uniformly flat across all regions of substrate 26. Fill material occupies recesses 30 in substrate 26 and forms an inlaid pattern 60 in substrate 26. Importantly, upper surface ~~50~~ 58 does not exhibit artifacts of the polishing process, such as erosion or dishing.

[0035] Following the polish removal of fill layer 36, the substrate is washed with deionized water and, in the case where fill layer 36 is copper, a passivation step is carried out. The passivation step reduces corrosion of the copper inlaid pattern. In accordance with an aspect of the invention, inert gas can be continuously introduced into the cleaning and passivation solutions. The gaseous phase functions to enhance the cleaning action of the deionized water and to uniformly distribute the passivation agent on the substrate.

[0036] Those skilled in the art will appreciate that a wide variety of polishing compositions are available for use in a CMP process. All such polishing compositions are potentially available for use in the inventive polishing process described here. Further, those skilled in the art will appreciate that a wide variety of polishing pad materials and compositional configurations are widely available for use in various types of commercially available polishing equipment. Further, those skilled in the art will recognize that polishing systems having various polish pad and platen configurations are commercially available and can be employed to carry out the inventive polishing process.

[0037] Those skilled in the art will further appreciate that the substrate illustrated in FIG. 6 can be further processed using a variety of known semiconductor processing techniques to form a wide variety of semiconductor devices. The polishing process illustrated in FIGS. 2-6 represents a polish planarization process that can be used at various stages in a semiconductor fabrication process to form a relatively smooth and flat surface upon which subsequent layers can be deposited to complete the fabrication of a semiconductor device. For example, semiconductor devices having multiple layers of metal interconnects can be formed using the inventive process described herein.

[0038] Thus, it is apparent that there has been described, in accordance with an illustrative embodiment of the invention a polishing process with inert gas injection that fully provides the advantages set forth above. Although the invention has been described and illustrated with reference to specific illustrative embodiments thereof, it is

CLAIMS

1. A polishing process comprising:

providing a substrate having an uneven surface characterized by high regions and low regions with respect to a principal surface;

introducing an inert gas into a polishing slurry distributed on a polishing pad;

contacting the uneven surface with the polishing slurry; and

polishing the uneven surface, such that a gaseous phase forms in regions of the polishing slurry in contact with the low regions of the uneven surface,

wherein the gaseous phase retards a localized polish rate in the low regions with respect to a localized polish rate in the high regions.

2. The method of claim 1, wherein introducing an inert gas comprises introducing a noble gas.

3. The method of claim 1, wherein introducing an inert gas into comprises introducing a nitrogen gas.

4. The method of claim 1, wherein introducing an inert gas comprises introducing a molecular gas containing carbon and oxygen.

5. The method of claim 1, wherein introducing an inert gas comprises providing a porous polishing pad and injecting an inert gas through pores in the polishing pad.

6. The method of claim 1 further comprising flushing the substrate with deionized water.

7. The method of claim 1, wherein introducing an inert gas into the polishing slurry comprises introducing the inert gas during polishing the uneven surface.

8. The method of claim1, wherein providing a substrate having an uneven surface comprises:

forming an insulating layer on the substrate, the insulating layer including an inlay pattern therein, the inlay pattern having areas of high feature density and areas of low feature density; and

forming a metal layer on the insulating layer, wherein the low regions of the uneven surface overlie areas of low feature density and the high regions of the uneven surface overlie areas of high feature density.

9. The method of claim 8, wherein forming a metal layer on the insulating layer comprises forming a copper or copper-containing layer on an insulating layer

10. The method of claim 1, wherein providing a substrate having an uneven surface comprises forming an insulating layer on the substrate, and wherein polishing the uneven surface comprises polishing the insulating layer.

11. The method of claim 1, wherein the polishing process comprises a process carried out in the fabrication of a semiconductor device.

12. A method for polishing a substrate, the method comprising:

forming a polishing composition on a polishing surface;

introducing an inert gas into the polishing composition;

contacting an uneven surface with the polishing composition, the uneven surface having low regions;

polishing the uneven surface; and

selectively forming a gaseous phase in regions of the polishing composition in spaced relationship to the low regions of the uneven surface.

13. The method of claim 12, wherein the gaseous phase retards a localized polish rate in the low regions with respect to the remainder of the uneven surface.

14. The method of claim 12, wherein introducing an inert gas into a polishing slurry comprises introducing a noble gas.

15. The method of claim 12, wherein introducing an inert gas into a polishing slurry comprises introducing a nitrogen gas.

16. The method of claim 12, wherein introducing an inert gas into a polishing slurry comprises introducing a molecular gas containing carbon and oxygen.

17. The method of claim 12, wherein introducing an inert gas into a polishing slurry comprises providing a porous polishing pad and injecting an inert gas through pores in the polishing pad.

18. The method of claim 12, wherein the polishing method comprises a process carried out in the fabrication of a semiconductor device.

19. A method for forming a polishing composition, the method comprising:

providing a polishing liquid and introducing an inert gas into a polishing liquid to form a bubble layer at the surface of the polishing liquid; and

contacting an uneven surface with the bubble layer, wherein the bubble concentration in the bubble layer varies in relation to features in uneven surface.

20. The method of claim 19, wherein introducing an inert gas comprises introducing a noble gas.

21. The method of claim 19, wherein introducing an inert gas comprises introducing a nitrogen gas.

22. The method of claim 19, wherein introducing an inert gas comprises introducing a molecular gas containing carbon and oxygen.

CLAIMS

1. A polishing process comprising:

providing a substrate having an uneven surface characterized by high regions and low regions with respect to a principal surface;

distributing a polishing slurry onto a porous polishing pad;

contacting the uneven surface with the polishing slurry and polishing the uneven surface; and

injecting a slurry-free inert gas through the porous polishing pad and into the polishing slurry distributed on the porous polishing pad before or during polishing, such that a gaseous phase forms in regions of the polishing slurry in contact with the low regions of the uneven surface,

wherein the gaseous phase retards a localized polish rate in the low regions with respect to a localized polish rate in the high regions.

2. The method of claim 1, wherein injecting a slurry-free inert gas comprises introducing a noble gas.

3. The method of claim 1, wherein injecting a slurry-free inert gas into comprises introducing a nitrogen gas.

4. The method of claim 1, wherein injecting a slurry-free inert gas comprises introducing a molecular gas containing carbon and oxygen.

5. The method of claim 1, wherein injecting a slurry-free inert gas through the porous polishing pad comprises injecting through holes in the porous polishing pad.

6. The method of claim 1 further comprising flushing the substrate with deionized water.

7. The method of claim 1, wherein injecting a slurry-free inert gas into the polishing slurry comprises introducing the inert gas during polishing the uneven surface.

8. The method of claim 1, wherein providing a substrate having an uneven surface comprises:

forming an insulating layer on the substrate, the insulating layer including an inlay pattern therein, the inlay pattern having areas of high feature density and areas of low feature density; and

forming a metal layer on the insulating layer, wherein the low regions of the uneven surface overlie areas of low feature density and the high regions of the uneven surface overlie areas of high feature density.

9. The method of claim 8, wherein forming a metal layer on the insulating layer comprises forming a copper or copper-containing layer on an insulating layer.

10. The method of claim 1, wherein providing a substrate having an uneven surface comprises forming an insulating layer on the substrate, and wherein polishing the uneven surface comprises polishing the insulating layer.

11. The method of claim 1, wherein the polishing process comprises a process carried out in the fabrication of a semiconductor device.

12. A method for polishing a substrate, the method comprising:

dispensing a polishing composition onto a surface of a porous polishing surface;

injecting a slurry-free inert gas into the polishing composition through the porous polishing surface;

contacting an uneven surface with the polishing composition, the uneven surface having low regions;

polishing the uneven surface; and

selectively forming a gaseous phase in regions of the polishing composition in spaced relationship to the low regions of the uneven surface.

13. The method of claim 12, wherein the gaseous phase retards a localized polish rate in the low regions with respect to the remainder of the uneven surface.

14. The method of claim 12, wherein injecting a slurry-free inert gas into a polishing slurry comprises introducing a noble gas.

15. The method of claim 12, wherein injecting a slurry-free inert gas into a polishing slurry comprises injecting a nitrogen gas.

16. The method of claim 12, wherein injecting a slurry-free inert gas into a polishing slurry comprises injecting a molecular gas containing carbon and oxygen.

17. The method of claim 12, wherein injecting a slurry-free inert gas into a polishing slurry comprises injecting an inert gas through holes in the polishing pad.

18. The method of claim 12, wherein the polishing method comprises a process carried out in the fabrication of a semiconductor device.

19. A method for forming a polishing composition, the method comprising:

providing a polishing liquid on a porous polishing pad and introducing a slurry-free inert gas into the polishing liquid through the porous polishing pad to form a bubble layer at the surface of the polishing liquid; and

contacting an uneven surface with the bubble layer, wherein the bubble concentration in the bubble layer varies in relation to features in the uneven surface.

20. The method of claim 19, wherein introducing a slurry-free inert gas comprises introducing a noble gas.

21. The method of claim 19, wherein introducing a slurry-free inert gas comprises introducing a nitrogen gas.

22. The method of claim 19, wherein introducing a slurry-free inert gas comprises introducing a molecular gas containing carbon and oxygen.

23. A polishing process comprising:

providing a substrate having an uneven surface characterized by high regions and low regions with respect to a principal surface;

distributing a polishing slurry onto a porous polishing pad;

contacting the uneven surface with the polishing slurry and polishing the uneven surface; and

injecting a slurry-free inert gas through a gas delivery system positioned on a back side of the porous polishing pad and into the polishing slurry distributed on a front side of the porous polishing pad before or during polishing, such that a gaseous phase forms in regions of the polishing slurry in contact with the low regions of the uneven surface,

wherein the gaseous phase retards a localized polish rate in the low regions with respect to a localized polish rate in the high regions.