

METHOD FOR STRIPPING COPPER IN DAMASCENE INTERCONNECTS

BACKGROUND OF THE INVENTION



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(1) Field of the Invention

The invention relates to a method of copper stripping in the fabrication of integrated circuits, and more particularly, to a cheap and safe method of copper stripping using a novel chemical mixture in the manufacture of integrated circuits.



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(2) Description of the Prior Art

In the manufacture of integrated circuits, copper stripping is required in a number of situations, for example, after electroplated copper deposition in a damascene process with complete selectivity to the barrier metal, or stripping of bulk copper from silicon wafers such as for rework. One method of removing copper has been to use nitric acid. This method has several drawbacks. High purity nitric acid is expensive. The corrosive nature of nitric acid renders the acid dangerous to operators and unsuitable for most cleaning equipment and creates a serious disposal problem. Finally, nitric acid oxidizes the surface of silicon and produces a thin oxide that hinders further removal of copper. It is desired to provide a safe,

inexpensive method for removing copper.

U.S. Patent 5,207,867 to Cordani teaches the use of an aqueous acid solution to be used after conventional copper stripping for the purpose of removing residual metal specie from the surface of an insulating layer. The solution includes a mineral acid, a fluoride ion, and an oxidizing agent such as hydrogen peroxide. U.S. Patent 5,348,590 to Shigemura et al discloses a preflux to be formed only on copper and copper alloys. A chelating agent for reacting with copper ions is added to the preflux. The chelating agent may comprise aminocarboxylic acids such as ethylene diamene triacetic acid. U.S. Patent 5,244,539 to McGrath et al teaches a solder-stripping aqueous solution that will not damage the underlying copper. The solution includes nitric acid, ferric ions, halide ions, and ammonium ions. U.S. Patent 5,410,396 to Somers et al also discloses a solder-stripping solution that includes ammonium fluoride, hydrogen peroxide, acid, and an 8-hydroxyquinoline compound.

SUMMARY OF THE INVENTION

A principal object of the present invention is to provide an effective and very manufacturable method of copper stripping in the fabrication of integrated circuits.

Another object of the present invention is to provide an effective and very manufacturable method of copper stripping without attacking or damaging the barrier metal layer in the fabrication of integrated circuits.

Yet another object of the invention is to provide an inexpensive and safe copper removal method in the fabrication of integrated circuits.

Yet another object of the invention is to provide a novel copper stripping method which can be employed using wet cleaning equipment without corroding or destroying the equipment.

A further object is to provide a novel copper stripping method which can be employed to remove minute copper contamination from any equipment without corroding or destroying equipment parts.

A still further object is to provide a novel copper stripping method employing a chemical mixture comprising an ammonium salt, an amine, and water.

In accordance with the objects of this invention an inexpensive and safe copper removal method in

the fabrication of integrated circuits is achieved. Copper is stripped or removed by a chemical mixture comprising an ammonium salt, an amine, and water. The rate of copper stripping can be controlled by the concentration of the ammonium salt component of the mixture.

Also in accordance with the objects of the invention, a novel chemical mixture for stripping copper is provided. The novel chemical mixture for removing or stripping copper comprises an ammonium salt, an amine, and water. For example, the novel chemical mixture may comprise ammonium fluoride, ethylenediamine, and water in a ratio of 1:1:1.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings forming a material part of this description, there is shown:

Fig. 1 schematically illustrates in cross-sectional representation a dual damascene application of the present invention.

Fig. 2 schematically illustrates in cross-sectional representation a single damascene application of

the present invention.

Fig. 3 schematically illustrates in cross-sectional representation a bulk copper stripping application of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Copper stripping is performed in a variety of applications. For example, Figs. 1 through 3 illustrate three of the many applications of the copper stripping process of the present invention. It is to be understood by those skilled in the art that the process and novel chemical mixture of the present invention are not limited to the applications illustrated in these figures. Rather, the process and chemical mixture of the invention can be used in any application in which it is desired to provide a safe and inexpensive method of copper removal.

Fig. 1 illustrates a dual damascene application. A dual damascene opening has been etched through the optional cap layer (23), dielectric (22, 18), etch stop layer (20), and passivation layer (16) to the underlying metal line 14 to be contacted. This metal line 14 may be a copper or aluminum-copper line or a tungsten lead.

A barrier metal layer 24, such as tantalum nitride or tungsten nitride is deposited over the topmost dielectric layer 22, or the optional cap layer 23, and within the dual damascene opening. A copper layer 26 is formed, for example, by vapor deposition and electroplating to fill the opening. Now, the excess copper 26 not within the dual damascene opening must be removed with complete selectivity to the barrier metal. It is also appropriate that all of the copper in the damascene opening can be removed with complete selectivity to the barrier metal.

Fig. 2 illustrates a single damascene in-laid application. A single damascene opening has been etched through the optional cap layer (23), dielectric (19), and passivation layer (16) to the underlying copper or aluminum-copper line or a tungsten lead (14) to be contacted. It is to be understood by those skilled in the art that the excess copper 26 deposited over the barrier metal layer 24 needs to be removed with complete selectivity to the barrier metal. It is also appropriate that all of the copper in the damascene opening can be removed with complete selectivity to the barrier metal and without attacking or damaging the barrier metal.

Fig. 3 illustrates a third example application of copper stripping. A wafer 10 is illustrated having a coating of copper 14 thereover. Stripping is indicated by arrows 15. For example, as shown in Fig. 3, copper 14 may be removed from the front side of the wafer only. In other examples, not shown, copper may be removed from the backside, from the bevel 17 only, from both front and back sides, or from the bevel and both front and back sides. This application may be used when rework is required.

Yet another unillustrated application of copper stripping is performed in any equipment found in a wafer fabrication plant. The copper stripping can be performed after the wafer or wafers have been processed, during preventive maintenance, or after breakage of a wafer in the equipment. In the event of wafer breakage, the wafer may incorporate copper in the form of 100% copper or in the form of aluminum-copper alloy, which occur in one or more layers in the fabrication of microelectronic devices or which occur as a sole film (with or without one or more layers above or below this film) on a silicon wafer. The copper stripping solution of the invention can be applied in this application by placing it on a cleanroom cloth and then wiping the equipment parts and surfaces with the cloth.

The process of the invention proposes a novel method for safe and inexpensive stripping or removal of copper in any application. The process of the invention can be employed using wet cleaning equipment without corroding or destroying the equipment. The method employed is the use of a chemical mixture that comprises an ammonium salt and an amine. It is pertinent that the ammonium salt be used in a form in which it is dissolved in a solution (for instance, water) and not in a solid form.

The chemical mixture for the dissolution of copper comprises an ammonium salt, water, and an amine. The ammonium salt is ammonium fluoride. Ammonium fluoride solution is commercially available as a 40% solution (e.g. from Ashland Chemicals). Amines may include ethylenediamine ($\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$), 1,2-diaminopropane ($\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{NH}_2$), and 1,3-diaminopropane ($\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{NH}_2$).

For example, a mixture of ammonium fluoride, ethylenediamine, and water in a ratio of 1:1:1 will be able to strip elemental copper at rates of about 5 microns per minute at room temperature. Furthermore, the reaction can be controlled by increasing or decreasing the ratio of ammonium fluoride and also by the quantity of water that is added to the mixture. For instance, a mixture of aluminum fluoride,

ethylenediamine, and water in a ratio of 1:1:10 will strip copper at a slower rate relative to the same mixture at a 1:1:1 ratio. Similarly, the rate of removal can be controlled by increasing or decreasing the ratio of ammonium fluoride in the solution, for example, from 1:1:1 to 0.5:1:1.

The process of the present invention provides a method for safe and inexpensive copper stripping for any application. A novel chemical mixture is employed to effect the desired safe and inexpensive copper stripping.

While the invention has been particularly shown and described with reference to the preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made without departing from the spirit and scope of the invention.

CLAIM

1. A method of copper stripping and contamination removal comprising:
providing a copper layer on an integrated circuit; and stripping portions of said copper layer using a chemical mixture consisting of an ammonium salt, water, and an amine.
2. The method according to Claim 1 wherein said ammonium salt is ammonium fluoride.
3. The method according to Claim 1 wherein said amine is chosen from the group containing: ethylenediamine, 1/2-diaminopropane, and 1/3-diaminopropane.
4. The method according to Claim 1 wherein said chemical mixture comprises ammonium fluoride, water, and ethylene diamine.
5. The method according to Claim 1 wherein said chemical mixture comprises ammonium fluoride, water, and ethylene diamine in a ratio of 1:1:1.

6. The method according to Claim 5 where said chemical mixture strips said copper at the rate of 5 microns per minute at room temperature.

7. The method according to Claim 4 wherein the rate of copper stripping can be controlled by varying the concentration of said ammonium fluoride in said chemical mixture.

8. The method according to Claim 4 wherein the rate of copper stripping can be controlled by varying the amount of said ammonium fluoride in said chemical mixture.

9. The method according to Claim 4 wherein the rate of copper stripping can be controlled by varying the amount of said water in said chemical mixture.

10. A method of copper stripping and contamination removal comprising:

providing a copper layer overlying an underlayer on an integrated circuit; and stripping portions of said copper layer using a chemical mixture consisting of an ammonium salt, water, and an amine wherein said underlayer is not removed.

11. The method according to Claim 10 wherein said ammonium salt is ammonium fluoride.

12. The method according to Claim 10 wherein said amine is chosen from the group containing: ethylenediamine, 1,2-diaminopropane, and 1,3-diaminopropane.

13. The method according to Claim 10 wherein said chemical mixture comprises ammonium fluoride, water, and ethylenediamine.

14. The method according to Claim 10 wherein said chemical mixture comprises ammonium fluoride, water, and ethylenediamine in a ratio of 1:1:1.

15. The method according to Claim 14 where said chemical mixture strips said copper at the rate of 5 microns per minute at room temperature.

16. The method according to Claim 13 where the rate of copper stripping can be controlled by varying the concentration of said ammonium fluoride.

17. The method according to Claim 13 where the rate of copper stripping can be controlled by varying the amount

of said ammonium fluoride in said chemical mixture.

18. The method according to Claim 13 where the rate of copper stripping can be controlled by varying the amount of said water in said chemical mixture.

19. A chemical mixture for stripping copper consisting of:

an ammonium salt;

water; and

an amine.

20. The chemical mixture according to Claim 19 wherein said ammonium salt is ammonium fluoride.

21. The chemical mixture according to Claim 19 wherein said amine complex is chosen from the group containing: ethylenediamine, 1,2-diaminopropane, and 1,3- diaminopropane.

22. The chemical mixture according to Claim 19 wherein said ammonium salt comprises ammonium fluoride and said amine comprises ethylenediamine.

23. The chemical mixture according to Claim 22 wherein said ammonium fluoride, water, and ethylenediamine are in a concentration of 1:1:1.

24. The chemical mixture according to Claim 22 wherein the rate of said copper stripping can be controlled by varying the concentration of said ammonium fluoride.

25. The method according to Claim 22 where said rate of copper stripping can be controlled by varying the amount of said ammonium fluoride in said chemical mixture.

26. The method according to Claim 22 where said rate of copper stripping can be controlled by varying the amount of said water in said chemical mixture.