Title

METHOD OF ETCHING A MULTI-LAYER

Background of the Invention

1. Field of the Invention

The present invention relates to a method of etching a multi-layer, especially to a method that can prevent excess polymer residue on the sidewall and the corrosion of the aluminum layer.

2. Description of the Prior Art

In modern society, the micro-processor system comprised of integrated circuits (IC) is a ubiquitous device, being utilized in such diverse fields as automatic control electronics, mobile communication devices and personal computers.

To connect various active or passive components on the semiconductor substrate, metal aluminum or its alloy is usually used as a conducting wire. By some patterning processes, a complex interconnection system is gradually formed. A conventional method of forming a patterned aluminum layer is to deposit a photoresist layer on the aluminum layer, and then performing a photo-etching-process (PEP) with a patterned photo mask, then transferring the pattern of the photoresist layer onto the aluminum layer.

Please refer to FIG. 1, illustrating a cross sectional schematic diagram of a

conventional method of forming a patterned aluminum layer. As shown in FIG. 1, a semiconductor substrate (not shown) is provided and a dielectric layer 10, a barrier layer 12, an aluminum layer 14, an anti-reflection coating (ARC) layer 16 and a photoresist layer 22 are disposed in series thereon. The barrier layer 12 is an optional structure and may include Ti/TiN or TaN. The barrier layer 12 is usually used in a conventional via plug forming process to cover the external layer of the via plug or to increase its adhesion. The ARC layer 16 is used to reduce the reflection phenomenon during the exposure process.

Due to the different materials of each layer in the multi-layer, it is necessary to use different etching gas recipes to accurately remove the ARC layer 16 and the aluminum layer 14. The etching gas recipes usually include chlorine gas, BCl_3 N_2, CHF_3 or hydrocarbon. The chlorine gas and BCl_3 are used as the etching gas to anisotropically etch the ARC layer 16 and the aluminum layer 14 when they are transferred to radical by the plasma in the etching chamber. In order to maintain the good directionality, a passivation gas is used to produce polymer on the sidewall to obtain a good sidewall protection.

It is known that BCl_3 can not only function as an etching gas but also has passivation effect. It has therefore been widely used in various anisotropic etching processes. However, using BCl_3 may also bring some shortcomings such as excess loose polymer residue formed on the sidewall and thus the corrosion of the aluminum layer or other shortcomings. As shown in FIG. 1, it is known that BCl_3 has passivation effect, but if BCl_3 and other passivation substances are used at the same time, excess polymer residue 24 is formed on

the sidewall which is not compact. And because of the excess loose polymer residue 24 on the sidewall, lots of Cl_{plasma} generated by the plasma is easily attached onto the polymer residue 24 and reacted with the aluminum layer 14 in the sidewall. Please refer to FIG. 2, illustrating a schematic diagram of a conventional aluminum corrosion reaction formed by the Cl_{plasma}. Please refer to FIG. 2. When the aluminum ($Al_{(s)}$) in the aluminum layer 14 reacts with the Cl radical (Cl_{plasma}), a gaseous and aqueous intermediate product $AlCl_x$ is produced. If the aqueous $AlCl_x$ comes in contact with water (H_2O), it will produce aluminum hydroxide ($Al(OH)_x$) and gaseous and aqueous hydrochloric acid ($HCl_{(g)+(aq)}$). Formed aqueous hydrochloric acid then soon reacts with the aluminum layer 14 and regenerates with $AlCl_x$. So the cycle re-entries the foregoing and continues to cycle indefinitely, making the aluminum layer 14 being etched seriously and leading to the phenomenon of aluminum layer corrosion. Although the action can be avoided by blocking of H_2O, but it will further increase the burden of the controlling factors required in the etching process, making it become a complex process.

As a result, a simple etching process to etch the aluminum layer and the ARC layer that can prevent excess polymer residue production and corrosion of aluminum layer is still needed.

Summary of the Invention

The present invention provides a method of etching a multi-layer, especially a method that can reduce the phenomenon of excess polymer residue and can produce more compact polymer residue so as to prevent the

corrosion of aluminum layer in the multi-layer.

According to the present invention, a method of etching a multi-layer is provided. The multi-layer comprises an aluminum layer disposed on a semiconductor substrate and an anti-reflection coating layer disposed on the aluminum layer. The method comprises: performing a first etching process to etch the anti-reflection coating layer by providing a first etching gas, wherein the first etching gas comprises a chlorine-containing substance; then performing a second etching process to etch the aluminum layer by providing a second etching gas, wherein the second etching gas does not comprise a chlorine-containing compound.

According to the present invention, a method of anisotropically etching an aluminum layer is provided. The method comprises: providing an etching gas to etch the aluminum layer, wherein the etching gas comprises a chlorine-containing substance, but does not comprise a chlorine-containing compound.

The method of etching a multi-layer in the present invention excludes chlorine-containing compound as an etching gas, not only providing a more simple process but also reducing the phenomenon of excess polymer residue and corrosion of aluminum layer, and leading to a better etching result.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed

description of the preferred embodiment that is illustrated in the various figures and drawings.

Brief Description of the Drawings

FIG. 1 illustrates a cross sectional schematic diagram of a conventional method of forming a patterned aluminum layer.

FIG. 2 illustrates a schematic diagram of a conventional aluminum corrosion reaction formed by the Cl_{plasma}.

FIG. 3 illustrates a flow chart of etching a multi-layer in the present invention.

FIG. 4 to FIG. 7 illustrate the structure schematic diagrams of each step of etching a multi-layer in the present invention.

Detailed Description

Please refer to FIG. 3, illustrating a flow chart of etching a multi-layer in the present invention. As shown in FIG. 3, the method of etching a multi-layer in the present invention comprises:

Step 100: providing a multi-layer disposed on a semiconductor substrate, wherein the multi-layer comprises at least an aluminum layer and an anti-reflection coating (ARC) layer disposed on the aluminum layer.

Step 102: utilizing a patterned mask to perform a first etching process to etch the ARC layer by providing a first etching gas and a first passivation gas, wherein the first etching gas comprises a chlorine-containing substance.

Step 104: after step 102, performing a second etching process to etch the aluminum layer by providing a second etching gas and a second passivation gas, wherein the second etching gas does not comprise a chlorine-containing compound.

Step 106: after etching the aluminum layer, performing an over etching

process to etch a barrier layer disposed under the aluminum layer.

For more detailed descriptions of each step, please refer to FIG. 4 to FIG. 7, illustrating the structure schematic diagrams of each step of etching a multi-layer in the present invention. As shown in FIG. 4 and step 100, a multi-layer on a semiconductor substrate 108 is provided. The multi-layer in series includes a dielectric layer 110, a barrier layer 112, an aluminum layer 114, an ARC layer 116 and a mask layer 122. The dielectric layer 110 includes SiO_2, SiN, SiC, tetraethoxysilane (TEOS), undoped silicon glass (USG), phosphorus silicon glass (PSG), boron phosphorus silicon glass (BPSG), other low-k dielectric material or the combination of above groups. The barrier layer 112 includes Ti/TiN, TaN, other suitable material or the combination of above groups. The aluminum layer 114 may include conventional metal aluminum or aluminum alloy such as copper-aluminum alloy. The ARC layer 116 includes Ti/TiN or other suitable material. The ARC layer 116 may include a mono-layer structure or a double-layer structure, for example, a bottom ARC layer and a top ARC layer. The bottom ARC layer includes TiN. The top ARC layer may include the same material as the bottom ARC layer or include different materials, such as an organic anti-reflection material, or inorganic anti-refection material like silicon oxynitride (SiON). The mask layer 122 includes a patterned structure, such as a photoresist, wherein the pattern of the mask layer 122 will be transferred to the ARC layer 116 and the aluminum layer 114 in the subsequent etching steps.

Please refer to FIG. 5 and step 102. A first etching process is provided to

etch the ARC layer 116 but less to etch the aluminum layer 114. After step 102 is performed, most ARC layer 116 is etched away and even a small part of the aluminum layer 114 is consumed. In some circumstance, a small part of the ARC layer 116 may still be retained on the substrate108. A first etching gas 126 and a first passivation gas are provided therefore. The first etching gas 126 includes various kinds of chlorine-containing substance but does not include a chlorine-containing compound, for instance, using only chlorine gas but not using BCl_3. In another embodiment of the present invention, the first etching gas 126 used to etch the ARC layer 116 but less to etch the aluminum layer 114 may also include all chlorine-containing substances, which means using the chlorine gas and various kinds of chlorine-containing compounds at the same time, for example, using chlorine gas and BCl_3 at the same time. The first passivation gas includes hydrocarbon or other suitable material, in the preferred embodiment of the present invention, the first passivation gas is ethylene (C_2H_4).

The first etching process is carried out in a plasma etching chamber. Table 1 provides a preferred etching recipe and operation condition when the first etching gas 126 is chlorine gas. As shown in Table 1, the first etching process is performed under a condition as follows: a pressure between 12 and 18 mTorr, a RF power between 1200 and 1600W, a bias power between 250W and 350W, a period between 120 and 180 seconds, a flow rate of chlorine gas between 150 and 210sccm (standard cubic centimeter per minute) and a flow rate of ethylene between 120 and 180sccm. The reaction time of the first etching process may be adjusted depending on the material or thickness of the

ARC layer 116. It can be longer or short and is not limited to Table 1.

Step	Step 102 First etching process	Step 104 Second etching process	Step 106 Over etching process
Time(sec)	150	End point detection (max = 400)	120
RF power(W)	1400	1500	1200
Bias power(W)	300	300	1500
Pressure(mTorr)	15	10	8
BCl_3(sccm)	0	0	100
Cl_2(sccm)	180	150	100
C_2H_4(sccm)	150	150	150

Table 1

Please refer to FIG. 6 and step 104. After etching the ARC layer 116, a second etching process to etch the aluminum layer 114 is provided. A second etching gas 128 and a second passivation gas are provided. In order to avoid forming excess polymer residue that results in serious etching and corrosion of the aluminum layer 114 by using BCl_3 in conventional arts, the second etching gas 128 in the present invention includes a chlorine-containing substance but does not include a chlorine-containing compound, for example, using only chlorine-containing substance such as chlorine gas but avoiding conventional chlorine-containing compound such as BCl_3. The second

passivation gas includes hydrocarbon or other suitable material, in the preferred embodiment of the present invention, the second passivation gas is C_2H_4. The second etching process can also be carried out in-situ in the plasma etching chamber. Referring to Table 1, the second etching process is performed under a condition as follows: a pressure between 8 and 12 mTorr, a RF power between 1300 and 1700W, a bias power between 250W and 350W, a flow rate of the first etching gas between 120 and 180sccm and a flow rate of the first passivation gas between 120 and 180sccm. It is noted that the reaction time of the second etching process is determined by the end point detection. When the thickness of the aluminum layer 114 or other metal layer is changed, the reaction time of the second etching process is adjusted as well. The time listed in Table 1 provides one embodiment and the etching method of the present invention should not be limited thereto.

When finishing step 102 and step 104, the pattern of the mask layer 122 has been transferred to the aluminum layer 114, forming a patterned aluminum layer 114. Referring to FIG. 7, as shown in step 106, an over etching process is in-situ provided. A third etching gas 130 is provided to etch the barrier layer 112 and some remained aluminum layer 114 on the substrate 108. A part of the dielectric layer 110 may be consumed in the third etching process to make sure the aluminum layer 114 and the barrier layer 112 being etched away completely. The etching recipe and operation condition are shown in Table 1, which is not described in detail. After step 106, the polymer residue is flushed by argon gas and the mask layer 122 is removed, the patterned aluminum layer 114 is thus completed.

As described above, BCl_3 is usually used as an etching and a passivation gas in conventional arts, which may results in excess polymer residue formed on the sidewall of the patterned aluminum layer and thus brings to the serious etching and even corrosion of the aluminum layer. The present invention therefore provides an etching method that avoids using chlorine-containing compound such as BCl_3 as an etching gas, and in combination with a passivation gas such as hydrocarbon. In conventional arts, BCl_3 produces sidewall polymer by bombarding the mask layer, but the formed sidewall polymer is usually not compact. In contrast, hydrocarbon has longer polymer chains and thus more condensed structure ([C-H]x), it can completely replace the passivation function of BCl_3. The sidewall protection is not reduced with the removal of BCl_3. On the contrary, removing BCl_3 can avoid corrosion of the aluminum layer caused by too much Cl_{plasma} trapped in the polymer residue. As a result, the method of etching a multi-layer in the present invention not only provides a simpler process by removing chlorine-containing compound as an etching gas, but also can reduce the phenomenon of excess polymer residue and corrosion of aluminum layer, leading to a better etching result.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention.

Claims

What is claimed is:

1. A method of etching a multi-layer, the multi-layer comprising an aluminum layer disposed on a semiconductor substrate and an anti-reflection coating (ARC) layer disposed on the aluminum layer, the method comprising:

performing a first etching process to etch the ARC layer by providing a first etching gas, wherein the first etching gas comprises a chlorine-containing substance; and

performing a second etching process to etch the aluminum layer by providing a second etching gas, wherein the second etching gas does not comprise a chlorine-containing compound.

2. The method as in claim 1, wherein the chlorine-containing compound comprises BCl_3.

3. The method as in claim 1, wherein the second etching gas comprises chlorine gas.

4. The method as in claim 1, wherein the first etching gas comprises chlorine gas and BCl_3.

5. The method as in claim 1, wherein the first etching gas comprises chlorine gas.

6. The method as in claim 1, wherein the first etching process further comprises providing a first passivation gas.

7. The method as in claim 6, wherein the first passivation gas comprises hydrocarbon.

8. The method as in claim 6, wherein the first passivation gas comprises ethylene (C_2H_4).

9. The method as in claim 1, wherein the second etching process further comprises providing a second passivation gas.

10. The method as in claim 9, wherein the second passivation gas comprises hydrocarbon.

11. The method as in claim 9, wherein the second passivation gas comprises ethylene.

12. The method as in claim 6, wherein the first etching process is performed under a condition as follows: a pressure between 12 and 18 mTorr, a RF power between 1200 and 1600W, a bias power between 250W and 350W, a period between 120 and 180 seconds, a flow rate of the first etching gas between 150 and 210sccm and a flow rate of the first passivation gas between 120 and 180sccm.

13. The method as in claim 9, wherein the second etching process is performed under a condition as follows: a pressure between 8 and 12 mTorr, a RF power between 1300 and 1700W, a bias power between 250W and 350W, a flow rate of the second etching gas between 120 and 180sccm and a flow rate of the second passivation gas between 120 and 180sccm.

14. A method of anisotropically etching an aluminum layer, comprising: providing an etching gas to etch the aluminum layer, wherein the etching gas comprises a chlorine-containing substance, but does not comprise a chlorine-containing compound.

15. The method as in claim 14, wherein the chlorine-containing compound comprises BCl_3.

16. The method as in claim 14, wherein the etching gas comprises chlorine gas.

17. The method as in claim 14, further comprising providing a passivation gas.

18. The method as in claim 17, wherein the passivation gas comprises hydrocarbon.

19. The method as in claim 17, wherein the passivation gas comprises ethylene.

20. The method as in claim 17, wherein the etching process is performed under a condition as follows: a pressure between 8 and 12 mTorr, a RF power between 1300 and 1700W, a bias power between 250W and 350W, a flow rate of the etching gas between 120 and 180sccm and a flow rate of the passivation gas between 120 and 180sccm.