the polishing composition relative to the wafer, and abrading the wafer to remove silicon from the wafer and thereby polish the wafer. For example, the dipolar aprotic solvent may include dimethyl sulfoxide and the polishing composition may include colloidal silica particles dispersed in a liquid carrier, and least one tetraalkylammonium salt, at least one aminophosphonic acid, at least one nitrogen containing heterocyclic compounds and may be free of dipolar aprotic solvent.

**[0013]** The disclosed compositions and methods may provide various technical advantages and improvements over the prior art. For example, the disclosed compositions and methods may enable silicon wafers to be polishing with improved flatness. For example, the disclosed compositions and methods may provide for improved flatness on the periphery of a silicon wafer, such as in the vicinity of hard laser marks. The disclosed embodiments may further provide for improved/reduced pad break-in time.

**[0014]** The polishing composition generally contains abrasive particles suspended in a liquid carrier. The liquid carrier is used to facilitate the application of the abrasive particles and any optional chemical additives to the surface of the substrate to be polished (e.g., planarized). The liquid carrier comprises preferably consists of, or consists essentially of, deionized water.

**[0015]** The abrasive particles preferably include silica particle and/or alumina particles and most preferably include colloidal silica particles suspended in the liquid carrier. As used herein the term colloidal silica particles refers to silica particles that are prepared via a wet process rather than a pyrogenic or flame hydrolysis process which produces structurally different particles. The colloidal silica particles may be aggregated or non-aggregated. Non-aggregated particles are individually discrete particles that may be spherical or nearly spherical in shape, but can have other shapes as well (such as generally elliptical, square, or rectangular cross-sections). Aggregated particles are particles in which multiple discrete particles are clustered or bonded together to form aggregates having generally irregular shapes. Aggregated colloidal silica particles are disclosed, for example, in commonly assigned U.S. Patent 9,309,442.

**[0016]** The colloidal silica particles may have substantially any suitable particle size. The particle size of a particle suspended in a liquid carrier may be defined in the industry using various means. For example, the particle size may be defined as the diameter of the smallest sphere that encompasses the particle and may be measured using a number of commercially available instruments, for example, including the CPS Disc Centrifuge, Model DC24000HR

aprotic solvents may include acetonitrile, dimethyl sulfoxide, dimethylformamide, hexamethylphosphoramide, ethyl acetate, pyridine, and mixtures thereof. Dimethyl sulfoxide is a most preferred dipolar aprotic solvent.

**[0020]** The polishing composition may include substantially any suitable amount of the dipolar aprotic solvent (e.g., dimethyl sulfoxide). The polishing composition may include about 0.001 wt. % or more (10 ppm by weight or more) of the dipolar aprotic solvent at point of use (e.g., about 0.01 wt. % or more, about 0.02 wt. % or more, 0.03 wt. % or more, or about 0.05 wt. % or more). The polishing composition may also include about 10 wt. % or less of the dipolar aprotic solvent at point of use (e.g., about 5 wt. % or less, about 3 wt. % or less, about 2 wt. % or less, or about 1 wt. % or less). Accordingly, the point of use concentration of the dipolar aprotic solvent in the polishing composition may be in a range bounded by any two of the above endpoints. For example, the amount of colloidal silica particles in the polishing composition may be in a range from about 0.001 wt. % to about 10 wt. % (e.g., from about 0.01 wt. % to about 5 wt. %, from about 0.02 wt. % to about 3 wt. %, from about 0.02 wt. % to about 2 wt. %, or from about 0.05 wt. % to about 1 wt. %).

**[0021]** The polishing composition has a pH of about 12 or less at point of use (e.g., about 11.5 or less or about 11 or less). The polishing composition may also have a pH of about 7 or more at point of use (e.g., about 8 or more, 8.5 or more, or 9 or more). Preferably, the polishing composition has a pH of about 7 to about 12 at point of use (e.g., about 8 to about 12, about 9 to about 12, about 7 to about 11, about 8 to about 11, or about 9 to about 11).

**[0022]** The polishing composition optionally includes pH adjusting agents, for example, potassium hydroxide, ammonium hydroxide, and/or nitric acid (depending, for example, on the desired pH). The polishing composition may also optionally include a pH buffering system, many of which are well-known in the art, e.g., including bicarbonate-carbonate buffer systems, aminoalkylsulfonic acids, and the like. The polishing composition may include any suitable amount of a pH adjustor and/or a pH buffering agent in order to achieve and/or maintain a desired pH (in either or both of a concentrate or point of use composition).

**[0023]** The polishing composition may optionally include other compounds, for example, including (i) one or more organic carboxylic acids, (ii) one or more polyaminocarboxylic acids, (iii) one or more aminophosphonic acids, (iv) one or more tetraalkylammonium salts, (v) one or more amines, (vi) one or more nitrogen containing heterocyclic compounds, and/or (vii) one or more bicarbonate salts. The polishing composition may further include a suitable amount of potassium hydroxide to achieve the preferred alkaline pH.

**[0024]** For example, the polishing composition may optionally include one or more carboxylic acids or salts thereof. Suitable organic carboxylic acid may include an alkyl carboxylic acid or aryl carboxylic acid and may be optionally substituted with groups selected from the group consisting of $C_1$-$C_{12}$ alkyl, amino, substituted amino (e.g., methylamino, dimethylamino, and the like), hydroxyl, halogen, and combinations thereof. Non-limiting examples of suitable carboxylic acids include malonic acid, lactic acid, malic acid, tartaric acid, acetohydroxamic acid, glycolic acid, 2-hydroxybutyric acid, benzilic acid, salicylic acid, 2,6-dihydroxybenzoic acid, glycine, alanine, proline, lysine, cysteine, leucine, aspartic acid, glutamic acid, 2-amino-4-thiazolacetic acid, 3-aminosalicylic acid 3-amino-4-hydroxybenzoic acid, picolinic acid, and nicotinic acid.

**[0025]** In embodiments including one or more organic carboxylic acids or salts, the polishing composition may include about 10 ppm by weight or more of the organic carboxylic acid at point of use (e.g., about 50 ppm by weight or more, about 100 ppm by weight or more, about 200 ppm by weight or more, or about 500 ppm by weight or more). The polishing composition may also include about 1 wt. % or less of the organic carboxylic acid at point of use (e.g., about 0.8 wt. % or less, about 0.5 wt. % or less, about 0.3 wt. % or less, or about 0.2 wt. % or less). Accordingly, the point of use amount of organic carboxylic acid in the polishing composition may be bounded by any two of the above endpoints. For example, the polishing composition may include about 10 ppm by weight (0.001 wt. %) to about 1 wt. % of the organic carboxylic acid at point of use (e.g., from about 50 ppm by weight to about 0.5 wt. %, or from about 200 ppm by weight to about 0.2 wt. %).

**[0026]** The polishing composition may optionally include one or more suitable polyaminocarboxylic acids or salts. The term polyaminocarboxylic as used herein refers to a compound having two or more amino groups and two or more carboxylic acid groups. Preferred polyaminocarboxylic acids are selected from the group consisting of ethylenediaminetetraacetic acid, diethylenetriaminepentaacetic acid, N-(hydroxyethyl)ethylenediaminetriacetic acid, nitrilotriacetic acid, methylglycinediacetic acid, salts thereof, and combinations thereof. Most preferred polyaminocarboxylic acids are selected from the group consisting of ethylenediaminetetraacetic acid, diethylenetriaminepentaacetic acid, salts thereof (e.g., a mono-, di-, tri-, or tetrasodium salt thereof), and mixtures thereof.

**[0027]** In embodiments including one or more polyaminocarboxylic acids or salts, the polishing composition may include about 5 ppm by weight or more of the

**[0039]** The polishing composition may be prepared using any suitable techniques, many of which are known to those skilled in the art. The polishing composition may be prepared in a batch or continuous process. Generally, the polishing composition may be prepared by combining the components (e.g., including the abrasive particles and optional compounds described above) thereof in any order. The term "component" as used herein includes the individual ingredients (e.g., the silica particles, the dipolar aprotic solvent, and other optional compounds).

**[0040]** For example, various polishing composition components (such as the dipolar aprotic solvent and a biocide) may be added directly to a dispersion including a suspended silica abrasive. The components may be blended together using any suitable techniques for achieving adequate mixing. Such blending/mixing techniques are well known to those of ordinary skill in the art. The polishing composition may advantageously be supplied as a one-package system including the composition comprising a colloidal silica having the above described physical properties and other optional components.

**[0041]** It will be understood that the dipolar aprotic solvent may be added at any time during the preparation of the polishing composition. The dipolar aprotic solvent may be provided as part of the above described one-package system (including the abrasive particles, the dipolar aprotic solvent, and other optional compounds). Alternatively, the dipolar aprotic solvent may be supplied separately from the other components of the polishing composition and may be combined, e.g., by the end-user, with the other components of the polishing composition shortly before use (e.g., within about 1 minute, or within about 10 minutes, or within about 1 hour, or within about 1 day, or within about 1 week of the polishing operation). The polishing composition also may also be prepared by mixing the components at the surface of the wafer (e.g., on the polishing pad) during the polishing operation. Various other two-container, or even three or more container, combinations of the components of the polishing composition are within the knowledge of one of ordinary skill in the art.

**[0042]** The polishing composition of the invention may also be provided as a concentrate which is intended to be diluted with an appropriate amount of water prior to use. In such an embodiment, the polishing composition concentrate may include the abrasive particles and other optional components such as a tetraalkylammonium salt, a polyaminocarboxylic acid, a nitrogen containing heterocyclic compounds, and/or a biocide with or without the dipolar aprotic solvent, in amounts such that, upon dilution of the concentrate with an appropriate amount of water, and the dipolar aprotic solvent if not already present in an appropriate

having at least one holding hole for holding the wafer; and said abrading in (e) removes silicon from opposing first and second sides of the wafer, thereby polishing the wafer.

**[0071]** A twenty-second embodiment includes any one of the seventeenth through twenty-first embodiments wherein: the wafer includes a hard laser mark; and contacting the polishing pad with the dipolar aprotic solvent in (b) and abrading the wafer in (e) improves a flatness of the wafer in a peripheral region of the wafer.

**[0072]** A twenty-third embodiment includes any one of the seventeenth through twenty-second embodiments wherein (b) further comprises rinsing said wetted pad with deionized water prior to said contacting in (c).

**[0073]** In a twenty-fourth embodiment a chemical mechanical polishing concentrate includes a water based liquid carrier; abrasive particles dispersed in the liquid carrier; about 0.2 weight percent to about 40 weight percent of a dipolar aprotic solvent; and a pH in a range from about 8 to about 12. The polishing concentrate may optionally further include any one or more of the components disclosed in the fifth through the twelfth embodiments.

**[0074]** A twenty-fifth embodiment includes the twenty-fourth embodiment, wherein the abrasive particles comprise colloidal silica particles and the polishing concentrate comprises at least 10 weight percent of the colloidal silica particles.

**[0075]** In a twenty-sixth embodiment a method of chemical mechanical polishing a wafer includes (a) providing a polishing concentrate including: (i) a water based liquid carrier, (ii) at least 5 weight percent colloidal silica particles dispersed in the liquid carrier; and (iii) a pH in a range from about 8 to about 12; (b) diluting the polishing concentrate provided in (a) to obtain a polishing composition by adding at least 4 parts of a mixture of water and a dipolar aprotic solvent to 1 part of the polishing concentrate such that the polishing composition includes about 0.01 weight percent to about 2 weight percent of the dipolar aprotic solvent; (c) moving the polishing composition relative to the wafer; and (d) abrading the wafer to remove silicon from the wafer and thereby polish the wafer.

**[0076]** A twenty-seventh embodiment includes the twenty-sixth embodiment, wherein the method uses a polishing apparatus having (i) an upper platen and a lower platen, each of said platens having a polishing pad adhered thereto, and (ii) a carrier plate having at least one holding hole for holding the wafer; and said abrading in (d) removes silicon from opposing first and second sides of the wafer, thereby polishing the wafer.

**[0077]** The following examples further illustrate the invention but, of course, should not be construed as in any way limiting its scope.

CLAIM(S):

1. A chemical mechanical polishing composition comprising:

an aqueous based liquid carrier;

abrasive particles dispersed in the liquid carrier;

about 0.01 weight percent to about 2 weight percent of a dipolar aprotic solvent; and

a pH in a range from about 8 to about 12.

2. The composition of claim 1, wherein the dipolar aprotic solvent is a member of the group consisting of acetonitrile, dimethyl sulfoxide, dimethylformamide, hexamethylphosphoramide, ethyl acetate, pyridine, and mixtures thereof.

3. The composition of claim 1, wherein the dipolar aprotic solvent is dimethyl sulfoxide.

4. The composition of claim 1, comprising from about 0.05 weight percent to about 0.5 weight percent of the dipolar aprotic solvent.

5. The composition of claim 1, further comprising one or more organic carboxylic acids.

6. The composition of claim 1, further comprising one or more polyaminocarboxylic acids.

7. The composition of claim 1, further comprising one or more tetraalkylammonium salts.

8. The composition of claim 1, further comprising one or more aminophosphonic acids.

9. The composition of claim 1, further comprising one or more nitrogen containing heterocyclic compounds.

10. The composition of claim 1, wherein the abrasive particles comprise colloidal silica abrasive particles.

11. The composition of claim 10, further comprising:

one or more tetraalkylammonium salts;

one or more polyaminocarboxylic acids; and

one or more nitrogen containing heterocyclic compounds.

12. The composition of claim 11, further comprising at least one of potassium hydroxide and potassium bicarbonate.

13. The composition of claim 11, wherein the dipolar aprotic solvent is dimethyl sulfoxide.

14. A method of chemical mechanical polishing a wafer, the method comprising:

(a) contacting the wafer with the polishing composition of any one of claims 1-13;

(b) moving the polishing composition relative to the wafer; and

(c) abrading the wafer to remove silicon from the wafer and thereby polish the wafer.

15. The method of claim 14, wherein

the method uses a polishing apparatus having (i) an upper platen and a lower platen, each of said platens having a polishing pad adhered thereto, and (ii) a carrier plate having at least one holding hole for holding the wafer; and

said abrading in (c) removes silicon from opposing first and second sides of the wafer, thereby polishing the wafer.

16. The method of claim 14, wherein:

the wafer includes a hard laser mark; and

said abrading in (c) improves a flatness of the wafer in a peripheral region of the wafer.

17. A method of polishing a silicon wafer, the method comprising:

(a) providing a polishing apparatus having at least one polishing pad mounted on a corresponding platen;

(b) contacting the polishing pad with a dipolar aprotic solvent to wet the polishing pad;

(c) contacting said wetted polishing pad with a polishing composition;

(d) moving the polishing composition relative to the wafer; and

(e) abrading the wafer to remove silicon from the wafer and thereby polish the wafer.

18. The method of claim 17, wherein the polishing composition is free of dipolar aprotic solvent.

19. The method of claim 17, wherein the dipolar aprotic solvent is dimethyl sulfoxide.

20. The method of claim 17, wherein the polishing composition comprises:

colloidal silica particles dispersed in an aqueous liquid carrier;

one or more tetraalkylammonium salts;

one or more polyaminocarboxylic acids;

one or more nitrogen containing heterocyclic compounds; and

a pH in a range from about 8 to about 12.

21. The method of claim 17, wherein:

the polishing apparatus comprises (i) an upper platen and lower platen, each of said platens having a polishing pad adhered thereto, and (ii) a carrier plate having at least one holding hole for holding the wafer; and

said abrading in (e) removes silicon from opposing first and second sides of the wafer, thereby polishing the wafer.

22. The method of claim 17, wherein:

the wafer includes a hard laser mark; and

contacting the polishing pad with the dipolar aprotic solvent in (b) and said abrading in (e) improves a flatness of the wafer in a peripheral region of the wafer.

23. The method of claim 17, wherein (b) further comprises rinsing said wetted pad with deionized water prior to said contacting in (c).

24. A chemical-mechanical polishing concentrate comprising:

a water based liquid carrier;

abrasive particles dispersed in the liquid carrier;

about 0.2 weight percent to about 40 weight percent of a dipolar aprotic solvent; and

a pH in a range from about 8 to about 12.

25. The polishing concentrate of claim 24, wherein:

the abrasive particles comprise colloidal silica particles; and

the polishing concentrate comprises at least 10 weight percent of the colloidal silica particles.

26. A method of chemical mechanical polishing a wafer, the method comprising:

(a) providing a polishing concentrate including: (i) a water based liquid carrier, (ii) at least 5 weight percent colloidal silica particles dispersed in the liquid carrier; and (iii) a pH in a range from about 8 to about 12;

(b) diluting the polishing concentrate provided in (a) to obtain a polishing composition by adding at least 4 parts of a mixture of water and a dipolar aprotic solvent to 1 part of the polishing concentrate such that the polishing composition includes about 0.01 weight percent to about 2 weight percent of the dipolar aprotic solvent;

(c) moving the polishing composition relative to the wafer; and

(d) abrading the wafer to remove silicon from the wafer and thereby polish the wafer.

27. The method of claim 26, wherein

the method uses a polishing apparatus having (i) an upper platen and a lower platen, each of said platens having a polishing pad adhered thereto, and (ii) a carrier plate having at least one holding hole for holding the wafer; and

said abrading in (d) removes silicon from opposing first and second sides of the wafer, thereby polishing the wafer.