METHOD AND APPARATUS FOR DETECTING THE ENDPOINT OF A PHOTORESIST STRIPPING PROCESS

BACKGROUND OF THE INVENTION

This disclosure relates generally to photoresist stripping processes, and more particularly to a method and apparatus for detecting the endpoint of a photoresist stripping process.

Fabrication of integrated circuits generally starts with a thin slice of silicon called a wafer. On this wafer one can fabricate several hundred individual chips. Each chip may contain 10 to 20,000 components for a total of several million devices per wafer. The devices include resistors, diodes, capacitors and transistors of various types. The fabrication of the devices includes depositing desired materials (such as silicon dioxide, aluminum, etc.) at certain locations.

A technique called photolithography is used to facilitate the introduction of materials at desired locations on the wafer and the removal of undesired material at other locations. As an example, a layer of aluminum is first deposited on the wafer. Next, the wafer is coated with a light sensitive polymer called photoresist. A mask is used to expose selected areas of photoresist to UV light. The UV light induces polymerization in the exposed photoresist. UV light causes the exposed photoresist to cross link, rendering it insoluble in developing solution. Such a photoresist is called a positive photoresist. A negative photoresist shows an opposite behavior. That is, exposure to UV makes the photoresist soluble in developing solution. After the exposure to light, the soluble portions of the photoresist are removed, leaving a pattern of photoresist.

Immediately after photolithography, the wafer with patterned photoresist is aluminum etched to remove the aluminum where there is no pattern. This has the effect of transferring the pattern to the aluminum, creating electrical connections among devices at different locations.

After the aluminum etch process is complete, the photoresist is removed from the wafer in a process called photoresist stripping. The stripping of photoresist from the wafer surface must be essentially complete, since photoresist left on the wafer surface will cause defects in the integrated circuit. An important consideration in the photoresist stripping process is determining a time, referred to as the endpoint, at which to end the process. This time must be chosen so that the photoresist is entirely removed from the wafer. Preferably, the time will not exceed the time when the photoresist has been entirely removed. since this decreases the efficiency of the fabrication of integrated circuits.

Figure 1 is a flow chart of a prior art method for stripping photoresist **2**. The prior art method begins in a step **4**. The photoresist stripping process includes introducing a flow of O atoms into a stripping chamber that holds the wafer. The O atoms react with the photoresist, removing the photoresist from the wafer. The products of this reaction are removed from the chamber in the flow of gases leaving the chamber. The prior art method **2** continues the photoresist stripping process for a predetermined time in a step **6**, and ends the photoresist stripping process in a step **8** after the predetermined time elapses. The predetermined time is chosen to ensure that enough time passes to ensure that essentially all the photoresist has been stripped from the wafer.

One problem with the prior art method shown in Figure 1 is that it provides no means of detecting if all of the photoresist has been stripped from the wafer. Even if the photoresist has not been completely stripped from the wafer, the prior art method still stops the stripping process after the predetermined time has elapsed. In such a case, the presence of photoresist on the wafer will not be discovered until later, and the wafer will either have to be put through the photoresist stripping process again or discarded. Either alternative adds expense and time to the fabrication of the integrated circuit. Another problem with the prior art method shown in Figure 1 is that the time of the photoresist stripping process is predetermined. As such, the time may not be optimally efficient. The time may be too short, in which case some or all of the wafers fail to be completely stripped of photoresist, requiring further processing of the wafers. Alternatively, the time may be too long, in which case the process continues after all the photoresist has been stripped from the wafer. This decreases throughput and fabrication efficiency.

It would therefore be desirable to provide a method and apparatus for detecting when essentially all the photoresist has been stripped from a wafer during the photoresist stripping process. Such a method and apparatus would preferably increase wafer fabrication throughput and efficiency.

SUMMARY OF THE INVENTION

Disclosed embodiments provide a method and apparatus for detecting the endpoint for a photoresist stripping process. Preferably, O and NO are introduced into the stripping chamber. When O and NO react, they produce NO_2 and emit light. However, while photoresist remains on the wafer, the O that is introduced mostly reacts with the photoresist and only a small amount of light is emitted from the O + NO reaction. After essentially all the photoresist has been stripped from the wafer, much of the O that would have reacted with the photoresist reacts with the NO instead. Thus, the rate of the O + NO reaction increases and the amount of light produced in the reaction increases. The method and apparatus detects the light emitted from the reaction of O and NO and uses the increase in the light emission levels to detect the endpoint of the photoresist stripping process.

According to a preferred embodiment, the apparatus includes a stripping chamber, a wafer disposed within the stripping chamber, and a light detecting apparatus for monitoring the intensity of light emitted within the stripping chamber. The light detecting apparatus detects the intensity of light emitted from the reaction of O and NO to form NO_2.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed embodiments will be better understood when consideration is given to the following detailed description in conjunction with the accompanying drawings, with like reference numerals designating like elements.

Figure 1 is a flow chart of a prior art method for stripping photoresist.

Figure 2 is a flow chart of a method for stripping photoresist.

Figure 3 is a flow chart showing the process of photoresist stripping according to an embodiment of the present invention.

Figure 4 is a schematic view of a first embodiment.

Figure 5 is a schematic view of a second embodiment.

Figure 6 is a schematic view of a third embodiment.

Figure 7 is a graph showing the intensity of light detected from the reaction of O and NO.

DETAILED DESCRIPTION OF THE PREFERED EMBODIMENTS

Figure 2 shows a flow chart depicting the major steps of a method **200** for detecting the endpoint of a photoresist stripping process. In an initial step **202**, the photoresist stripping process begins. The photoresist stripping process is detailed further in Figure 3 and its accompanying description.

In a step **204**, an increase in emitted light is detected. Preferably, the light is emitted from the reaction of O and NO to form NO_2. Suitable choice of an apparatus to detect the increase in emitted light, and suitable placement of the apparatus to detect the increase in emitted light are well within the capabilities of those skilled in the art of wafer processing. The increase in emitted light signals the endpoint of the photoresist stripping process.

The photoresist stripping process continues for a predetermined time in a step **206**. In a preferred embodiment, the predetermined time is twenty seconds. While the increase in light emitted signals that substantially all of the photoresist has been stripped from the wafer, the extra time for the photoresist stripping process ensures that the wafer has been sufficiently stripped of photoresist.

Finally, in a step **208**, the photoresist stripping process is ended. The photoresist has been stripped from the wafer and the wafer is ready for further processing.

Figure 3 shows a flow chart depicting the photoresist stripping process **300** of a preferred embodiment. The photoresist stripping process **300** begins in a step **302**. As the process **300** begins, O and NO are introduced into the stripping chamber in a step **304**. In other embodiments, NO is not introduced into the chamber, but is introduced downstream from the stripping chamber outlet, into a flow of gas coming from the stripping chamber. In a preferred embodiment, the O and NO are produced by introducing O_2 and N_2 into a plasma chamber, dissociating the O_2 and N_2 within the plasma chamber so that a flow of O and NO forms and enters the stripping chamber, in such a manner that substantially no plasma enters the stripping chamber.

In a step **306**, the photoresist is stripped from a wafer. This occurs by a reaction of O with the photoresist, which removes the photoresist from the wafer. While the photoresist stripping occurs, most of the O introduced into the stripping chamber is consumed by the reaction with the photoresist. Only a small amount is available to combine with NO to create NO_2 and emit light. Thus, only a small amount of light is emitted.

In a step **308**, the photoresist stripping is completed. At this point substantially all of the photoresist has been removed from the wafer. Since the photoresist has been removed, the O no longer primarily reacts with the photoresist. As seen in a step **310**, the O is now available to combine with NO to create NO_2 and emit light. The increased availability of O increases the reaction of O and NO to create NO_2 and light. Thus, the intensity of emitted light increases. This increase in emitted light is a visible signal, as seen in a step **312**. The signal is observed and used to signal the endpoint of the photoresist stripping process in a step **314**.

Figure 4 is a schematic view of a first embodiment of an apparatus **10**. A plasma chamber **12** comprises an inlet **14** and an outlet **16**. In a preferred embodiment, a flow of O_2 and N_2 enters the plasma chamber **12** through the plasma chamber inlet **14**. Within the plasma chamber **12**, the O_2 and N_2 are dissociated so that NO and O are formed. The flow of NO and O exits the plasma chamber **12** through the plasma chamber outlet **16**. A stripping chamber **18** comprises an inlet **20** and an outlet **22**. The plasma chamber outlet **16** is in fluid communication with the stripping chamber inlet **20**. Thus, the flow of NO and O enters the stripping chamber **18** as it leaves the plasma chamber **12**. Substantially no plasma enters the stripping chamber **18** from the plasma chamber **12**, only uncharged gas.

A wafer **24**, at least partially coated with a layer of photoresist **26**, is disposed inside the stripping chamber **18**. As the flow of O and NO passes through the stripping chamber **18**, the O reacts with the layer of photoresist **26** and removes the layer of photoresist **26** from the wafer **24**. Inside the stripping chamber **18**, O reacts with NO to form NO_2 and emit light. However, while the layer of photoresist **26** remains on the wafer **24**, much of the O is consumed by reacting with the layer of photoresist **26**. Little O is left over to react with NO, so little light is emitted. When the layer of photoresist **26** is substantially entirely removed from the wafer **24**, the O is no longer consumed by a reaction with the layer of photoresist **26**. The O now reacts with NO. More O reacts with NO after the layer of photoresist **26** is removed, so more light is emitted from the reaction of O and NO to form NO_2. Therefore, the amount of emitted light increases after the layer of photoresist **26** has been essentially entirely removed.

A detecting apparatus **28** detects the level of light emitted by the reaction of O and NO to form NO_2 and emit light. In a preferred embodiment, the detecting apparatus **28** detects the light through a window **30**. However, there are many ways to arrange the detecting apparatus **28** so that it can detect the emitted light. In a preferred embodiment, the light emissions from the reaction of O and NO to form NO_2 are summed over the wavelength range of 470-770 nm while detecting intensity levels.

Figure 5 is a schematic view of a second embodiment of the apparatus **10**. In this embodiment, a flow of O_2 enters the plasma chamber **12** through the plasma chamber inlet **14**. Within the plasma chamber **12**, the O_2 is dissociated so that O is formed. The flow of O exits the plasma chamber **12** through the plasma chamber outlet **16**. The flow of O enters the stripping chamber **18** as it leaves the plasma chamber **12**. Substantially no plasma enters the stripping chamber **18** from the plasma chamber **12**, only uncharged gas. A separate input **40** to the stripping chamber **18** is provided to supply a flow of NO to the stripping chamber **18**.

In the embodiment shown in Figure 5, the window **30** and detecting apparatus **28** are placed close to the NO input, to aid detection of the light emitted in the reaction of O and NO. The detecting apparatus **28** detects the intensity of light emitted by the reaction of O and NO to form NO_2, just as in the embodiment shown in Figure 4.

Figure 6 is a schematic view of a third embodiment of the apparatus **10**. In this embodiment, the reaction of NO and O to produce NO_2 and light does not occur within the stripping chamber **18**. In this embodiment, a flow of O_2 enters the plasma chamber **12** and is dissociated so that a flow of O enters the stripping chamber **18**, while substantially no plasma enters the stripping chamber **18**. Substantially no NO exists in the stripping chamber **18**, so the level of light emitted inside the stripping chamber **18** from the reaction of O and NO to form NO_2 is essentially zero. As a flow of O leaves the stripping chamber **18** through the stripping chamber outlet **22**, it enters a downstream channel **60**. A flow of NO in introduced into the downstream channel **60** through an inlet **62** into the downstream channel **60**. In the downstream channel **60**, the flow of NO and the flow of O react to produce NO_2 and light. This light in the downstream channel **60** is detected by the detecting apparatus **28**. Preferably, the detecting apparatus detects the light through a window **30** in the downstream channel **60**, although there are many ways to arrange the detecting apparatus to detect the emitted light. The window **30** and detecting apparatus **28** are preferably located close to the inlet **60** into the downstream channel **60** to aid in detecting the light emitted in the reaction of O and NO.

Figure 7 is a graph **70** showing the intensity of light detected from the reaction of O and NO during a preferred embodiment of the photoresist stripping process. The intensity levels on the graph **70** represent the summation of the intensity of light over the range of 470-770 nm. At a first time **72**, the photoresist stripping process has not begun and the light detected is at a low level. At a time **74**, the photoresist stripping process begins, and a flow of O and NO enters the stripping chamber. Some of the O and NO reacts to form NO_2 and emit light. As can be seen in the graph **70**, the intensity of light detected increases after O and NO enter the chamber at a time **74** until the intensity reaches a higher level at a time **76**. From a time **76** to a later time **78**, much

of the O reacts with the photoresist, and is not available to react with NO. At a time **78**, substantially no photoresist remains on the wafer, and the O is now free to react with the NO. Thus from a time **78** to a later time **80**, the intensity of light detected greatly increases, more than doubling in intensity. This increase signals the endpoint of the photoresist stripping at a time **80**. The photoresist stripping process and the flow of NO and O continues until a time **82** to ensure essentially all the photoresist has been stripped from the wafer. At a time **82**, the flow of O and NO into the stripping chamber ends, and the intensity of light detected returns to a low level.

Although only a few embodiments have been described in detail herein, it should be understood that the described method and apparatus may be embodied in many other specific forms without departing from the spirit or scope of the invention. Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive, and the method and apparatus are not to be limited to the details given herein, but may be modified within the scope of the appended claims.

CLAIMS

1. A method for detecting an endpoint of a photoresist stripping process comprising the steps of:

stripping photoresist from a wafer disposed inside a chamber, wherein the chamber contains substantially no plasma;

detecting an intensity of light emitted; and

using a change in the intensity of light emitted to detect the endpoint of the photoresist stripping process.

2. The method of claim 1, further comprising the step of introducing a flow of O and a flow of NO into the chamber.

3. The method of claim 2 wherein the emitted light is emitted in a reaction of NO and O to form NO_2.

4. The method of claim 2, wherein the O reacts with the photoresist to strip the photoresist from the wafer.

5. The method of claim 2 wherein the step of detecting a change in the intensity of light emitted further comprises detecting an increase in the intensity of light emitted from a reaction of NO and O.

6. The method of claim 5, wherein the increase in intensity of the light emitted from the reaction of NO and O signals the endpoint of the photoresist stripping process.

7. The method of claim 5, wherein the emitted light detected is in the wavelength range of about 470 nm to about 770 nm.

8. The method of claim 5, wherein a wall of the chamber includes a window, the intensity of the light emitted being detected through the window by a light detecting apparatus.

9. The method of claim 1, further comprising the steps of:

introducing a flow of O into the chamber;

providing an outlet from the chamber;

providing a downstream channel, the downstream channel being in fluid communication with the chamber outlet;

introducing a flow of NO into the downstream channel;

detecting an increase in intensity of the light emitted from a reaction of NO and O, wherein the increase in intensity of the light emitted from the reaction of NO and O signals the endpoint of the photoresist stripping process.

10. The method of claim 9, wherein a wall of the downstream channel includes a window, the intensity of the light emitted being detected through the window by a light detecting apparatus.

11. An apparatus for detecting an endpoint of a photoresist stripping process for stripping photoresist from a wafer, comprising:

a stripping chamber in which the stripping process is performed by reacting O with the photoresist, the stripping chamber having an inlet and an outlet;

a plasma chamber having an inlet and an outlet, the plasma chamber outlet being in fluid communication with the stripping chamber inlet, the plasma chamber being effective to dissociate O_2 into O, the O leaving the plasma chamber through the plasma chamber outlet and entering the stripping chamber through the stripping chamber inlet;

a downstream channel in fluid communication with the stripping chamber outlet to receive O that was not reacted with the photoresist;

an NO supply for introducing NO into the downstream channel so that when substantially all of the photoresist is removed from the wafer a rate of reaction of O with NO to form NO_2 increases with an accompanying increase in an intensity of light emitted from the reaction of O with NO to form NO_2; and

a detecting apparatus for detecting the intensity of light emitted from the reaction of O with NO to indicate the endpoint.

12. The apparatus as recited by claim 11, further comprising a window in a wall of the downstream channel, the detecting apparatus being outside the downstream channel and detecting the light intensity through the window.