SILICON POLISHING COMPOSITIONS WITH HIGH RATE AND LOW DEFECTIVITY

BACKGROUND OF THE INVENTION

[0001] Silicon wafers used in electronic devices are typically prepared from a single crystal silicon ingot that is first sliced into thin wafers using a diamond saw and then ground to remove surface imperfections arising from the sawing process. The silicon wafers thereafter typically require a final polishing step to provide surfaces having very low surface roughness before the silicon wafers are acceptable for use in electronic devices.

[0002] Current methods of performing the final polishing of silicon wafers often employ polishing compositions that contain silica as an abrasive in an aqueous carrier and further comprising additives such as amines or quaternary ammonium salts as polishing rate enhancers. Conventional polishing compositions for silicon wafers generally require over 10 minutes of polishing in order to remove 10-20 microns of silica.

[0003] Polishing compositions are desired that can be used to polish silicon more quickly to improve throughput and more effectively utilize production capacity. It is well known to use amines in silicon slurries to increase the removal rate. However, the use of amines in polishing slurries is accompanied by an increase in particle defects and haze on the substrate. Further, in view of environmental concerns such as waste water treatment regulations, the use of amine additives is undesirable.

[0004] Thus, there is a need in the art for improved chemical-mechanical polishing compositions exhibiting a high removal rate, low particle defects, and low haze.

~~BRIEF~~ SUMMARY ~~OF THE INVENTION~~

[0005] The disclosure~~invention~~ provides a chemical-mechanical polishing composition comprising an abrasive, a rate accelerator, a polysaccharide, a base, optionally a surfactant and/or polymer, optionally a reducing agent, and water.

[0006] The disclosure~~invention~~ particularly provides a chemical-mechanical polishing composition comprising (a) silica, (b) one or more organic carboxylic acids or salts thereof, (c) one or more polysaccharides selected from the group consisting of a hydroxyalkylcellulose, carrageenan, and xanthan gum, (d) one or more bases, (e) optionally one or more surfactants and/or polymers, (f) optionally one or more reducing agents, (g) optionally one or more biocides, and (h) water, wherein the polishing composition has an alkaline pH.

[0007] The disclosed chemical-mechanical polishing composition ~~in accordance with the invention~~ desirably exhibits a high removal rate, low particle defectivity, and low haze. Moreover, at

least some embodiments of the disclosed polishing composition ~~in accordance with the invention~~ have a low solids content, thereby being of relatively low cost.

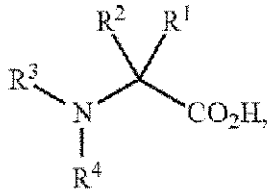
[0008] The disclosure~~invention~~ further provides a method of chemically-mechanically polishing a substrate with the inventive chemical-mechanical polishing composition. Typically, the substrate comprises silicon.

[0008a] In one aspect, there is provided a chemical-mechanical polishing composition consisting essentially of: (a) silica, (b) one or more organic carboxylic acids, salts, or hydrates thereof selected from the group consisting of (i) dicarboxylic acids of the formula:



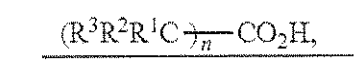
wherein n is an integer of 0-8 and each of R^1 and R^2 is independently selected from the group consisting of hydrogen, a hydroxyl group, and C_1-C_6 alkyl groups, or R^1 and R^2 together form an oxo group, and when n is 2 or more, the bonds between the CR^1R^2 groups are independently selected from the group consisting of single, double, or triple bonds;

(ii) amino acids of the formula:

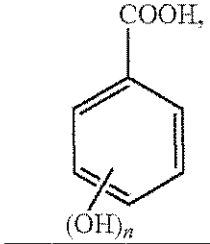


wherein each of R^1, R^2, R^3, and R^4 is independently selected from the group consisting of hydrogen, an aminoalkyl group, a carboxyalkyl group, a hydroxyalkyl group, a $-(CH_2)_n-$ group, and $-(CH=CH-)_n$ group connecting either R^1 or R^2 with either R^3 or R^4, wherein n is an integer of 1-6;

(iii) hydroxy acids of formula (1):



wherein n is an integer of 0-8, and each of R^1-R^3 is independently selected from the group consisting of hydrogen, alkyl, hydroxy, and hydroxyalkyl, wherein at least one of R^1-R^3 is hydroxy or hydroxyalkyl, or formula (2):



wherein n is an integer of 1-5;

(iv) carboxy substituted pyrazine compounds; and

(v) carboxy substituted triazole compounds,

(c) one or more polysaccharides selected from the group consisting of a hydroxyalkylcellulose, carrageenan, and xanthan gum,

(d) one or more bases,

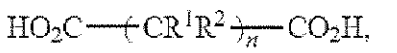
(e) optionally one or more surfactants and/or polymers,

(f) optionally one or more reducing agents,

(g) optionally one or more biocides, and

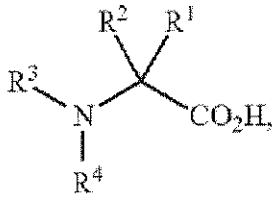
(h) water, wherein the polishing composition has an alkaline pH.

[0008b] In another aspect, there is provided a method of chemically-mechanically polishing a substrate comprising: (i) contacting a substrate with a polishing pad and a chemical-mechanical polishing composition consisting essentially of: (a) silica, (b) one or more organic carboxylic acids or salts thereof selected from the group consisting of (i) dicarboxylic acids of the formula:



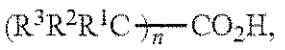
wherein n is an integer of 0-8 and each of R^1 and R^2 is independently selected from the group consisting of hydrogen, a hydroxyl group, and C_1-C_6 alkyl groups, or R^1 and R^2 together form an oxo group; and when n is 2 or more, the bonds between the CR^1R^2 groups are independently selected from the group consisting of single, double, or triple bonds;

(ii) amino acids of the formula:

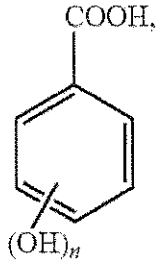


wherein each of R^1, R^2, R^3, and R^4 is independently selected from the group consisting of hydrogen, an aminoalkyl group, a carboxyalkyl group, a hydroxyalkyl group, a $-(CH_2)_n-$ group, a $-(CH=CH-)_n$ group connecting either R^1 or R^2 with either R^3 or R^4, wherein n is an integer of 1-6;

(iii) hydroxy acids of the formula (1):



wherein n is an integer of 0-8, and each of R^1-R^3 is independently selected from the group consisting of hydrogen, alkyl, hydroxy, and hydroxyalkyl, wherein at least one of R^1-R^3 is hydroxy or hydroxyalkyl, or the formula (2):



wherein n is an integer of 1-5;

(iv) carboxy substituted pyrazine compounds; and

(v) carboxy substituted triazole compounds,

(c) one or more polysaccharides selected from the group consisting of a hydroxyalkylcellulose, carrageenan, and xanthan gum,

(d) one or more bases,

(e) optionally one or more surfactants and/or polymers,

(f) optionally one or more reducing agents,

(g) optionally one or more biocides, and

(h) water, wherein the polishing composition has an alkaline pH,

(ii) moving the polishing pad relative to the substrate with the chemical-mechanical polishing composition therebetween, and

(iii) abrading at least a portion of the substrate to polish the substrate.

DETAILED DESCRIPTION OF THE INVENTION

[0009] The invention provides a chemical-mechanical polishing composition and a method of chemically-mechanically polishing a substrate (e.g., silicon wafer), wherein the polishing composition comprises one or more polysaccharides and one or more rate accelerators. Applicants have found that conventional amine rate accelerators lead to increased particle defects and increased haze in polished substrates.

[0010] In an embodiment, the chemical-mechanical polishing composition comprises, consists essentially of, or consists of (a) silica, (b) one or more organic carboxylic acids or salts thereof, (c) one or more polysaccharides selected from the group consisting of a hydroxyalkylcellulose, carrageenan, and xanthan gum, (d) one or more bases, (e) optionally one or more surfactants and/or polymers, (f) optionally one or more reducing agents, (g) optionally one or more biocides, and (h) water, wherein the organic carboxylic acid is selected from the group consisting of dicarboxylic acids, amino acids, hydroxy acids, amino-carboxy substituted pyrazine compounds, and amino-carboxy substituted triazole compounds, and wherein the polishing composition has an alkaline pH.

[0011] The polishing composition of the invention desirably exhibits a high removable rate when polishing a substrate according to a method of the invention. For example, when polishing silicon wafers in accordance with an embodiment of the invention, the polishing composition desirably exhibits a removal rate of 500 Å/min or higher, preferably 700 Å/min or higher, and more preferably 1000 Å/min or higher.

[0012] Moreover, the polishing composition of the invention desirably exhibits low particle defects when polishing a substrate, as determined by suitable techniques. Particle defects on a substrate polished with the inventive polishing composition can be determined by any suitable technique. For example, laser light scattering techniques, such as dark field normal beam composite (DCN) and dark field oblique beam composite (DCO), can be used to determine particle defects on polished substrates. A substrate, especially silicon, polished with the inventive polishing composition desirably has a DCN value of 4000 counts or less, e.g., 3500 counts or less, 3000 counts or less, 2500 counts or less, 2000 counts or less, 1500