APPARATUS AND METHOD FOR POLYMER REMOVAL AFTER METAL ETCHING IN A PLASMA REACTOR

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The invention relates to processes for the manufacture of semiconductor devices and more particularly to the reduction of corrosion following plasma etching of metal layers.

(2) Description of prior art

The fabrication of integrated circuits not only involves the forming of semiconductor devices within the surface of a semiconductor wafer but also the creation of a complex network of wiring interconnections which comprise the electrical circuitry of the completed chip. These interconnections are accomplished by the alternate deposition of thin layers of conductive and insulating materials over the semiconductor devices. Each conductive layer is patterned by photolithographic techniques to form the wiring design for a level of

circuitry.

A photoresist pattern is first formed over the metal layer and then the unwanted metal is etched away either by reactive-ion-etching(RIE) or by plasma etching. The conductive layers are typically of aluminum or of an aluminum alloy. The etching of these layers is usually done in an ambient containing Cl_2 and BCl_3. Products of the reaction include $AlCl_3$ and polymeric residues derived from the photoresist and $AlCl_3$. These materials are extremely hygroscopic and, if allowed to remain on the wafer, react with the slightest moisture to produce acids which cause severe corrosion of aluminum. Free chlorine, as well, trapped in polymeric residues, is hydrolyzed by moisture and becomes corrosive to aluminum. A brief discussion of this metal corrosion problem is given by Wolf,S. and Tauber, R.N.,"Silicon Processing for the VLSI Era", Vol.1, Lattice Press, Sunset Beach,CA, (1986),p563.

Many procedures have been developed which address this problem. The simplest consists of immediately rinsing the wafers in water after removal of the photoresist by plasma ashing. However, this method is not effective when applied to aluminum or aluminum/copper alloys. Chlorine containing metallic polymer residues are not adequately removed and corrosion problems persist.

Miyamoto US5,246,888 performs a plasma process, after chlorine etching of an aluminum alloy, using first a microwave plasma containing an oxygen-ammonia mixture followed by ashing in an oxygen plasma. Accelerated testing in steam showed that ammonia, in low proportions inhibits corrosion. **Rhoades US5,221,424** strips the photoresist after the pattern etch and removes or passivates chlorine containing residues by first flowing a fluorocarbon/oxygen mixture over the heated wafer. Then, after igniting a plasma for a period of time, the wafer is heated in the presence of flowing H_2O_2/H_2O vapors.

Referring to Fig. **1**, there is shown a configurational view of a plasma etching tool **10** which has its functional components mounted on console table **12**. A commercial example of such a tool is the TCP 9600 manufactured by LAM Research Corporation, 4650 Cushing Parkway, Fremont, California, 94538, U.S.A. Phone: 510-659-0200 Fax: 510-659-2935. The evacuable chambers comprise a load lock **14**, an etching chamber **16** and an ashing chamber **18**. Automated transfer of wafers through these chambers occurs through mechanical ports **22A**, **22B**, **22C**, and **22D**. A photoresist patterned wafer enters load lock **14** through port **22D**, and then passes into the etching chamber **16** where a metal pattern is etched. The wafer then enters the ashing chamber **18**

where residual photoresist is removed, typically with an oxygen plasma. The oxygen plasma does not effectively remove metallic polymer residues when aluminum or aluminum alloys have been etched. Upon completion of the ashing operation, the wafer exits the chamber **18** through port **22A** and is transported by mechanical arm **24** to a vacuum chuck **26** in a coordinated Atmospheric Process Module(APM) **20**. Typically, the APM **20** is used to rinse wafers after plasma ashing, thereby removing sundry debris and water soluble residues. The rinsing is done with hot de-ionized water(DI H_2O) after which the wafer is spun dry. A nozzle **28** discharges hot DI H2O over the center of the spinning wafer **30** in the APM enclosure **32**.

After the rinse step, residual polymer remains on the wafer. This polymer is then removed by subjecting the wafer to an additional liquid stripping operation using solvents such as photoresist developer or EKC265 stripper. EKC265 is a commercial product for polymer removal supplied by EKC Technology, Inc. 2520 Barrington Hayward, CA 94545 PH:(510) 784-9119.

The inclusion of this liquid stripping operation in the current process requires additional wafer handling and an additional processing equipment.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a method for thoroughly removing chlorine containing polymer residues from wafers after metal pattern etching with chlorine containing etchants.

It is a further object of this invention to consolidate the process of polymer residue removal with a water rinse process thereby sequencing the processes with dispatch and with reducing wafer handling.

It is yet another object of this invention to minimize metal corrosion, reduce process cycle time, and eliminate the need for additional liquid polymer stripping equipment.

These objects are achieved by fitting a post plasma etch rinse station with an additional dispensing mechanism whereby polymer residue solvent is applied sequentially with a hot DI water rinse. The dispensing mechanism comprises a pressurized canister containing polymer solvent and a delivery line from the canister to a dispensing nozzle located adjacent to the hot DI water dispensing nozzle.

The rinse station is located near the exit port of the plasma ashing chamber 18 so that the polymer dissolution and rinsing may proceed with swiftness and minimal handling.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. **1** is a configurational view of a plasma (RIE) etching tool having an APM station located adjacent to the exit port of an ashing chamber.

Fig. **2** is a cross sectional view of the APM station.

Fig. **3** is a top view of the APM station showing an added nozzle for the discharge of polymer solvents as taught by this invention.

Fig. **4** is a view of the pressurized storage canister containing polymer solvent and means for delivering it to the APM station.

Fig. **5** is a flow chart outlining the process steps used by this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Accordingly, there is given, a first embodiment which comprises an apparatus used to accomplish the objects of this invention.

Referring to Fig. **2** there is shown a cross sectional view of an APM station **20** provided adjacent to the loading port on an etcher such as the one shown in Fig.**1**. The conventional nozzle **28** is provided to supply Hot DI H_2O to the etch bath enclosure **32** from an auxiliary tank/heater located elsewhere. The nozzle **28** discharges to the center of the wafer **30**. The wafer **30** is mounted on a spinning vacuum chuck **26**. Centrifugal force flows the liquid across the wafer **30**, flinging it off the edges into the catch basin **32**, and thence out the drain **34**.

Referring now to Fig. **3**, a top view of the APM station is shown. In this embodiment an additional nozzle **35** is fitted alongside the conventional nozzle **28** so that both nozzles discharge as close to the center of the wafer **30** as possible. Nozzle **28** is connected to a source of DI water **36**. Nozzle **35** is connected to a pressurized source of polymer solvent **38** which is shown in greater detail in Fig. **4**. The canister **40** contains the solvent which is

pressurized by dry nitrogen **42**. A means for heating the solvent within the canister may be provided to accommodate solvents such as EKC265 which require heating. A flow controller **44** driven by an electrical signal **45** regulates the flow of solvent through piping **46** to the nozzle **35**.

Outfitted with the additional nozzle **35** and its solvent supply **38**, the APM station is now capable of sequentially removing all polymer residues and providing the necessary hot DI H_2O rinse which removes debris and water soluble residues.

The utilization of this apparatus in a preferred embodiment to clean a wafer after a metallization patterning etch will now be described with reference to the flow chart in Fig. **5**.

A silicon wafer having integrated circuit devices formed within its surface is provided. An insulative layer having contacts or vias to subjacent circuitry is formed over the wafer. A first metal layer, preferably of an aluminum alloy, is formed over the insulative layer and a layer of photoresist is patterned over the metal layer by well known photolithographic techniques to define a layer of

interconnection wiring.

Referring to Fig. **5** and preceding figures showing the apparatus of the first embodiment, the photoresist patterned wafer is placed into a plasma etching chamber and using a gas mixture comprising Cl_2 and BCl_3, the exposed metal is anisotropically etched away to form a wiring pattern **50**(step 1). During this operation, polymeric residues are formed by the interaction of chlorine species from the etching plasma, the metal layer, and components of the photoresist. Metallic polymer residues containing $AlCl_3$ and, when aluminum/copper alloys are used, $CuCl_2$ remain on the wafer.

After etching the wafer is transferred to the plasma ashing chamber and the residual photoresist is removed by plasma ashing in an ambient of O_2 **50**(step 2). The wafer is then removed from the plasma tool and transferred **52** to the APM station shown in Fig. **2** and described in the first embodiment. The APM station **20** is located close to the exit door of the ashing chamber so that the transfer can be made swiftly. The wafer is place on chuck **26** of the APM station **20** ,vacuum is applied and the wafer is set spinning.

Solvent flow through nozzle **35** is begun **54** and maintained at a flow rate of about 0.2 to 0.5 liters/minute for a period of between about 2 and 5 minutes. The solvent flows over the wafer and exits the cleaning bath enclosure via the drain **34**. When the solvent flow time period has elapsed, the flow is stopped and a flow of hot DI H_2O through the nozzle **28** is begun **56**. The DI H_2O is heated to a temperature of between about 60°C and 95°C. This final rinse removes water soluble residues and particulates from the wafer surface. The final rinse is carried out for a period of about 1 to 4 minutes whereafter the wafer is dried **58** by spinning under N_2 flow.

Solvents which may be used to remove residual polymer are photoresist developer, EKC265 or other commercial photoresist stripper, Ammonium hydroxide, and choline. The solvent used in the preferred embodiment is photoresist developer. If EKC265 is used, the canister **40** must be heated to between about 60°C and 90°C.

While this 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. Application of this invention to other levels of metallization is an obvious extension of these embodiments.

Claims

CLAIMS

1. A cleaning station for the dissolution and removal of polymeric residues and particulates from a wafer following the plasma etching of a metal layer with a gaseous etchant containing chlorine comprising:

(a) a tank having a chuck for supporting and spinning said wafer;

(b) a drain in said tank;

(c) a first nozzle directed into said tank for discharge of a first liquid;

(d) a second nozzle directed into said tank for discharge of a second liquid;

(e) means for delivery of said first liquid; and

(f) means for delivery of said second liquid.

2. The cleaning station of claim 1 wherein said tank is cylindrical.

3. The cleaning station of claim 1 wherein said means of delivery of said first liquid comprises:

a canister for solvent pressurized by nitrogen;

piping from said canister to said first nozzle;

a flow controller in line with said piping; and

means for heating said solvent in said canister.

4. The cleaning station of claim 1 wherein said second liquid is DI H_2O.

5. The cleaning station of claim 4 wherein said means of delivery of said second liquid comprises:

a storage container;

a input supply of pressurized DI H_2O to said storage container;

piping from said storage container to said second nozzle;

a flow controller in line with said piping; and

means for heating said DI H_2O.

6. A method for the dissolution and removal of polymeric residues and particulates from a wafer following the plasma etching of a metal layer on said wafer with a gaseous etchant containing chlorine comprising:

(a) providing a wafer having a metal layer deposited over its surface;

(b) depositing and patterning a photoresist layer over said metal layer;

(c) inserting said wafer into a plasma etching tool;

(d) etching said metal layer with an anisotropic etching technique;

(e) ashing said photoresist layer;

(f) removing said wafer from said plasma etching tool;

(g) providing a cleaning station comprising:

(i) a tank having a chuck for supporting and spinning said wafer;

(ii) a drain in said tank;

(iii) a first nozzle directed into said tank;

(iv) a second nozzle directed into said tank;

(v) means for delivery of a first liquid to said first nozzle; and

(vi) means for delivery of a second liquid to said second nozzle;

(h) mounting said wafer onto said chuck;

(i) flowing a said first liquid over said wafer through said first nozzle while said wafer is spinning;

(j) flowing a said second liquid over said wafer through said second nozzle while said wafer is spinning; and

(k) drying and removing said wafer.

7. The method of claim 6 wherein said metal layer is selected from the group containing aluminum, and an aluminum alloy.

8. The method of claim 6 wherein said anisotropic etching technique is reactive ion etching.

9. The method of claim 6 wherein said first liquid is selected from the group consisting of a photoresist developer, a photoresist stripper, ammonium hydroxide, and EKC265.

10. The method of claim 6 wherein said second liquid is DI H_2O.

11. The method of claim 10 wherein said DI H_2O is heated to a temperature of between about 60°C and 95°C.

12. The method of claim 6 wherein said means of delivery of said first liquid comprises:

a canister for solvent pressurized by nitrogen;

piping form said canister to said first nozzle;

a flow controller in line with said piping; and

means for heating said solvent in said canister.

13. The method of claim 10 wherein said means of delivery of said second liquid comprises:

a storage container;

an input supply of pressurized DI H_2O to said storage container;

piping from said storage container to said second nozzle;

a flow controller in line with said piping; and

means for heating said DI H_2O.