silicon nitride" applications, such as in shallow trench isolation (STI). Typical STI slurries utilize silica abrasives at high pH and high abrasive concentrations to achieve reasonable silicon nitride removal rates. The use of high abrasive particle concentrations has been associated with a high level of scratch defects in the polished devices.

[0010] There is an ongoing need to develop new polishing methods and compositions that provide relatively high rates of removal of silicon nitride and for selective removal of silicon nitride in preference to polysilicon, silicon oxide, or both. The present invention addresses these ongoing needs. These and other advantages of the invention, as well as additional inventive features, will be apparent from the description of the invention provided herein.

BRIEF SUMMARY ~~OF THE INVENTION~~

[0011] The present ~~invention~~disclosure provides an acidic aqueous polishing composition (e.g., having a pH of 2 to 6) suitable for removal of silicon nitride from a surface of a substrate in a chemical-mechanical polishing (CMP) process. The composition comprises a particulate calcined ceria abrasive, at least one cationic polymer, optionally a polyoxyalkylene polymer, and an aqueous carrier. The at least one cationic polymer is selected from a poly(vinylpyridine) polymer and a combination of a poly(vinylpyridine) polymer and a quaternary ammonium-substituted polymer, such as a quaternary ammonium-substituted acrylate or methacrylate polymer.

[0012] The abrasive concentration in the composition is 0.01 to 10 percent by weight (wt %), preferably 0.05 to 5 wt %. Preferably, the concentration of the abrasive in the composition, at the point of use in the present methods, is in the range of 0.01 to 2 wt%, more preferably 0.05 to 0.5 wt%. The concentration of the at least one cationic polymer in the composition is in the range of 10 parts-per-million (ppm) to 100,000 ppm, preferably 15 ppm to 10,000 ppm. At point of use, the composition preferably comprises 10 ppm to 1000 ppm of the at least one cationic polymer, more preferably 15 ppm to 100 ppm for each cationic polymer present. In a preferred embodiment, the polyoxyalkylene polymer is present in the composition at a concentration in the range of 10 to 200,000 ppm, more preferably 200 to 100,000 ppm. At point of use, the composition preferably comprises 10 ppm to 2000 ppm of the polyoxyalkylene polymer, more preferably 200 ppm to 1000 ppm.

[0013] In some preferred embodiments, the polyoxyalkylene polymer comprises a poly(ethylene glycol) polymer (i.e., a PEG) having an average number of ethylene glycol monomer units in the range of 200 to 2000, more preferably 300 to 1500 monomer units. In other preferred embodiments, the polyoxyalkylene polymer comprises a poly(ethylene glycol)-co-poly(propylene glycol) block copolymer, such as a poly(ethylene glycol)-end capped poly(propylene glycol), i.e., a PEG-PPG-PEG block copolymer.

[0014] In some preferred embodiments the at least one cationic polymer comprises a combination of a poly(vinylpyridine) polymer and a quaternary ammonium-substituted acrylate or methacrylate polymer, e.g., 10 to about 90 ppm of a poly(vinylpyridine) polymer and 15 to 100 ppm of a quaternary ammonium-substituted acrylate or methacrylate polymer, at point of use.

[0015] In another ~~aspect~~embodiment, the present ~~invention~~disclosure provides a chemical-mechanical polishing method for polishing a silicon nitride-containing substrate with the CMP composition described above. A preferred method comprises the steps of contacting a surface of a silicon nitride-containing substrate with a polishing pad and the aqueous polishing composition, and causing relative motion between the polishing pad and the substrate while maintaining a portion of the polishing composition in contact with the surface between the pad and the substrate for a time period sufficient to abrade at least a portion of the substrate surface. The polishing composition comprises, at point of use, 0.01 to 2.0 percent by weight of the particulate calcined ceria abrasive, 10 to 1000 ppm of the at least one cationic polymer, 10 to 2000 ppm of the polyoxyalkylene polymer, and an aqueous carrier, as described above.

[0015a] In one aspect, there is provided an acidic aqueous polishing composition suitable for polishing a silicon nitride-containing substrate in a chemical-mechanical polishing (CMP) process, the composition comprising:

(a) about 0.01 to about 10 percent by weight of a particulate calcined ceria abrasive;

(b) about 10 to about 100,000 ppm of at least one cationic polymer selected from the group consisting of (a) a poly(vinylpyridine) polymer and (b) a combination of a poly(vinylpyridine) polymer and a quaternary ammonium-substituted polymer;

(c) about 10 to about 200,000 ppm of a polyoxyalkylene polymer; and

(d) an aqueous carrier therefor, wherein the composition has a pH in the range of about 3 to about 6.

[0015b] In another aspect, there is provided a chemical-mechanical polishing (CMP) method for polishing a surface of a substrate, the method comprising abrading the surface of the substrate with a composition as defined above, wherein the composition, as used, comprises about 0.01 to about 2 percent by weight of the ceria abrasive, about 10 to about 1000 ppm of the at least one cationic polymer, and about 10 to about 2000 ppm of the polyoxyalkylene polymer.

[0015c] In another aspect, there is provided an acidic aqueous polishing composition suitable for selective removal of silicon nitride relative to polysilicon in a chemical-mechanical polishing (CMP) process, the composition comprising:

(a) about 0.05 to about 5 percent by weight of a particulate calcined ceria abrasive;

(b) about 15 to about 10,000 ppm of at least one cationic polymer selected from the group consisting of (a) a poly(vinylpyridine) polymer and (b) a combination of a poly(vinylpyridine) polymer and a quaternary ammonium-substituted polymer;

(c) about 200 to about 100,000 ppm of a polyoxyalkylene polymer selected from a poly(ethylene glycol) polymer, a poly(ethylene glycol)-co-poly(propylene glycol) block copolymer, or a combination thereof; and

(d) an aqueous carrier therefor;

wherein the composition has a pH in the range of about 3 to about 6.

[0015d] In another aspect, there is provided a chemical-mechanical polishing (CMP) method for polishing a surface of a substrate, the method comprising abrading the surface of the substrate with a composition as defined above, wherein the composition, as used, comprises about 0.05 to about 0.5 percent by weight of the ceria abrasive, about 10 to about 100 ppm of the at least one cationic polymer, and about 200 to about 1000 ppm of the polyoxyalkylene polymer.

[0015e] In another aspect, there is provided a chemical-mechanical polishing (CMP) method for selectively removing silicon nitride from a surface of a substrate in preference to removal of polysilicon, the method comprising the steps of:

(a) contacting a surface of a silicon nitride- and polysilicon-containing substrate with a polishing pad and an acidic aqueous CMP composition; and

(b) causing relative motion between the polishing pad and the substrate while maintaining a portion of the CMP composition in contact with the surface between the pad and the substrate for a time period sufficient to abrade silicon nitride from the surface;

wherein the CMP composition comprises:

(i) about 0.01 to about 2 percent by weight of a particulate calcined ceria abrasive;

(ii) about 10 to about 1000 ppm of at least one cationic polymer selected from the group consisting of (a) a poly(vinylpyridine) polymer and (b) a combination of a poly(vinylpyridine) polymer and a quaternary ammonium-substituted polymer;

(iii) about 10 to about 2000 ppm of a polyoxyalkylene polymer; and

(iv) an aqueous carrier therefor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 provides a graph of removal rate for silicon oxide (Oxide), polysilicon (PolySi), and silicon nitride (Nitride) obtained by polishing blanket wafers with selected compositions of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The present invention provides compositions and methods for polishing a silicon nitride-containing surface. In a preferred embodiment, a composition of the present invention comprises an acidic aqueous carrier containing 0.01 to 10 wt% of a particulate calcined ceria abrasive, 10 to 100,000 ppm of at least one cationic polymer, and optionally, 10 to 200,000 ppm of a polyoxyalkylene polymer.

[0018] The particulate calcined ceria abrasive can be present in the polishing composition at a concentration in the range of 0.01 to 10 wt%. Preferably, the ceria is present in the CMP composition at a concentration in the range of 0.05 to 5 wt%. At point of use, the ceria abrasive preferably is present at a concentration of 0.01 to 2 wt%, more preferably 0.05 to 0.5 wt% (e.g., 0.1 to 0.3 wt%). The abrasive particles preferably have a mean particle size in the range of 30 nm to 200 nm, more preferably 75 nm to 125 nm, as determined by laser light scattering techniques, which are well known in the art.