

POLISHING COMPOSITION FOR NICKEL-PHOSPHOROUS-COATED MEMORY DISKS

BACKGROUND OF THE INVENTION

[0001] The demand for increased storage capacity in memory or rigid disks and the trend towards miniaturization of memory or rigid disks (due to the requirement for smaller hard drives in computer equipment) continues to emphasize the importance of the memory or rigid disk manufacturing process, including the planarization or polishing of such disks for ensuring maximal performance. While there exist several chemical-mechanical polishing (CMP) compositions and methods for use in conjunction with semiconductor device manufacture, few conventional CMP methods or commercially available CMP compositions are well-suited for the planarization or polishing of memory or rigid disks.

[0002] As the demand for increased storage capacity has increased, so has the need for improved processes for the polishing of such memory or rigid disks. The term "memory or rigid disk" refers to any magnetic disk, hard disk, rigid disk, or memory disk for retaining information in electromagnetic form. The memory or rigid disk typically has a surface that comprises nickel-phosphorus, but the memory or rigid disk surface can comprise any other suitable material. The planarity of the memory or rigid disks must be improved, as the distance between the recording head of a disk drive and the surface of the memory or rigid disk has decreased with improvements in recording density that demand a lower flying height of the magnetic head with respect to the memory or rigid disk. In order to permit a lower flying height of the magnetic head, improvements to the surface finish of the memory or rigid disk are required.

[0003] Improvements to the surface finish of the memory or rigid disk require that scratches and micro defects caused by abrasive particles must be reduced. It has been hypothesized that frictional forces generated between a polishing pad and a substrate being polished leads to increased scratching and micro defects. However, the presence of additives intended to reduce frictional forces typically lead to agglomeration of abrasive particles, with a consequent increase in scratching and micro defects. Accordingly, there is a need in the art for polishing compositions exhibiting reduced scratching and micro defects and also exhibiting good surface topography and practicable removal rates.

BRIEF SUMMARY OF THE INVENTION

[0004] The invention provides a method of chemically-mechanically polishing a substrate, which method comprises (i) providing a substrate comprising at least one layer of nickel-phosphorous, (ii) providing a polishing pad, (iii) providing a polishing composition comprising (a) wet-process silica, (b) an oxidizing agent that oxidizes nickel-phosphorous, (c) a chelating agent, (d) polyvinyl alcohol, (e) water, wherein the polishing composition has a pH of 1 to 4, (iv) contacting a surface of the substrate with the polishing pad and the polishing composition, and (v) abrading at least a portion of the surface of the substrate to remove at least some nickel-phosphorous from the surface of the substrate and to polish the surface of the substrate.

[0005] The invention also provides a chemical-mechanical polishing composition comprising (a) wet-process silica, (b) an oxidizing agent that oxidizes nickel-phosphorous, (c) a chelating agent, (d) polyvinyl alcohol, wherein the polyvinyl alcohol has a molecular weight of 8,000 g/mol to 50,000 g/mol, (e) water, wherein the polishing composition has a pH of 1 to 4, and wherein the polishing composition does not comprise a heterocyclic compound.

DETAILED DESCRIPTION OF THE INVENTION

[0006] The invention provides a chemical-mechanical polishing composition comprising, consisting essentially of, or consisting of (a) wet-process silica, (b) an oxidizing agent that oxidizes nickel-phosphorous, (c) a chelating agent, (d) polyvinyl alcohol, wherein the polyvinyl alcohol has a molecular weight of 8,000 g/mol to 50,000 g/mol, (e) water, wherein the polishing composition has a pH of 1 to 4.

[0007] The polishing composition comprises wet-process silica particles (e.g., condensation-polymerized or precipitated silica particles). Preferably, the wet-process silica particles are condensation-polymerized silica particles. Condensation-polymerized silica particles typically are prepared by condensing Si(OH)_4 to form colloidal particles, where colloidal is defined as having an average particle size between 1 nm and 1000 nm. Such abrasive particles can be prepared in accordance with U.S. Patent 5,230,833 or can be obtained as any of various commercially available products, such as the Akzo-Nobel Bindzil 50/80 product and the Nalco 1050, 1060, 2327, and 2329 products, as well as other similar products available from DuPont, Bayer, Applied Research, Nissan Chemical, Fuso, and Clariant. Other examples of suitable wet-process silica include but are not limited to XP320, XP442, CC-

301, and CC401 (EKA, Mannheim, Germany), N1115, N8691, N1030C, and N8699 (supplied by Nalco Co., Naperville, IL), ST-N and ST-O (Nissan Chemical America, Houston, TX), and Nexsil 20, 20A, 12, 8, and 5 (Nyacol Nano Technologies, Ashland, MA).

[0008] The silica particles can have any suitable average particle size (i.e., average particle diameter). The silica particles can have an average particle size of 10 nm or more, e.g., 15 nm or more, 20 nm or more, or 25 nm or more. Alternatively, or in addition, the silica can have an average particle size of 80 nm or less, e.g., 75 nm or less, 70 nm or less, 60 nm or less, 50 nm or less, 40 nm or less, or 30 nm or less. Thus, the silica can have an average particle size bounded by any two of the above endpoints. For example, the silica can have an average particle size of 10 nm to 80 nm, 10 nm to 70 nm, 10 nm to 60 nm, 10 nm to 50 nm, 10 nm to 40 nm, 10 nm to 30 nm, 20 nm to 80 nm, 20 nm to 60 nm, 20 nm to 40 nm, or 20 nm to 30 nm.

[0009] The polishing composition can comprise any suitable amount of silica. Typically, the polishing composition can contain 0.01 wt.% or more, e.g., 0.05 wt.% or more, 0.1 wt.% or more, 0.5 wt.% or more, or 1 wt.% or more of silica. Alternatively, or in addition, the polishing composition can contain 10 wt.% or less, e.g., 9 wt.% or less, 8 wt.% or less, 7 wt.% or less, 6 wt.% or less, or 5 wt.% or less of silica. Thus, the polishing composition can comprise silica in amounts bounded by any two of the above endpoints recited for silica. For example the polishing composition can comprise 0.01 wt.% to 10 wt.%, 0.5 wt.% to 10 wt.%, 1 wt.% to 10 wt.%, 0.5 wt.% to 10 wt.%, 0.5 wt.% to 9 wt.%, 0.5 wt.% to 8 wt.%, 0.5 wt.% to 7 wt.%, 0.5 wt.% to 6 wt.%, 0.5 wt.% to 5 wt.%, or 1 wt.% to 5 wt.% of silica.

[0010] The abrasive particles preferably are colloidally stable. The term colloid refers to the suspension of abrasive particles in the liquid carrier. Colloidal stability refers to the maintenance of that suspension through time. In the context of this invention, an abrasive is considered colloidally stable if, when the abrasive is placed into a 100 ml graduated cylinder and allowed to stand unagitated for a time of 2 hours, the difference between the concentration of particles in the bottom 50 ml of the graduated cylinder ([B] in terms of g/ml) and the concentration of particles in the top 50 ml of the graduated cylinder ([T] in terms of g/ml) divided by the initial concentration of particles in the abrasive composition ([C] in terms of g/ml) is less than or equal to 0.5 (i.e., $\frac{[B] - [T]}{[C]} \leq 0.5$). More preferably, the value of $[B] - [T]/[C]$ is less than or equal to 0.3, and most preferably is less than or equal to 0.1.

[0011] The polishing composition comprises an oxidizing agent that oxidizes nickel-phosphorous. Preferred oxidizing agents are selected from the group consisting of hydrogen peroxide, urea hydrogen peroxide, peroxysulfuric acid, peroxyacetic acid, perboric acid, salts thereof, and combinations thereof. More preferably, the oxidizing agent is hydrogen peroxide. Typically, the polishing composition can contain 0.5 wt.% or more, e.g., 1 wt.% or more, or 2 wt.% or more, of the oxidizing agent that oxidizes nickel-phosphorous. Alternatively, or in addition, the polishing composition can contain 10 wt.% or less, e.g., 8 wt.% or less, or 6 wt.% or less, or 4 wt.% or less, of the oxidizing agent that oxidizes nickel-phosphorous. Thus, the polishing composition can comprise silica in amounts bounded by any two of the above endpoints recited for the oxidizing agent that oxidizes nickel-phosphorous. For example the polishing composition can comprise 0.5 wt.% to 10 wt.%, or 1 wt.% to 8 wt.%, or 2 wt.% to 6 wt.% of the oxidizing agent that oxidizes nickel-phosphorous.

[0012] The polishing composition comprises a chelating agent. Desirably, the chelating agent is a chelating agent for nickel. The chelating agent can be any suitable chelating agent, especially any suitable chelating agent for nickel. The chelating agent preferably is chosen so that the polishing composition exhibits low dissolution behavior when in contact with a substrate comprising nickel-phosphorous. Non-limiting examples of suitable chelating agents include glycine and alanine. In a preferred embodiment, the chelating agent is glycine.

[0013] Typically, the polishing composition can contain 0.1 wt.% or more, e.g., 0.2 wt.% or more, or 0.3 wt.% or more, or 0.4 wt.% or more, or 0.5 wt.% or more, of the chelating agent. Alternatively, or in addition, the polishing composition can contain 2 wt.% or less, e.g., 1.8 wt.% or less, or 1.6 wt.% or less, or 1.4 wt.% or less, or 1.2 wt.% or less, or 1 wt.% or less, of the chelating agent. Thus, the polishing composition can comprise the chelating agent in amounts bounded by any two of the above endpoints recited for the chelating agent. For example the polishing composition can comprise 0.1 wt.% to 2 wt.%, or 0.2 wt.% to 1.8 wt.%, or 0.3 wt.% to 1.6 wt.%, 0.4 wt.% to 1.4 wt.%, or 0.5 wt.% to 1.2 wt.% of the chelating agent.

[0014] The polishing composition comprises polyvinyl alcohol. The polyvinyl alcohol can be any suitable polyvinyl alcohol. In some embodiments, the polyvinyl alcohol has a molecular weight of 8,000 g/mol or more, e.g., 10,000 g/mol or more, 12,000 g/mol or more, or 13,000 g/mol or more. In some embodiments, alternatively, or in addition, the polyvinyl alcohol has a molecular weight of 50,000 g/mol or less, e.g., 45,000 g/mol or less, or 40,000

g/mol or less, or 35,000 g/mol or less, or 30,000 g/mol or less, 25,000 g/mol or less, or 23,000 g/mol or less. Thus, in some embodiments, the polyvinyl alcohol has a molecular weight bounded by any two of the above endpoints recited for the polyvinyl alcohol. For example the polyvinyl alcohol can have a molecular weight of 8,000 g/mol to 50,000 g/mol, 10,000 g/mol to 45,000 g/mol, 10,000 g/mol to 40,000 g/mol, 10,000 g/mol to 35,000 g/mol, 10,000 g/mol to 30,000 g/mol, 12,000 g/mol to 25,000 g/mol, or 13,000 g/mol to 23,000 g/mol.

[0015] The polyvinyl alcohol can have any suitable degree of hydrolysis. Typically, polyvinyl alcohol has a degree of hydrolysis of 90% or more, or 92% or more, or 94% or more, or 96% or more, or 98% or more. As is well known in the art, polyvinyl alcohol is typically prepared by hydrolysis of polyvinyl acetate. The degree of hydrolysis refers to the percentage of acetate groups in the polyvinyl acetate that have been hydrolyzed. In other words, the degree of hydrolysis refers to the percentage of free hydroxyl groups present in the polyvinyl alcohol.

[0016] Typically, the polishing composition can contain 0.1 wt.% or more, e.g., 0.2 wt.% or more, or 0.3 wt.% or more, or 0.4 wt.% or more, or 0.5 wt.% or more, of polyvinyl alcohol. Alternatively, or in addition, the polishing composition can contain 2 wt.% or less, e.g., 1.8 wt.% or less, or 1.6 wt.% or less, or 1.4 wt.% or less, or 1.2 wt.% or less, or 1 wt.% or less, of polyvinyl alcohol. Thus, the polishing composition can comprise polyvinyl alcohol in amounts bounded by any two of the above endpoints recited for polyvinyl alcohol. For example the polishing composition can comprise 0.1 wt.% to 2 wt.%, or 0.2 wt.% to 1.8 wt.%, or 0.3 wt.% to 1.6 wt.%, or 0.4 wt.% to 1.4 wt.%, or 0.5 wt.% to 1.2 wt.% of polyvinyl alcohol.

[0017] Typically, the polishing composition has a pH of 1 or more, e.g., 2 or more, or 3 or more. Alternatively, or in addition, the polishing composition has a pH of 4 or less, e.g., 3 or less, or 2 or less. Thus, the polishing composition has a pH bounded by any two of the above endpoints recited for the pH of the polishing composition. For example, the polishing composition can have a pH of 1 to 4, 1 to 3, 2 to 4, 3 to 4, or 1 to 2.

[0018] In certain embodiments, the polishing composition does not comprise a heterocyclic compound. More particularly, the polishing composition substantially comprises less than 100 ppb (parts per billion), e.g., less than 75 ppb, or less than 50 ppb, less than 25 ppb, less than 5 ppb, or less than 1 ppb, of any heterocyclic compounds. In some embodiments, the polishing composition contains an undetectable amount of heterocycle

compounds. In particular, heterocyclic compounds that complex with copper on the surface of a copper substrate to form an insoluble complex on the surface of the copper substrate are excluded from the polishing composition of the invention. Non-limiting examples of specific heterocyclic compounds that are excluded from the polishing composition of the invention include 5-aminotetrazole, imidazole, benzotriazole, benzimidazole, triazole, tolyltriazole, quinaldinic acid, quinolinic acid, amino compounds, imino compounds, carboxy compounds, mercapto compounds, nitro compounds, urea compounds, and thiourea compounds, and derivatives thereof. Desirably, the polishing composition does not contain any heterocyclic compounds.

[0019] The polishing composition can be prepared by any suitable technique, many of which are known to those skilled in the art. The polishing composition can be prepared in a batch or continuous process. Generally, the polishing composition can be prepared by combining the components thereof in any order. The term "component" as used herein includes individual ingredients (e.g., wet-process silica, oxidizing agent that oxidizes nickel-phosphorous, chelating agent, polyvinyl alcohol, etc.) as well as any combination of ingredients (e.g., wet-process silica, oxidizing agent that oxidizes nickel-phosphorous, chelating agent, polyvinyl alcohol, etc.).

[0020] For example, the wet-process silica can be dispersed in water. The chelating agent and polyvinyl alcohol can then be added, and mixed by any method that is capable of incorporating the components into the polishing composition. The oxidizing agent that oxidizes nickel-phosphorous can be added at any time during the preparation of the polishing composition. The polishing composition can be prepared prior to use, with one or more components, such as the oxidizing agent that oxidizes nickel-phosphorous, added to the polishing composition just before use (e.g., within 1 minute before use, or within 1 hour before use, or within 7 days before use). The polishing composition also can be prepared by mixing the components at the surface of the substrate during the polishing operation.

[0021] The polishing composition can be supplied as a one-package system comprising wet-process silica, oxidizing agent that oxidizes nickel-phosphorous, chelating agent, polyvinyl alcohol, and water. Alternatively, the wet-process silica can be supplied as a dispersion in water in a first container, and chelating agent and polyvinyl alcohol can be supplied in a second container, either in dry form, or as a solution or dispersion in water. The oxidizing agent that oxidizes nickel-phosphorous desirably is supplied separately from the other components of the polishing composition and is combined, e.g., by the end-user, with

the other components of the polishing composition shortly before use (e.g., 1 week or less prior to use, 1 day or less prior to use, 1 hour or less prior to use, 10 minutes or less prior to use, or 1 minute or less prior to use). The components in the first or second container can be in dry form while the components in the other container can be in the form of an aqueous dispersion. Moreover, it is suitable for the components in the first and second containers to have different pH values, or alternatively to have substantially similar, or even equal, pH values. Other two-container, or three or more-container, combinations of the components of the polishing composition are within the knowledge of one of ordinary skill in the art.

[0022] The polishing composition of the invention also can 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 can comprise the wet-process silica, chelating agent, polyvinyl alcohol, and water, with or without the oxidizing agent that oxidizes nickel-phosphorous, in amounts such that, upon dilution of the concentrate with an appropriate amount of water, and the oxidizing agent that oxidizes nickel-phosphorous if not already present in an appropriate amount, each component of the polishing composition will be present in the polishing composition in an amount within the appropriate range recited above for each component. For example, the wet-process silica, chelating agent, and polyvinyl alcohol can each be present in the concentration in an amount that is 2 times (e.g., 3 times, 4 times, or 5 times) greater than the concentration recited above for each component so that, when the concentrate is diluted with an equal volume of (e.g., 2 equal volumes of water, 3 equal volumes of water, or 4 equal volumes of water, respectively), along with the oxidizing agent that oxidizes nickel-phosphorous in a suitable amount, each component will be present in the polishing composition in an amount within the ranges set forth above for each component. Furthermore, as will be understood by those of ordinary skill in the art, the concentrate can contain an appropriate fraction of the water present in the final polishing composition in order to ensure that other components are at least partially or fully dissolved in the concentrate.

[0023] The invention also provides a method of chemically-mechanically polishing a substrate with the polishing composition described herein. In particular, the inventive method comprises (i) contacting a substrate with a polishing pad and the chemical-mechanical polishing composition described herein, (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.

[0024] The substrate to be polished using the method of the invention can be any suitable substrate, especially a substrate that contains nickel-phosphorous. A preferred substrate comprises at least one layer, especially an exposed layer for polishing, comprising, consisting essentially of, or consisting of nickel-phosphorous. Particularly suitable substrates include, but are not limited to, memory or rigid disks, such as aluminum disks coated with nickel-phosphorous.

[0025] The polishing method of the invention is particularly suited for use in conjunction with a chemical-mechanical polishing (CMP) apparatus. Typically, the apparatus comprises a platen, which, when in use, is in motion and has a velocity that results from orbital, linear, or circular motion, a polishing pad in contact with the platen and moving with the platen when in motion, and a carrier that holds a substrate to be polished by contacting and moving relative to the surface of the polishing pad. The polishing of the substrate takes place by the substrate being placed in contact with the polishing pad and the polishing composition of the invention and then the polishing pad moving relative to the substrate, so as to abrade at least a portion of the substrate to polish the substrate.

[0026] A substrate can be planarized or polished with the chemical-mechanical polishing composition with any suitable polishing pad (e.g., polishing surface). Suitable polishing pads include, for example, woven and non-woven polishing pads. Moreover, suitable polishing pads can comprise any suitable polymer of varying density, hardness, thickness, compressibility, ability to rebound upon compression, and compression modulus. Suitable polymers include, for example, polyvinylchloride, polyvinylfluoride, nylon, fluorocarbon, polycarbonate, polyester, polyacrylate, polyether, polyethylene, polyamide, polyurethane, polystyrene, polypropylene, coformed products thereof, and mixtures thereof.

[0027] Desirably, the CMP apparatus further comprises an *in situ* polishing endpoint detection system, many of which are known in the art. Techniques for inspecting and monitoring the polishing process by analyzing light or other radiation reflected from a surface of the workpiece are known in the art. Such methods are described, for example, in U.S. Patent 5,196,353, U.S. Patent 5,433,651, U.S. Patent 5,609,511, U.S. Patent 5,643,046, U.S. Patent 5,658,183, U.S. Patent 5,730,642, U.S. Patent 5,838,447, U.S. Patent 5,872,633, U.S. Patent 5,893,796, U.S. Patent 5,949,927, and U.S. Patent 5,964,643. Desirably, the inspection or monitoring of the progress of the polishing process with respect to a workpiece being polished enables the determination of the polishing end-point, i.e., the determination of when to terminate the polishing process with respect to a particular workpiece.

[0028] A chemical-mechanical polishing process can be characterized in a number of ways, such as in terms of the removal rate of a substrate, the resulting surface roughness, and the resulting edge roll-off of a substrate.

[0029] The removal rate of a substrate can be determined using any suitable technique. Examples of suitable techniques for determining the removal rate of a substrate include weighing the substrate before and after use of the inventive polishing method to determine the amount of substrate removed per unit of polishing time, which can be correlated with the removal rate in terms of thickness of substrate removed per unit of polishing time, and determining the thickness of the substrate before and after use of the inventive polishing method to directly measure the removal rate of the substrate per unit of polishing time.

[0030] One measure of defectivity is the total scratch count as defined as the sum of shallow, micro, and deep scratches on the surface of a substrate after polishing. Another measure of defectivity is the count of micro particles that either adhere to the surface or are embedded in the surface of a substrate that has been polished. The substrate, such as a nickel-phosphorous coated memory disk, can be inspected using optical defect scanning equipment such as the Candela 6100 and 6300 series and similar instruments available from KLA Tencor (Milpitas, CA).

[0031] Desirably, the inventive polishing composition and method disclosed herein result in reduction in the total scratch count and/or in the count of micro particles when used to polish substrates comprising a nickel-phosphorous coated memory disk.

[0032] The following example further illustrates the invention but, of course, should not be construed as in any way limiting its scope.

EXAMPLE

[0033] This example demonstrates the effect on defectivity achievable by the inventive polishing composition in the polishing of nickel-phosphorous-coated aluminum memory disks.

[0034] Similar substrates comprising nickel-phosphorous-coated aluminum memory disks were separately polished on one side with four different polishing compositions. Each of the polishing compositions comprised 5 wt.% of a wet-process silica having an average particle size of ≤ 30 nm, 1 wt.% glycine, and 0.6 wt.% hydrogen peroxide in water at a pH of 1.9. Polishing Composition A (control) did not contain any polyvinyl alcohol. Polishing Compositions B, C, and D further comprised 250 ppm, 500 ppm, and 1000 ppm of a

polyvinyl alcohol, respectively, wherein the polyvinyl alcohol had a molecular weight in the range of 13,000-23,000 g/mol and a degree of hydrolysis of 98%.

[0035] Following polishing, the substrates were examined for total scratch counts, shallow scratch counts, deep scratch counts, micro scratch counts, and micro particle counts, wherein micro particle counts refers to particles adhered to or imbedded in the substrate surface. The results are set forth in the Table.

Table

Composition	A* (control)	B (invention)	C (invention)	D (invention)
Total scratch count	56	7	12	7
Shallow scratch count	30	5	5	4
Deep scratch count	5	1	1	1
Micro scratch count	22	2	6	3
Micro particle count	925	906	584	485

* average of two experiments

[0036] As is apparent from the results set forth in the Table, the inventive polishing compositions B-D exhibited approximately 79-88% reductions in the total scratch count, approximately 83-87% reductions in the shallow scratch count, approximately 80% reductions in the deep scratch count, and approximately 73-91% reductions in the micro scratch count, compared to the control polishing composition A. Inventive polishing compositions C and D, which contained 500 ppm and 1000 ppm, respectively, of polyvinyl alcohol, exhibited approximately 38% and 48% reductions in the micro particle count compared to control polishing composition A.

CLAIMS

1. A method of chemically-mechanically polishing a substrate, which method comprises:
 - (i) providing a substrate comprising at least one layer of nickel-phosphorous,
 - (ii) providing a polishing pad,
 - (iii) providing a polishing composition comprising:
 - (a) wet-process silica,
 - (b) an oxidizing agent that oxidizes nickel-phosphorous,
 - (c) a chelating agent,
 - (d) polyvinyl alcohol,
 - (e) water,wherein the polishing composition has a pH of 1 to 4,
 - (iv) contacting a surface of the substrate with the polishing pad and the polishing composition, and
 - (v) abrading at least a portion of the surface of the substrate to remove at least some nickel-phosphorous from the surface of the substrate and to polish the surface of the substrate.
2. The method of claim 1, wherein the wet-process silica comprises two or more different types of silica particles.
3. The method of claim 1, wherein the wet-process silica has an average particle size of 10 nm to 80 nm.
4. The method of claim 3, wherein the wet-process silica has an average particle size of 10 nm to 30 nm.
5. The method of claim 1, wherein the polishing composition comprises 1 wt.% to 10 wt.% of wet-process silica.
6. The method of claim 1, wherein the oxidizing agent is hydrogen peroxide.
7. The method of claim 1, wherein the chelating agent is glycine or alanine.
8. The method of claim 1, wherein the polishing composition comprises 0.1 wt.% to 2 wt.% of the chelating agent.
9. The method of claim 1, wherein the polyvinyl alcohol has a molecular weight of 8,000 g/mol to 50,000 g/mol.
10. The method of claim 9, wherein the polyvinyl alcohol has a molecular weight of 13,000 g/mol to 23,000 g/mol.

11. The method of claim 1, wherein the polyvinyl alcohol has a degree of hydrolysis of 90% or more.
12. The method of claim 1, wherein the polishing composition comprises 0.1 wt.% to 2 wt.% of polyvinyl alcohol.
13. The method of claim 1, wherein the polishing composition has a pH of 1 to 3.
14. The method of claim 1, wherein the substrate is a nickel-phosphorous-coated aluminum disk.
15. A chemical-mechanical polishing composition comprising:
 - (a) wet-process silica,
 - (b) an oxidizing agent that oxidizes nickel-phosphorous,
 - (c) a chelating agent,
 - (d) polyvinyl alcohol, wherein the polyvinyl alcohol has a molecular weight of 8,000 g/mol to 50,000 g/mol,
 - (e) water,wherein the polishing composition has a pH of 1 to 4, and wherein the polishing composition does not comprise a heterocyclic compound.
16. The composition of claim 15, wherein the wet-process silica comprises two or more different types of silica particles.
17. The composition of claim 15, wherein the wet-process silica has an average particle size of 10 nm to 80 nm.
18. The composition of claim 17, wherein the wet-process silica has an average particle size of 10 nm to 30 nm.
19. The composition of claim 15, wherein the polishing composition comprises 1 wt.% to 10 wt.% of wet-process silica.
20. The composition of claim 15, wherein the oxidizing agent is hydrogen peroxide.
21. The composition of claim 15, wherein the chelating agent is glycine or alanine.
22. The composition of claim 15, wherein the polishing composition comprises 0.1 wt.% to 2 wt.% of the chelating agent.
23. The composition of claim 15, wherein the polyvinyl alcohol has a molecular weight of 13,000 g/mol to 23,000 g/mol.

24. The composition of claim 15, wherein the polyvinyl alcohol has a degree of hydrolysis of 90% or more.

25. The composition of claim 15, wherein the polishing composition comprises 0.1 wt.% to 2 wt.% of polyvinyl alcohol.

26. The composition of claim 15, wherein the polishing composition has a pH of 1 to 3.

27. A method of chemically-mechanically polishing a substrate, which method comprises:

- (i) providing a substrate,
- (ii) providing a polishing pad,
- (iii) providing the polishing composition of claim 15,
- (iv) contacting a surface of the substrate with the polishing pad and the polishing composition, and
- (v) abrading at least a portion of the surface of the substrate to remove at least some portion of the surface of the substrate so as to polish the surface of the substrate.