

PRECLEANING CHAMBER AND PLASMA PROCESSING APPARATUS

Field of the Invention

The present invention relates to the field of semiconductor device manufacture, and specifically relates to a precleaning chamber and a plasma processing apparatus.

Background of the Invention

Plasma processing apparatuses are widely applied in current manufacturing process of semiconductor integrated circuits, solar cells, flat panel displays and the like. The types of plasma processing apparatuses that have been widely used in the industry include, for example, DC discharge plasma, capacitively coupled plasma (CCP), inductively coupled plasma (ICP) and electron cyclotron resonance (ECR) plasma, and these types of plasma processing apparatuses are currently used in processes such as depositing, etching and cleaning.

In a process, in order to improve product quality, a wafer is precleaned before performing a deposition process to remove foreign matters such as an oxide on a surface of the wafer. Generally, the basic principle of a precleaning chamber is that a cleaning gas, such as argon, helium or hydrogen, which is introduced into the cleaning chamber, is excited to form plasma to chemically react with and physically bombard the wafer so that foreign matters on the surface of the wafer can be removed.

Fig. 1 is a structural schematic view of an existing precleaning chamber. Fig. 2 is an enlarged partial view of Fig. 1. Referring to both Figs. 1 and 2, the precleaning chamber is formed by a cavity 8 and a dielectric window 4 disposed at a top of the cavity 8. A base 1 for carrying a wafer 2 is provided in the precleaning chamber and is connected to a first RF power supply 12 via a first adapter 11; the dielectric window 4 is an arched top cover made of an insulating material (e.g., ceramic or quartz), a coil 5 is provided above the dielectric window 4, and the coil 5 is a solenoid coil and connected to a second RF power supply 6 via a second adapter 3. Moreover, in the precleaning chamber, a process assembly 7 is provided surrounding the base 1, the process assembly 7, the base 1 and the dielectric window 4 together form a process

cavity 41, and a space of the cavity 8 formed below the base 1 is used as a loading/unloading cavity; and, as shown in Fig. 2, the process assembly 7 forms an inlet/outlet passage with a maze structure for the process gas in the loading/unloading cavity to get in/out of the process cavity 41. Moreover, an inlet line 9 is further provided on the cavity 8 for transporting a process gas into the loading/unloading cavity. A flowing direction of the process gas is represented by the arrows in Fig. 1, the process gas enters into the loading/unloading cavity through the inlet line 9, and then enters into the process cavity 41 to be excited into plasma after diffusing upwards and being homogenized through the maze structure formed by the process assembly 7. The process gas after reaction enters into the loading/unloading cavity after passing through the process assembly 7 and is pumped out by a vacuum pump 10.

In practical application, the above precleaning chamber inevitably has the following problems:

firstly, the path along which the process gas enters into the process cavity 41 is too long, so that it takes a relatively long time to reach the process cavity 41, thereby affecting process efficiency;

secondly, since an air pressure within the process cavity 41 is greater than an air pressure in the vicinity of a pumping hole of the vacuum pump 10, and the vacuum pump 10 keeps in operation during the process, most of the process gas is directly pumped out by the vacuum pump 10 before entering into the process cavity 41, thus it is required to replenish a great amount of process gas continuously via the inlet line 9 to keep the plasma in an excited state and maintain a desired plasma density, thereby causing a waste of the process gas.

Summary of the Invention

The present invention aims to solve at least one of the technical problems in the prior art and provides a precleaning chamber and a plasma processing apparatus which may not only shorten an entering path of a process gas, but also reach a desired plasma density with less process gas introduced, thereby reducing the usage cost.

The present invention provides a precleaning chamber comprising a cavity and a dielectric window disposed at a top of the cavity, wherein a base and a process assembly surrounding the base are provided in the precleaning chamber, the base, the process assembly and the dielectric window together form a process sub-cavity above the base, and a space of the cavity located below the base is used as a loading/unloading sub-cavity; the precleaning chamber further comprises an inlet device including an inlet for directly transporting a process gas into the process sub-cavity from above the process assembly.

Preferably, the inlet device further comprises an annular flow homogenizing cavity in communication with the inlet, and in communication with the process sub-cavity via a plurality of outlets that are uniformly distributed in a circumferential direction of the process sub-cavity.

Preferably, the inlet device comprises: an inlet ring located between and respectively hermetically connected to the dielectric window and the cavity; wherein at least one first through hole used as the inlet is formed on an inner circumferential wall of the inlet ring and penetrates through the inner circumferential wall in a radial direction thereof; and a flow homogenizing ring located at an inner side of the inlet ring and forming an annular space used as the annular flow homogenizing cavity together with the inner circumferential wall of the inlet ring; wherein an annular flow homogenizing unit is formed at a top of the flow homogenizing ring, and comprises a plurality of second through holes uniformly distributed in the circumferential direction of the process sub-cavity, and the second through holes are respectively in communication with the annular space and the process sub-cavity, and used as the outlets.

Preferably, the inlet comprises one central inlet disposed at a central position of the dielectric window.

Preferably, the inlet comprises at least two top inlets that are uniformly distributed at different positions on the dielectric window.

Preferably, the precleaning chamber further comprises a filter plate that partitions the process sub-cavity into an upper sub-space in communication with the inlet and a

lower sub-space; a plurality of vent holes are distributed on the filter plate and are respectively in communication with the upper sub-space and the lower sub-space so that while a plasma formed in the upper sub-space passes through the vent holes, ions in the plasma are filtered.

Preferably, the process assembly comprises an upper ring body and a lower ring body, the upper ring body is located at an inner side of the lower ring body, and an annular gap is formed between an outer circumferential wall of the upper ring body and an inner circumferential wall of the lower ring body; a plurality of third through holes, which are uniformly distributed in the circumferential direction of the process sub-cavity, are disposed on the inner circumferential wall of the lower ring body and above a lower end of the upper ring body; the annular gap and each of the third through holes form an exhaust port for discharging gas in the process sub-cavity into the loading/unloading sub-cavity.

Preferably, the dielectric window has an arched structure or a barrel structure.

Preferably, a Faraday shield member made of a metal material or an insulating material plated with a conductive material is disposed around an inner side the dielectric window; and the Faraday shield member is provided with at least one slit in an axial direction thereof.

As another technical solution, the present invention further provides a plasma processing apparatus comprising the precleaning chamber provided in the present invention.

The present invention has the beneficial effects as follows.

The precleaning chamber provided in the present invention can, by directly transporting the process gas from above the process assembly into the process sub-cavity through the inlet of the inlet device, shorten the entering path of the process gas and reduce the time required for the process gas to reach the plasma generation area to thus improve the process efficiency, and can also enable all of the process gas from the inlet to enter into the process sub-cavity, so that a case in the prior art where part of the process gas is directly pumped out without reaction is avoided to thus reach a higher plasma density with less process gas introduced,

thereby reducing the usage cost.

The plasma processing apparatus provided in the present invention can, by adopting the precleaning chamber provided in the present invention, not only shorten the entering path of the process gas, but also reach a desired plasma density with less process gas introduced, thereby reducing the usage cost.

Brief Description of the Drawings

Fig. 1 is a structural schematic view of an existing precleaning chamber;

Fig. 2 is an enlarged partial view of Fig. 1;

Fig. 3A is a cross-sectional view of a precleaning chamber provided in a first embodiment of the invention;

Fig. 3B is an enlarged view of an area I in Fig. 3A;

Fig. 3C is a partial cross-sectional view of a process assembly used in an embodiment of the invention;

Fig. 3D is a cross-sectional view of a lower ring body of a process assembly used in an embodiment of the invention;

Fig. 4 is a top view of a flow homogenizing ring used in an embodiment of the invention;

Fig. 5 is a cross-sectional view of a flow homogenizing ring used in an embodiment of the invention;

Fig. 6 is a cross-sectional view of a precleaning chamber provided in a second embodiment of the invention; and

Fig. 7 is a cross-sectional view of a precleaning chamber provided in a third embodiment of the invention.

Detailed Description of the Embodiments

To enable those skilled in the art to better understand the technical solutions of the present invention, the precleaning chamber and the plasma processing apparatus provided by the invention will be described in detail below in conjunction with the accompanying drawings.

Fig. 3A is a cross-sectional view of a precleaning chamber provided in a first embodiment of the invention. Fig. 3B is an enlarged view of an area I in Fig. 3A. Referring to both Figs. 3A and 3B, the precleaning chamber 100 is formed by a cavity 20 and a dielectric window 21 disposed at a top of the cavity 20. A base 22 for carrying a wafer 23 is provided in the precleaning chamber 100 and is connected to a first RF power supply 30 via a first adapter 29; the dielectric window 21 is an arched top cover made of an insulating material (e.g., ceramic or quartz), a coil 26 is provided above the dielectric window 21, and the coil 26 is a solenoid coil and connected to a second RF power supply 28 via a second adapter 27. Moreover, in the precleaning chamber 100, a process assembly 24 is provided surrounding the base 22, and when the base 22 is at a process position, the process assembly 24, the base 22 and the dielectric window 21 together form a process sub-cavity 211 above an upper surface of the base 22, while the cavity 20 and the base 22 together form a loading/unloading sub-cavity 202 below the upper surface of the base 22.

The precleaning chamber 100 further comprises an inlet device 32 including an inlet for directly transporting a process gas into the process sub-cavity 211 from above the process assembly 24. The process gas usually includes Ar, H₂, He or the like. During a precleaning process, a flowing direction of the process gas entering into the process sub-cavity 211 through the inlet is represented by the arrows in Fig. 3A, the process gas diffuses upwards and towards the center from the periphery of the process sub-cavity 211. The second RF power supply 28 and the first RF power supply 30 are turned on at the same time to excite the process gas within the process sub-cavity 211 into plasma, the plasma diffuses towards the base 22 at a bottom of the process sub-cavity 211, and is attracted to bombard foreign matters on the wafer 23 under the action of an RF self-bias voltage generated by the wafer 23, thereby realizing precleaning of the wafer 23.

By transporting the process gas directly from above the process assembly 24 into the process sub-cavity 211 through the inlet of the inlet device 32, it can not only shorten the entering path of the process gas and reduce the time required for the process gas to reach the plasma generation area to thus improve the process efficiency,

but also enable all of the process gas from the inlet to enter into the process sub-cavity to avoid a case in the prior art where part of the process gas is directly pumped out without reaction to thus obtain a higher plasma density with less process gas introduced, thereby reducing the usage amount of the process gas as well as the process cost.

A structure of the inlet device 32 will be described below in detail. Specifically, as shown in Fig. 3B, the inlet device 32 comprises an inlet ring 321 and a flow homogenizing ring 322. The inlet ring 321 is located between and respectively hermetically connected to the dielectric window 21 and the cavity 20. Moreover, at least one first through hole 323 is formed on a side wall of the inlet ring 321 and penetrates through the side wall in a radial direction thereof. The first through hole 323 is used as the inlet and connected to an inlet line 33. The flow homogenizing ring 322 is located at an inner side of the inlet ring 321 and forms an annular space 324 together with an inner circumferential wall of the inlet ring 321. The annular space 324 is used as an annular flow homogenizing cavity with a flow homogenizing function and is in communication with the first through hole 323. Moreover, a specific structure of the flow homogenizing ring 322 is as shown in Figs. 4 and 5, an annular flow homogenizing unit is formed at a top of the flow homogenizing ring 322, and comprises a plurality of second through holes 3221 uniformly distributed in a circumferential direction of the process sub-cavity 211. The second through holes 3221 are respectively in communication with the annular space 324 and the process sub-cavity 211 and are used as the outlets of the annular flow homogenizing cavity. Moreover, the flow homogenizing ring 322 is further provided on an inner side thereof a plurality of mounting holes 3222 that are uniformly distributed in the circumferential direction of the process sub-cavity 211, so as to fixedly connect the flow homogenizing ring 322 to the cavity 20 by mounting a fastening member such as a bolt. During a precleaning process, the flowing direction of the process gas entering the process sub-cavity 211 from the inlet line 33 is represented by the arrows in Fig. 3B, the process gas enters into the annular space 324 through the first through hole 323, diffuses around until the annular space 324 is filled, and then uniformly flows

into the process sub-cavity 211 through each of the plurality of second through holes 3221.

It is easy to understand that by disposing the second through holes 3221 at the top of the annular space 324, the process gas flowing out of the second through holes 3221 is able to diffuse towards an upper portion of the process sub-cavity 211 to be excited into plasma at the upper portion of the process sub-cavity 211 and diffuse towards the base 22. Obviously, the present invention is not limited thereto. In practical application, the second through holes 3221 may also be disposed on an inner side of the annular space 324, i.e., being disposed on a vertical side wall of the flow homogenizing ring 322. Actually, as long as the second through holes 3221 are disposed above the process assembly 24, the process gas can be directly transported into the process sub-cavity 211, and thus the objective of the invention can be achieved.

In this embodiment, as shown in Figs. 3B-3D, the process assembly 24 is disposed surrounding the base 22 to form the process sub-cavity 211 above the base 22 together with the base 22 and the dielectric window 21. Specifically, the base 22 is liftable, it may be moved up to a process position to process the wafer 23 placed thereon, or moved down to a loading/unloading position in the loading/unloading sub-cavity 202 to take away or place a wafer with a manipulator. When the base 22 is at the process position, the wafer 23 is mechanically fixed on the base 22 by using a press ring 25, and at this point, the press ring 25 is in contact with a marginal area of an upper surface of the wafer 23 so that the process sub-cavity 211 is closed. When the base 22 leaves the process position, the press ring 25 is separated from the marginal area of the wafer 23 and is carried by the process assembly 24.

Further, as shown in Fig. 3C, the process assembly 24 comprises an upper ring body 242 and a lower ring body 241, wherein a cross-sectional view of the side wall of the upper ring body 242 taken along a plane where an axis thereof is located is in an inverted L shape; and a cross-sectional view of the side wall of the lower ring body 241 taken along a plane where an axis thereof is located is in a hook shape, which may also be seen as an L and an inverted L spliced together, wherein an end (the

rightmost end) of the horizontal stroke of L is connected with an end (the lower most end) of the vertical stroke of the inverted L. A vertical portion of the upper ring body 242 is at an inner side of a vertical portion of the lower ring body 241 (hereinafter abbreviated as "the upper ring body 242 is at an inner side of the lower ring body 241"), and an annular gap 244 is formed between an outer circumferential wall of the vertical portion of the upper ring body 242 (hereinafter abbreviated as "outer circumferential wall of the upper ring body") and an inner circumferential wall of the vertical portion of the lower ring body 241 (hereinafter abbreviated as "inner circumferential wall of the lower ring body"). Moreover, a plurality of third through holes 243, which are uniformly distributed in the circumferential direction of the process sub-cavity 211, are disposed on the inner circumferential wall of the lower ring body 241 and above a lower end of the upper ring body 242, as shown in Fig. 3D. The annular gap 244 and the third through holes 243 form an exhaust port for discharging gas in the process sub-cavity 211 into the loading/unloading sub-cavity 202. During the precleaning process, a discharging direction of the process gas after reaction is represented by the arrows in Fig. 3C, the process gas after reaction passes through the annular gap 244 and each of the third through holes 243 successively to be discharged into the loading/unloading sub-cavity 202, and then is pumped out by a vacuum pump 31 from an exhaust port 201 at the bottom of the cavity 20. It is easy to understand that the maze structure of the annular gap 244 is helpful for improving the gas flow stability within the process sub-cavity 211.

It should be noted that in practical application, the annular flow homogenizing cavity may be omitted, instead, a plurality of first through holes serving as inlets are provided in the circumferential direction of the process sub-cavity and are in direct communication with the process sub-cavity to uniformly transport the process gas from the periphery to the center of the process sub-cavity.

It should be further noted that although the dielectric window 21 has an arched structure in this embodiment, the present invention is not limited thereto. In practical application, the dielectric window may have any other structure such as a barrel structure according to specific requirements. In addition, a Faraday shield member

made of a metal material or an insulating material plated with a conductive material is preferably disposed around an inner side the dielectric window. With the Faraday shield member, it can not only shield an electromagnetic field to reduce erosion to the process sub-cavity by the plasma, so as to prolong service life of the process sub-cavity, but also facilitate cleaning of the chamber to reduce the usage cost of the chamber. In addition, the Faraday shield member is provided with at least one slit in an axial direction thereof, i.e., the Faraday shield member is completely cut off at the slit and is a discontinuous barrel structure so as to effectively prevent eddy current loss and heat generation of the Faraday shield member.

Fig. 6 is a cross-sectional view of the precleaning chamber provided by a second embodiment of the invention. Referring to Fig. 6, the precleaning chamber 200 provided in this embodiment merely differs from that of the first embodiment in that the precleaning chamber 200 further comprises a filter plate 34. Specifically, the filter plate 34 is made of an insulating material or a metal plated with an insulating material such as ceramic or quartz. Moreover, the filter plate 34 partitions the process sub-cavity 211 into an upper sub-space 2111 and a lower sub-space 2112. The inlet of the inlet device 32 is in communication with the upper sub-space 2111 for directly transporting the process gas into the upper sub-space 2111. Further, a plurality of vent holes 341 are distributed on the filter plate 34 and are in communication with the upper sub-space 2111 and the lower sub-space 2112 respectively so that while a plasma formed in the upper sub-space 2111 passes through the vent holes, ions in the plasma are filtered. Since spaces in the vent holes 341 are narrow and small, when the plasma passes through the vent holes 341, chances for the ions in the plasma to contact charged particles such as electrons are greatly increased, so that the ions can easily capture charged particles such as electrons and be converted into forms such as atoms. In this way, the plasma passing through the vent holes 341 includes no ions, but only free radicals, atoms, molecules and the like, and these free radicals, atoms and molecules continue to diffuse downwards after entering into the lower sub-space 2112 until reaching a surface of the wafer 23 placed on the base 22 to etch. Thus, with the filter plate 34, a function of "filtering" the ions in the plasma can be achieved, so

that the material on the wafer 23 is prevented from being adversely affected by the ions in the plasma, thereby improving performance of the product. In practical application, a size of the vent hole 341 may be designed in an experimental manner as long as it can achieve a function of filtering ions.

In addition, the plurality of vent holes 341 may be uniformly distributed with respect to a plane where the filter plate 34 is located, or a local distribution density of the vent holes 341 may be appropriately adjusted in accordance with the process deviation among individual areas of the surface of the wafer 23 to change plasma densities corresponding to respective areas of the surface of the wafer 23, thereby improving process uniformity.

It should be noted that although there is only one filter plate 34 in this embodiment, but the present invention is not limited thereto. In practical application, there may be two or three or more filter plates arranged in a vertical direction at intervals to perform filtration and gas homogenization on the plasma for multiple times. It is easy to understand that the sub-space above the topmost filter plate is the plasma generation area, and the inlet of the inlet device should directly deliver the process gas towards the sub-space.

Fig. 7 is a cross-sectional view of a precleaning chamber provided in a third embodiment of the invention. As shown in Fig. 7, the precleaning chamber 300 provided in this embodiment merely differs from those of the first and second embodiments in that the inlet device is at a different position with respect to the process sub-cavity. Specifically, the inlet of the inlet device 32' comprises one central inlet 212 disposed at a central position of the dielectric window 21' and connected to the inlet line 33 so that gas may directly enter from the central position at the top of the process sub-cavity 211, which can not only make the gas flow smoother, but also obtain a more stable process effect.

It should be noted that in practical application, the inlet of the inlet device may also comprise at least two top inlets that are uniformly distributed at different positions on the dielectric window. With the plurality of top inlets, gas is introduced simultaneously from different positions on the top of the process sub-cavity 211,

which can achieve partitioned air admission, thereby improving the gas distribution uniformity in the process sub-cavity 211.

It should be further noted that the base 22 comprises an electrostatic chuck or a mechanical chuck for carrying the wafer 23 in each of the above embodiments. Moreover, the base 22 may be further provided with a heater for controlling a temperature of the wafer 23 according to specific requirements.

As another technical solution, an embodiment of the present invention further provides a plasma processing apparatus comprising the precleaning chamber provided in any one of the above embodiments of the invention.

The plasma processing apparatus provided in the embodiment of the invention can, by adopting the precleaning chamber provided in any one of the above embodiments of the invention, not only shorten the entering path of the process gas, but also obtain a desired plasma density with less process gas introduced, thereby reducing the usage amount of the process gas as well as the process cost.

It should be understood that the above implementations are merely exemplary implementations for the purpose of illustrating the principle of the invention, and the invention is not limited thereto. Various modifications and improvements can be made by a person having ordinary skill in the art without departing from the spirit and essence of the invention, and these modifications and improvements also fall into the protection scope of the invention.

Claims

1. A precleaning chamber, comprising a cavity and a dielectric window disposed at a top of the cavity, wherein a base and a process assembly surrounding the base are provided in the precleaning chamber, the base, the process assembly and the dielectric window together form a process sub-cavity above the base, and a space of the cavity located below the base is used as a loading/unloading sub-cavity; the precleaning chamber further comprises an inlet device including an inlet, characterized in that

the inlet is used for directly transporting a process gas into the process sub-cavity from above the process assembly, and the inlet device enables the process gas to diffuse upwards and towards the center from the periphery of the process sub-cavity.

2. The precleaning chamber according to claim 1, characterized in that the inlet device further comprises an annular flow homogenizing cavity,

the annular flow homogenizing cavity is in communication with the inlet, and in communication with the process sub-cavity via a plurality of outlets that are uniformly distributed in a circumferential direction of the process sub-cavity.

3. The precleaning chamber according to claim 2, characterized in that the inlet device comprises:

an inlet ring, which is located between and respectively hermetically connected to the dielectric window and the cavity; wherein at least one first through hole used as the inlet is formed on an inner circumferential wall of the inlet ring and penetrates through the inner circumferential wall in a radial direction of the inlet ring; and

a flow homogenizing ring, which is located at an inner side of the inlet ring and forms an annular space used as the annular flow homogenizing cavity together with the inner circumferential wall of the inlet ring; wherein an annular flow homogenizing unit is formed at a top of the flow homogenizing ring, and comprises a plurality of second through holes uniformly distributed in the circumferential direction of the process sub-cavity, and the second through holes are respectively in communication with the annular space and the process sub-cavity and used as the outlets.

4. The precleaning chamber according to claim 1, characterized in that the inlet comprises one central inlet disposed at a central position of the dielectric window.

5. The precleaning chamber according to claim 1, characterized in that the inlet comprises at least two top inlets that are uniformly distributed at different positions on the dielectric window.

6. The precleaning chamber according to any one of claims 1 to 5, characterized in that the precleaning chamber further comprises a filter plate that partitions the process sub-cavity into an upper sub-space in communication with the inlet and a lower sub-space; and

a plurality of vent holes are distributed on the filter plate and are respectively in communication with the upper sub-space and the lower sub-space so that while a plasma formed in the upper sub-space passes through the vent holes, ions in the plasma are filtered.

7. The precleaning chamber according to any one of claims 1 to 5, characterized in that the process assembly comprises an upper ring body and a lower ring body, wherein the upper ring body is located at an inner side of the lower ring body, and an annular gap is formed between an outer circumferential wall of the upper ring body and an inner circumferential wall of the lower ring body; and

a plurality of third through holes, which are uniformly distributed in the circumferential direction of the process sub-cavity, are disposed on the inner circumferential wall of the lower ring body and above a lower end of the upper ring body; the annular gap and each of the third through holes form an exhaust port for discharging gas in the process sub-cavity into the loading/unloading sub-cavity.

8. The precleaning chamber according to any one of claims 1 to 5, characterized in that the dielectric window has an arched structure or a barrel structure.

9. The precleaning chamber according to any one of claims 1 to 5, characterized in that a Faraday shield member made of a metal material or an insulating material plated with a conductive material is disposed around an inner side of the dielectric window; and

the Faraday shield is provided with at least one slit in an axial direction thereof.

10. A plasma processing apparatus comprising a precleaning chamber, characterized in that the precleaning chamber is the precleaning chamber according to any one of claims 1 to 9.