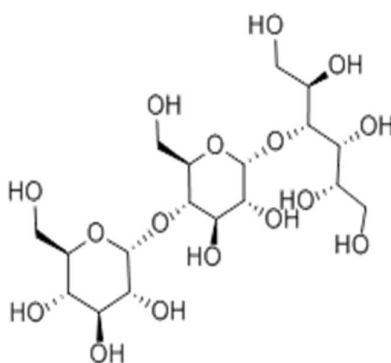
the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected

15 from (2);

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) $\leq$ 3.0% over shelf time of $\geq$ 30 days at a temperature ranging from 20 to 60 °C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under; and

5 ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket HDP film removal rate($\text{\AA}/\text{min.}$) is $\leq$ 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,
10 as shown below:



Maltotrititol;

and the solvent is deionized (DI) water;

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) $\leq$ 2.0%; and
15

ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket oxide film removal rate($\text{\AA}/\text{min.}$) is $\leq$ 0.05.

16. The method of claim 11, wherein the composition comprises ceria-coated colloidal
20 silica particles; the chemical additive selected from the group consisting of maltitol, lactitol, maltotrititol 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
25 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.%

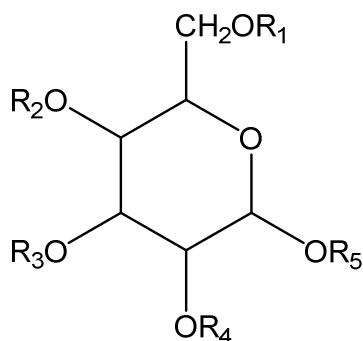
of the pH adjusting agent selected from the group consisting of nitric acid, hydrochloric acid, sulfuric acid, phosphoric acid, other inorganic or organic acids, and mixtures thereof for acidic pH conditions; or selected from the group consisting of sodium hydride, potassium hydroxide, ammonium hydroxide, 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 consisting essentially of
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
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

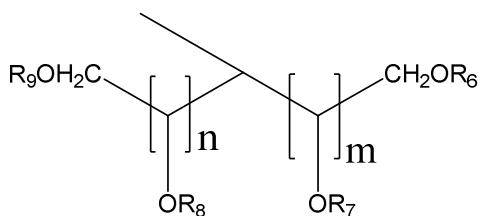
the chemical additive has at least four hydroxyl functional groups in its molecular structure as shown in (a):



(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

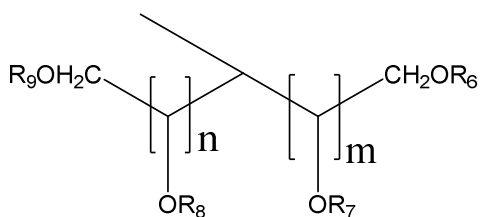
(ii) each of other Rs in the group of R1 to R5 is independently selected from the group consisting of hydrogen, alkyl, alkoxy, organic group with one or more hydroxyl groups, substituted organic sulfonic acid or salt, substituted organic

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):

5

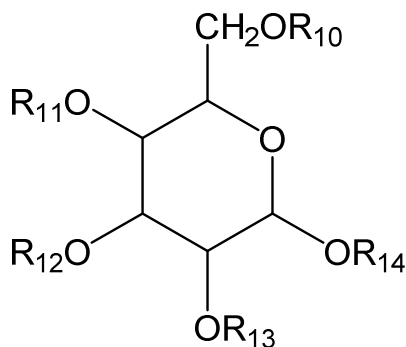


(b);

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;

10

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



(c);

15

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;

20

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) $\leq 5.0\%$ over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 °C; wherein D99(nm) is a particle size that 99 wt.% of the particles fall on and under; and

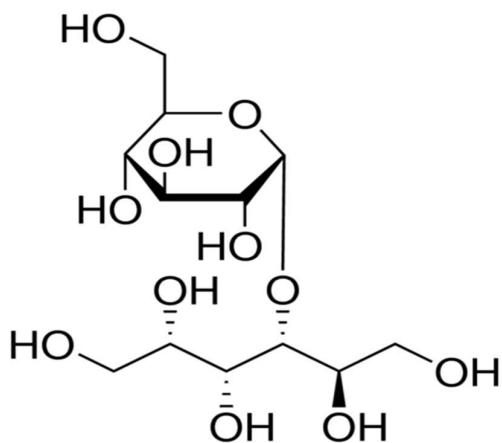
the chemical mechanical polishing (CMP) composition has a pH of 3 to 10.

21. The system of claim 19; wherein

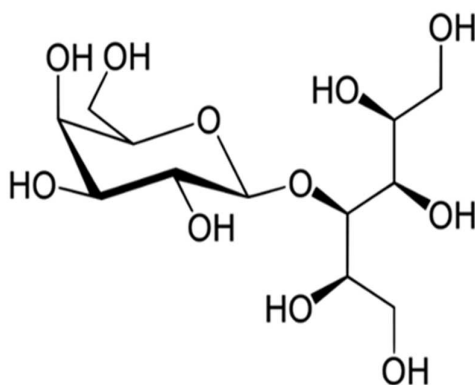
the chemical additive has R1, R2, R3, R4 and R5 (Rs in group R1 to R5) selected from (1);

the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) $\leq$ 3.0% over shelf time of $\geq$ 30 days at a temperature ranging from 20 to 60 °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 $\leq$ 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

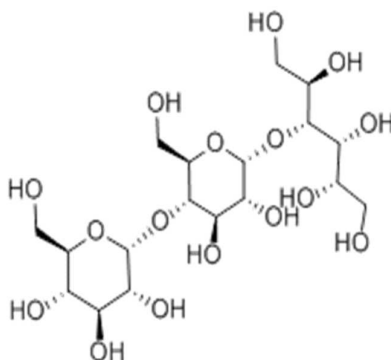
the abrasive particles have changes of mean particle size MPS(nm) and D99(nm) $\leq$ 2.0%; and

ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket oxide film removal rate($\text{\AA}/\text{min.}$) is ≤ 0.05 .

23. The system of claim 19; wherein

- 5 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) $\leq 3.0\%$ over shelf time of ≥ 30 days at a temperature ranging from 20 to 60 $^{\circ}\text{C}$; wherein
10 D99(nm) is a particle size that 99 wt.% of the particles fall on and under;
and
ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket HDP film removal rate($\text{\AA}/\text{min.}$) is ≤ 0.1 .

- 15 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;

- 20 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) $\leq 2.0\%$; and
ratio of oxide trench dishing rate ($\text{\AA}/\text{min.}$) vs the blanket oxide film removal rate($\text{\AA}/\text{min.}$) is ≤ 0.05 .

25

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.
- 5 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,
10 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.