COMPOSITION AND METHOD FOR POLISHING BULK SILICON

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, lapped to improve flatness, and etched to remove subsurface damage caused by lapping. The silicon wafers are then typically polished in a two-step process to remove nanotopography caused by etching and to achieve the desired thickness before the wafers are acceptable for use in electronic devices.

[0002] In the first polishing step, a high removal rate is required, and ideally the nanotopography would not be worsened during this step. Nanotopography is a parameter that measures the front-surface topology of an area and is defined as the deviation of a surface within a spatial wavelength of around 0.2 to 20 mm. Nanotopography differs from surface flatness in that, for nanotopgraphy, the flatness of the wafer surface is measured relative to the wafer surface itself, while for surface flatness, the flatness of the wafer surface is measured relative to a flat chuck used to hold the wafer. Thus, a wafer may have perfect flatness, yet still have nanotopography. If a wafer has surface irregularities on the front and back sides of the wafer, but the front and back surfaces are parallel, the wafer has perfect flatness. However, the same wafer will exhibit nanotopography. Nanotopography bridges the gap between roughness and flatness in the topology map of wafer surface irregularities in spatial frequency.

[0003] Conventional polishing compositions for silicon wafers exhibit high removal rates for silicon, but produce increased nanotopograpy of the silicon wafers. The increased nanotopography puts increased demands on the second, final polishing step to produce silicon wafers suitable for further processing into semiconductor substrates. Thus, there remains a need in the art for improved polishing compositions for silicon wafers.

BRIEF SUMMARY OF THE INVENTION

[0004] The disclosure~~invention~~ provides a polishing composition comprising (a) silica, (b) a compound or compounds that increases the removal rate of silicon, (c) a tetraalkylammonium salt, and (d) water, wherein the polishing composition has a pH of 7 to 11.

[0004a] In one aspect, there is provided a chemical-mechanical polishing composition consisting essentially of:

(a) about 0.5 wt.% to about 20 wt.% of silica,

(b) about 0.02 wt.% to about 5 wt.% of one or more organic carboxylic acids,

(c) about 0.05 wt.% to about 2 wt.% of one or more aminophosphonic acids,

(d) about 0.1 wt.% to about 5 wt.% of one or more tetraalkylammonium salts selected from the group consisting of tetraalkylammonium hydroxide, chloride, bromide, sulfate, and hydrogensulfate salts,

(e) potassium bicarbonate,

(f) optionally potassium hydroxide, and

(g) water,

wherein the polishing composition has a pH of about 8 to about 11.

[0005] A first embodiment of the inventive chemical-mechanical polishing composition comprises a chemical mechanical polishing composition consisting essentially of or consisting of (a) 0.5 wt.% to 20 wt.% of silica, (b) 0.02 wt.% to 5 wt.% of one or more

organic carboxylic acids, (c) 0.02 wt.% to 2 wt.% of one or more aminophosphonic acids, (d) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts, (e) optionally one or more bicarbonate salts, (f) optionally potassium hydroxide, and (g) water, wherein the polishing composition has a pH of 7 to 11.

[0006] A second embodiment of the inventive chemical-mechanical polishing composition comprises a chemical mechanical polishing composition consisting essentially of or consisting of (a) 0.5 wt.% to 20 wt.% of silica, (b) 0.01 wt.% to 2 wt.% of one or more polyaminocarboxylic acids, (c) 0.05 wt.% to 5 wt.% of one or more amines, (d) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts, (e) 0.001 wt.% to 1 wt.% of one or more diol compounds, (f) optionally one or more bicarbonate salts, and (g) water, wherein the polishing composition has a pH of 7 to 11.

[0007] A third embodiment of the inventive chemical-mechanical polishing composition comprises a chemical mechanical polishing composition consisting essentially of or consisting of (a) 0.5 wt.% to 20 wt.% of silica, (b) 0.01 wt.% to 2 wt.% of one or more polyaminocarboxylic acids, (c) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts, (d) 0.01 wt.% to 5 wt.% of one or more organic carboxylic acids, (e) optionally 0.1 wt.% to 5 wt.% of one or more amines, (f) optionally one or more bicarbonate salts, and (g) water, wherein the polishing composition has a pH of 7 to 11.

[0008] A fourth embodiment of the inventive chemical-mechanical polishing composition comprises a chemical mechanical polishing composition consisting essentially of or consisting of (a) 0.5 wt.% to 20 wt.% of silica, (b) 0.02 wt.% to 5 wt.% of one or more nitrogen-containing heterocyclic compounds, (c) 0.05 wt.% to 2 wt.% of one or more aminophosphonic acids, (d) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts, (e) optionally one or more bicarbonate salts, and (f) water, wherein the polishing composition has a pH of 7 to 11.

[0009] The disclosure~~invention~~ also provides a method for chemically-mechanically polishing a substrate with the inventive chemical-mechanical polishing composition.

[0010] A first embodiment of the inventive method for chemically-mechanically polishing a substrate comprises (i) contacting a substrate with a polishing pad and a chemical mechanical polishing composition consisting essentially of or consisting of (a) 0.5 wt.% to 20 wt.% of silica, (b) 0.02 wt.% to 5 wt.% of one or more organic carboxylic acids, (c) 0.02 wt.% to 2 wt.% of one or more aminophosphonic acids, (d)0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts, (e) optionally one or more bicarbonate salts, (f) optionally

CLAIMS

1. A chemical-mechanical polishing composition consisting essentially of:

(a) 0.5 wt.% to 20 wt.% of silica,

(b) 0.02 wt.% to 5 wt.% of one or more organic carboxylic acids,

(c) 0.05 wt.% to 2 wt.% of one or more aminophosphonic acids,

(d) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts,

(e) optionally one or more bicarbonate salts,

(f) optionally potassium hydroxide, and

(g) water,

wherein the polishing composition has a pH of 7 to 11.

2. The polishing composition of claim 1, wherein the polishing composition contains 5 wt.% to 20 wt.% of silica.

3. The polishing composition of claim 2, wherein the polishing composition contains 10 wt.% to 15 wt.% of silica.

4. The polishing composition of claim 1, wherein the silica is wet-process silica.

5. The polishing composition of claim 1, wherein the silica is fumed silica.

6. The polishing composition of claim 1, wherein the polishing composition contains 0.1 wt.% to 2 wt.% of organic carboxylic acid.

7. The polishing composition of claim 1, wherein at least one organic carboxylic acid is a hydroxycarboxylic acid.

8. The polishing composition of claim 7, wherein the organic carboxylic acid is an aliphatic hydroxycarboxylic acid.

9. The polishing composition of claim 8, wherein the organic carboxylic acid is selected from the group consisting of lactic acid, 2-hydroxybutyric acid, benzilic acid, and combinations thereof.

10. The polishing composition of claim 1, wherein at least one organic carboxylic acid is a hydroxybenzoic acid.

11. The polishing composition of claim 10, wherein the organic carboxylic acid is selected from the group consisting of salicylic acid, 2,6-dihydroxybenzoic acid, and combinations thereof.

12. The polishing composition of claim 10, wherein the organic carboxylic acid is an amino hydroxybenzoic acid.

13. The polishing composition of claim 1, wherein at least one carboxylic acid is an amino acid.

14. The polishing composition of claim 13, wherein the amino acid is selected from the group consisting of proline, glycine, alanine, and combinations thereof.

15. The polishing composition of claim 1, wherein the polishing composition contains 0.1 wt.% to 1 wt.% of at least one aminophosphonic acid.

16. The polishing composition of claim 15, wherein the aminophosphonic acid is selected from the group consisting of ethylenediaminetetra(methylene phosphonic acid), amino tri(methylene phosphonic acid), diethylenetriaminepenta(methylene phosphonic acid), and combinations thereof.

17. The polishing composition of claim 16, wherein the aminophophonic acid is amino tri(methylene phosphonic acid).

18. The polishing composition of claim 1, wherein at least one bicarbonate salt is present in the polishing composition, and wherein the bicarbonate salt is potassium bicarbonate.

19. The polishing composition of claim 1, wherein potassium hydroxide is present in the polishing composition.

20. The polishing composition of claim 1, wherein the polishing composition has a pH of 8 to 10.

21. A chemical-mechanical polishing composition consisting essentially of:

(a) 0.5 wt.% to 20 wt.% of silica,

(b) 0.1 wt.% to 2 wt.% of one or more polyaminocarboxylic acids,

(c) 0.1 wt.% to 5 wt.% of one or more amines,

(d) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts,

(e) 0.001 wt.% to 1 wt.% of one or more 1,3-diol compound,

(f) optionally one or more bicarbonate salts, and

(g) water,

wherein the polishing composition has a pH of 7 to 11.

22. The polishing composition of claim 21, wherein the polishing composition contains 5 wt.% to 20 wt.% of silica.

23. The polishing composition of claim 21, wherein the polishing composition contains 10 wt.% to 15 wt.% of silica.

24. The polishing composition of claim 21, wherein the silica is wet-process silica.

25. The polishing composition of claim 21, wherein the silica is fumed silica.

26. The polishing composition of claim 21, wherein the polishing composition contains 0.1 wt.% to 1 wt.% of the polyaminocarboxylic acid.

27. The polishing composition of claim 21, wherein the polyaminocarboxylic acid is selected from the group consisting of ethylenediaminetetraacetic acid, diethylenetriaminepentaacetic acid, N-(hydroxyethyl)ethylenediaminetriacetic acid, nitrilotriacetic acid, salts, thereof, and combinations thereof.

28. The polishing composition of claim 27, wherein the polyaminocarboxylic acid is ethylenediaminetetraacetic acid.

29. The polishing composition of claim 21, wherein the polishing composition contains 0.1 wt.% to 2 wt.% of the amine.

30. The polishing composition of claim 21, wherein the amine is selected from the group consisting of piperazine, 1-(2-aminoethyl) piperazine, 2-methyl-1-aminoethanol, (2-aminoethyl)aminoethanol, and combinations thereof.

31. The polishing composition of claim 21, wherein the 1,3-diol compound is selected from the group consisting of 1,3-butanediol, 2,4-pentanediol, 2,4-hexanediol, and combinations thereof.

32. The polishing composition of claim 21, wherein at least one bicarbonate salt is present in the polishing composition, and wherein the bicarbonate salt is potassium bicarbonate.

33. The polishing composition of claim 21, wherein the polishing composition has a pH of 8 to 10.

34. A chemical-mechanical polishing composition consisting essentially of:

(a) 0.5 wt.% to 20 wt.% of silica,

(b) 0.1 wt.% to 2 wt.% of one or more polyaminocarboxylic acids,

(c) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts,

(d) 0.1 wt.% to 5 wt.% of one or more organic carboxylic acids,

(e) optionally 0.1 wt.% to 5 wt.% of one or more amines,

(f) optionally one or more bicarbonate salts, and

(g) water,

wherein the polishing composition has a pH of 7 to 11.

35. The polishing composition of claim 34, wherein the polishing composition contains 5 wt.% to 20 wt.% of silica.

36. The polishing composition of claim 34, wherein the polishing composition contains 10 wt.% to 15 wt.% of silica.

37. The polishing composition of claim 34, wherein the silica is wet-process silica.

38. The polishing composition of claim 34, wherein the silica is fumed silica.

39. The polishing composition of claim 34, wherein the polishing composition contains 0.1 wt.% to 1 wt.% of the polyaminocarboxylic acid.

40. The polishing composition claim 34, wherein the polyaminocarboxylic acid is selected from the group consisting of ethylenediaminetetraacetic acid, diethylenetriaminepentaacetic acid, N-(hydroxyethyl)ethylenediaminetriacetic acid, nitrilotriacetic acid, salts, thereof, and combinations thereof.

41. The polishing composition of claim 40, wherein the polyaminocarboxylic acid is ethylenediaminetetraacetic acid.

42. The polishing composition of claim 34, wherein the polishing composition contains 0.1 wt.% to 2 wt.% of the organic carboxylic acid.

43. The polishing composition of claim 34, wherein at least one organic carboxylic acid is a dicarboxylic acid.

44. The polishing composition of claim 43, wherein the organic carboxylic acid is oxalic acid or benzilic acid.

45. The polishing composition of claim 34, wherein the polishing composition contains 0.1 wt.% to 2 wt.% of the amine.

46. The polishing composition of claim 34, wherein the amine is selected from the group consisting of piperazine, 1-(2-aminoethyl) piperazine, 2-methyl-1-aminoethanol, (2-aminoethyl)aminoethanol, and combinations thereof.

47. The polishing composition of claim 34, wherein at least one bicarbonate salt is present in the polishing composition, and wherein the bicarbonate salt is potassium bicarbonate.

48. The polishing composition of claim 34, wherein the polishing composition has a pH of 8 to 10.

49. A chemical-mechanical polishing composition consisting essentially of:

(a) 0.5 wt.% to 20 wt.% of silica,

(b) 0.02 wt.% to 5 wt.% of one or more nitrogen-containing heterocyclic compounds,

(c) 0.05 wt.% to 2 wt.% of one or more aminophosphonic acids,

(d) 0.1 wt.% to 5 wt.% of one or more tetraalkylammonium salts,

(e) optionally one or more bicarbonate salts, and

(f) water,

wherein the polishing composition has a pH of 7 to 11.

50. The polishing composition of claim 49, wherein the polishing composition contains 5 wt.% to 20 wt.% of silica.

51. The polishing composition of claim 50, wherein the polishing composition contains 10 wt.% to 15 wt.% of silica.

52. The polishing composition of claim 49, wherein the silica is wet-process silica.

53. The polishing composition of claim 49, wherein the silica is fumed silica.

54. The polishing composition of claim 49, wherein the polishing composition contains 0.1 wt.% to 2 wt.% of the nitrogen-containing heterocyclic compound.

55. The polishing composition of claim 49, wherein at least one nitrogen-containing heterocyclic compound is a triazole.

56. The polishing composition of claim 55, wherein the nitrogen-containing heterocyclic compound is an aminotriazole.

57. The polishing composition of claim 56, wherein the aminotriazole is selected from the group consisting of 3-amino-1,2,4-triazole, 3-amino-1,2,4-triazole-5-carboxylic acid, 3-amino-5-mercapto-1,2,4-triazole, and 4-amino-5-hydrazino-1,2,4-triazole-3-thiol.

58. The polishing composition of claim 49, wherein at least one nitrogen-containing heterocyclic compound is a thiazole.

59. The polishing composition of claim 58, wherein the thiazole is selected from the group consisting of 2-amino-5-methylthiazole, 2-amino-thiazoleacetic acid, and thiazole.

60. The polishing composition of claim 49, wherein at least one nitrogen-containing heterocyclic compound is a heterocyclic N-oxide.

61. The polishing composition of claim 60, wherein the nitrogen-containing heterocyclic compound is selected from the group consisting of 2-hydroxypyridine-N-oxide, 4-methylmorpholine-N-oxide, and picolinic acid N-oxide.

62. The polishing composition of claim 49, wherein the polishing composition contains 0.1 wt.% to 1 wt.% of at least one aminophosphonic acid.

63. The polishing composition of claim 62, wherein the aminophosphonic acid is selected from the group consisting of ethylenediaminetetra(methylene phosphonic acid), amino tri(methylene phosphonic acid), diethylenetriaminepenta(methylene phosphonic acid), and combinations thereof.

64. The polishing composition of claim 63, wherein the aminophophonic acid is amino tri(methylene phosphonic acid).

65. The polishing composition of claim 49, wherein at least one bicarbonate salt is present in the polishing composition, and wherein the bicarbonate salt is potassium bicarbonate.

66. The polishing composition of claim 49, wherein the polishing composition has a pH of 8 to 10.

CLAIMS

1. A chemical-mechanical polishing composition consisting essentially of:

(a) about 0.5 wt.% to about 20 wt.% of silica,

(b) about 0.02 wt.% to about 5 wt.% of one or more organic carboxylic acids,

(c) about 0.05 wt.% to about 2 wt.% of one or more aminophosphonic acids,

(d) about 0.1 wt.% to about 5 wt.% of one or more tetraalkylammonium salts selected from the group consisting of tetraalkylammonium hydroxide, chloride, bromide, sulfate, and hydrogensulfate salts,

(e) potassium bicarbonate,

(f) optionally potassium hydroxide, and

(g) water,

wherein the polishing composition has a pH of about 8 to about 11.

2. The polishing composition of claim 1, wherein the silica is present in the polishing composition in an amount of from about 5 wt.% to about 20 wt.%.

3. The polishing composition of claim 2, wherein the silica is present in the polishing composition in an amount of from about 10 wt.% to about 15 wt.%.

4. The polishing composition of claim 1, wherein the silica is wet-process silica.

5. The polishing composition of claim 1, wherein the organic carboxylic acid is present in the polishing composition in an amount of from about 0.1 wt.% to about 2 wt.%.

6. The polishing composition of claim 1, wherein at least one organic carboxylic acid is a hydroxycarboxylic acid.

7. The polishing composition of claim 6, wherein the organic carboxylic acid is an aliphatic hydroxycarboxylic acid.

8. The polishing composition of claim 7, wherein the organic carboxylic acid is selected from the group consisting of lactic acid, 2-hydroxybutyric acid, benzilic acid, and combinations thereof.

9. The polishing composition of claim 1, wherein at least one organic carboxylic acid is a hydroxybenzoic acid.

10. The polishing composition of claim 9, wherein the organic carboxylic acid is selected from the group consisting of salicylic acid, 2,6-dihydroxybenzoic acid, and combinations thereof.

11. The polishing composition of claim 9, wherein the organic carboxylic acid is an amino hydroxybenzoic acid.

12. The polishing composition of claim 1, wherein at least one carboxylic acid is an amino acid.

13. The polishing composition of claim 12, wherein the amino acid is selected from the group consisting of proline, glycine, alanine, and combinations thereof.

14. The polishing composition of claim 1, wherein the at least one aminophosphonic acid is present in the polishing composition in an amount of from about 0.1 wt.% to about 1 wt.%.

15. The polishing composition of claim 14, wherein the aminophosphonic acid is selected from the group consisting of ethylenediaminetetra(methylene phosphonic acid), amino tri(methylene phosphonic acid), diethylenetriaminepenta(methylene phosphonic acid), and combinations thereof.

16. The polishing composition of claim 15, wherein the aminophophonic acid is amino tri(methylene phosphonic acid).

17. The polishing composition of claim 1, wherein potassium hydroxide is present in the polishing composition.

18. The polishing composition of claim 1, wherein the polishing composition has a pH of about 8 to about 10.