

REACTION CHAMBER AND PLASMA PROCESSING APPARATUS

Field of the Invention

The present invention relates to the field of semiconductor apparatus fabrication, and particularly relates to a reaction chamber and a plasma processing apparatus.

Background of the Invention

TSV (Through Silicon Vias) interconnection technology is widely used in processes such as 3D stacked package, MEMS (Micro-electromechanical Systems) package, and the like. In the TSV process, in order to achieve relatively high etching selectivity and etching rate, a remote high density plasma (hereinafter referred to as a remote HDP) source is generally adopted, that is, a wafer is positioned downstream of plasma and keeps a relatively large distance from a coil for generating plasma, so that an area where the wafer is positioned has high free radical concentration but low ion density, which can reduce loss of a mask layer due to ion bombardment, thereby achieving both high etching rate and decent etching selectivity.

Fig. 1 is a schematic diagram of an existing reaction chamber. As shown in Fig. 1, the reaction chamber 1 includes an electrostatic chuck 2, a dielectric window 3, a coil 4, a first power supply 5 and a second power supply 6. The electrostatic chuck 2 is provided at the bottom region in the reaction chamber 1, and is used for holding a wafer. The dielectric window 3 is positioned vertically above the electrostatic chuck 2 and keeps a relatively large distance from the electrostatic chuck 2. The coil 4 is wound around the dielectric window 3 at an outer side thereof, and is electrically connected to the first power supply 5; the first power supply 5 supplies power to the coil 4, so that the coil generates an electromagnetic field in the reaction chamber 1, which excites process gas introduced into the reaction chamber 1 into plasma. The second power supply 6 is electrically connected to the electrostatic chuck 2, and is used for supplying power to the electrostatic chuck 2 to generate a bias voltage on the electrostatic chuck 2, so as to attract the plasma to bombard the wafer placed on the electrostatic chuck 2, so that a physical reaction and/or a chemical reaction happens

between the plasma and the wafer, thereby implementing an etching process on the wafer.

In the above reaction chamber 1, because both inductive coupling and capacitive coupling exist between the coil 4 and the plasma, and power consumed by the capacitive coupling is generally 50% of that consumed by the inductive coupling, the first power supply 5 needs to supply higher power to the coil 4 to obtain a large density of plasma in the area where the wafer is positioned in the reaction chamber 1, so as to achieve a relatively high etching rate. In this case, because skin current resulted from skin effect increases rapidly and has a direction opposite to that of current in the coil 4, a part of the power supplied to the coil 4 by the first power supply 5 is consumed, which reduces effective power of the coil 4 for generating an electromagnetic field and exciting plasma. In the meanwhile, when the first power supply 5 supplies higher power to the coil 4, strengths of effects such as recombination of active particles in the plasma, ion bombardment on the dielectric window, optical radiation, and the like are enhanced, which results in higher temperature rise of the dielectric window 3, and larger temperature gradient on the dielectric window 3, and thus the dielectric window 3 is more prone to crack.

Summary of the Invention

The present invention is intended to solve at least one of the technical problems existing in the prior art, and provides a reaction chamber having plural sets of coils and a plasma processing apparatus, so that skin current effect caused by a single set of coil can be reduced, further more of the power applied to the coil is allowed to be used for exciting plasma, and ionization rate of process gas is improved; in the meanwhile, uniformity of distribution of plasma is improved macroscopically, as a result, strengths of effects such as recombination of active particles in the plasma, ion bombardment on the dielectric window, optical radiation, and the like are reduced, and further temperature rise and temperature gradient in the dielectric window during the process is reduced, thereby decreasing possibility of the cracking of the dielectric window and prolonging service life of the dielectric window as well.

To achieve the object of the present invention, there is provided a reaction chamber, including a chamber body, a dielectric window and a power supply unit, the dielectric window is provided above the chamber body and is hermetically connected with the chamber body, an outer side of the dielectric window is provided thereon with a plurality of sets of coils arranged at an interval in a vertical direction and wound around the dielectric window, and the power supply unit supplies power to the plurality of sets of coils.

Here, the power supply unit includes a power supply and a matcher, and the plurality of sets of coils are connected to the power supply via the matcher.

Here, the number of the power supply is one; the plurality of sets of coils are connected in parallel and electrically connected to the power supply; and winding directions of the plurality of sets of coils are the same, so that a current in each set of coil has a same direction when the power supply supplies power to the plurality of sets of coils.

Here, the number of the power supplies is plural, the number of the matchers corresponds to the number of the power supplies, and each power supply is electrically connected to one set of coil via one matcher; currents in the plurality of sets of coils have a same direction when the power supplies supply power to the coils.

Here, the number of the power supplies is plural, the number of the matchers corresponds to the number of the power supplies, and each power supply is electrically connected to more than one set of coil via one matcher; for each power supply, a winding direction of the more than one set of coil corresponding thereto is the same, so that a current in each set of coil has a same direction when the power supply supplies power to the more than more set of coil.

Here, the reaction chamber includes a first connection member, a second connection member, a third connection member and a fourth connection member; the first connection member and the second connection member are arranged in a vertical direction, the plurality of sets of coils have first ends connected to the first connection member, and second ends connected to the second connection member, the third connection member have two ends respectively connected to the power supply and the

first connection member; and the fourth connection member has one end connected to the second connection member and the other end grounded.

Here, a position of the first connection member at which the first connection member is connected to the third connection member and a position of the second connection member at which the second connection member is connected to the fourth connection member are set according to currents required by the plurality of sets of coils.

Here, one end of the third connection member is connected to a middle position of the first connection member; and one end of the fourth connection member is connected to a middle position of the second connection member.

Here, the number of turns in each set of coil is plural, and a spacing between two adjacent sets of coils is at least twice as long as that between two adjacent turns of the coil in each set of coil.

As another technical solution, the present invention further provides a plasma processing apparatus, including a reaction chamber, which is the above reaction chamber provided by the present invention.

The present invention has the beneficial effects as follows.

In the reaction chamber provided by the present invention, the outer side of the dielectric window is provided with plural sets of coils, which are arranged at an interval in the vertical direction and wound around the dielectric window, so that process gas is ionized sequentially by electromagnetic fields generated by the plural sets of coils after being introduced into the reaction chamber, moreover, during the process, the generated plasma diffuses in both horizontal direction and vertical direction, so that the plasma is distributed evenly in the reaction chamber, and thus uniformity of the process can be improved; in the meanwhile, by using the plural sets of coils to ionize the process gas for plural times, ionization efficiency of the process can also be improved. In addition, in the reaction chamber provided by the present invention, power for exciting plasma is applied to the plural sets of coils, respectively, so that the power in each set of coil is relatively low, as a result, influence of skin currents in the plural sets of coils can be reduced, and more of the power applied to

the plural sets of coils can be used for exciting plasma, thereby improving effective power applied to the coils; also, strengths of effects such as recombination of active particles in the plasma, ion bombardment on the dielectric window, optical radiation, and the like can be reduced, and temperature rise and temperature gradient of the dielectric window during the process can be lowered, so as to prevent the dielectric window from cracking, and service life of the dielectric window can thus be prolonged.

In the plasma processing apparatus provided by the present invention, by adopting the above reaction chamber provided by the present invention, plasma is distributed evenly in the reaction chamber, and density of plasma in the reaction chamber is improved, thereby improving both uniformity and efficiency of the process; meanwhile, effective power for exciting plasma can be improved, and both temperature rise and temperature gradient of the dielectric window during the process can be lowered, so as to prevent the dielectric window from cracking, and prolong the service life of the dielectric window.

Brief Description of the Drawings

FIG. 1 is a schematic diagram of an existing reaction chamber;

FIG. 2 is a schematic structural diagram of a reaction chamber provided by an embodiment of the present invention;

FIG. 3 is a schematic diagram illustrating connection between coils and a power supply in an embodiment of the present invention;

FIG. 4 is a schematic diagram illustrating arrangement positions of a first connection member, a second connection member, a third connection member and a fourth connection member;

FIG. 5 is a schematic diagram of an upper coil; and

FIG. 6 is a schematic diagram of a lower coil.

Detailed Description of the Embodiments

To enable those skilled in the art to better understand the technical solutions of

the present invention, a reaction chamber and a plasma processing apparatus provided by the present invention will be described in detail below in conjunction with the accompanying drawings.

Referring to Fig. 2, Fig. 2 is a schematic structural diagram of a reaction chamber provided by an embodiment of the present invention. The reaction chamber 10 is used for processing a to-be-processed workpiece 14, and includes a chamber body 100, a cover body 1001, a holding member 11, a dielectric window 12, a coil 15, a gas supply system 20, a power supply unit and a bias power supply 13. The cover body 1001 is provided above the chamber body 100 of the reaction chamber 10, and accommodates the dielectric window 12, the coil 15 and the power supply unit therein. The holding member 11 is provided within the reaction chamber 10 and is used for holding the to-be-processed workpiece 14. The dielectric window 12 is provided on the chamber body 100 of the reaction chamber 10 and provided right above the holding member 11, and is made of an alumina ceramic, quartz, or other non-conductive material. An outer side of the dielectric window 12 is provided thereon with plural sets of coils 15 arranged at a certain interval in a vertical direction and wound around the dielectric window 12. The gas supply system 20 is used for introducing process gas into the reaction chamber 10, and includes an inlet line, and a pneumatic valve (not shown) and a mass flow controller (not shown) both provided on the inlet line, wherein the process gas is introduced into the reaction chamber 10 through the inlet line, the pneumatic valve is used for turning on and turning off the inlet line, and the mass flow controller is used for controlling flow rate of the process gas introduced into the reaction chamber 10. The power supply unit supplies power to the plural sets of coils 15, and includes a power supply 16 and a matcher 17, wherein the power supply 16 is connected to the coils 15, and supplies power to the coils 15, so as to generate an electromagnetic field in the reaction chamber 10 to excite the process gas introduced into the reaction chamber 10 into plasma. The matcher 17 is connected between the power supply 16 and the coils 15, and is used for adjusting load impedance of the power supply 16 such that the load impedance matches output impedance of the power supply 16, thus, power reflection of the power supply 16 is

reduced, and output power of the power supply 16 can be fully applied to the coils 15. The bias power supply 13 is connected to the holding member 11 and is used for supplying a bias power to the holding member 11, so that a bias voltage is generated on the holding member 11 to attract the plasma to react chemically or physically with the to-be-processed workpiece 14 placed on the holding member 11.

In the embodiment, the power supply unit includes one power supply 16, and the plural sets of coils 15 are electrically connected to the power supply 16. Specifically, as shown in Figs. 3 and 4, the reaction chamber 10 includes a first connection member 101, a second connection member 102, a third connection member 103 and a fourth connection member 104, wherein the first connection member 101 and the second connection member 104, wherein the first connection member 101 and the second connection member 102 are arranged in the vertical direction, first ends of the plural sets of coils 15 are connected to the first connection member 101, and second ends thereof are connected to the second connection member 102; two ends of the third connection member 103 are connected to the power supply 16 and the first connection member 101, respectively, and the fourth connection member 104 has one end connected to the second connection member 102 and the other end grounded. That is to say, the plural sets of coils 15 are connected in parallel. Moreover, for every set of coil 15, the direction from the first end connected to the first connection member 101 to the second end connected to the second connection member 102 is the same, i.e., winding directions of the plural sets of coils 15 are the same, so that current directions in the plural sets of coils 15 are the same when the power supply 16 supplies power to the plural sets of coils 15, so as to generate electromagnetic fields having a same direction.

During the process, process gas is introduced into the reaction chamber 10 through the inlet line and flows towards the holding member 11 from top to bottom. The process gas sequentially flows through areas corresponding to the plural sets of coils 15 during the flowing process thereof, and the plural sets of coils 15 ionize the process gas sequentially. Thereinafter, a process of generating plasma in the reaction chamber 10 is described by taking a case where the process gas is ionized by two sets of coils 15 as an example. Specifically, as shown in Figs. 2, 3, 5 and 6, when the

process gas flows to the area corresponding to the upper coil 15', the process gas is ionized in the electromagnetic field generated by the coil 15', wherein a small portion of the process gas is ionized into electrons and ions directly, and a larger portion of the process gas is ionized into free radicals; in the ionized process gas, content of the free radicals is generally 100 to 1000 times as large as that of the ions. The process gas continues flowing upwards after being ionized by the upper coil 15' for a first time, at this point, the process gas includes a small amount of ions and a large amount of free radicals, and includes a large amount of process gas that has not been ionized as well. When the process gas flows to the area corresponding to the lower coil 15'', the process gas is ionized for a second time in the electromagnetic field generated by the coil 15''; during this ionization process, among the process gas that has not been ionized in the first ionization process, a small portion thereof is ionized into electrons and ions directly, and a larger portion thereof is ionized into free radicals; also, the free radicals obtained in the first ionization process is further ionized into electrons and ions during this ionization process.

It is known from the above that, both the coil 15' and the coil 15'' ionize a part of the process gas into electrons and ions, so as to generate plasma in the reaction chamber 10. In practical applications, because the electromagnetic fields generated by the coils 15 in the reaction chamber 10 are generally non-uniform, generation rate of plasma in the area corresponding to each coil 15 is different. In general, the generation rate of plasma in an area corresponding to the axial center of each coil 15 is higher than that in an area close to the dielectric window 12 in the reaction chamber 10, and as a result, during the process, the plasma will diffuse, in a horizontal direction, from an area having a higher generation rate of plasma to an area having a lower generation rate of plasma. In addition, in the embodiment, since the coil 15' and the coil 15'' are arranged at an interval, and no plasma is generated in an area between the coil 15' and the coil 15'', the plasma in an area, in which generation rate of plasma is high, within the areas corresponding to the coil 15' and the coil 15'' will diffuse to the area between the coil 15' and the coil 15'', thus, the generation rate of plasma counterbalances outward diffusion rate of plasma in the area, in which generation rate

of plasma is high, within the areas corresponding to the coil 15' and the coil 15'', and densities of plasma in an area, in which generation rate of plasma is low, within the areas corresponding to the coil 15' and the coil 15'' and in the area between the coil 15' and the coil 15' are improved, thereby improving distribution uniformity of the plasma in the reaction chamber 10.

In the process, the plasma is distributed evenly in the reaction chamber 10, which can reduce influence caused by skin currents in the plural sets of coils 15, and allow more of the power applied to the coils 15 by the power supply 16 to be used to generate electromagnetic fields in the reaction chamber 10 to excite the process gas into plasma, so that density of plasma in the reaction chamber 10 can be improved; meanwhile, higher power can be applied to the coils 15 by the power supply 16 due to the decreased skin currents, so that power capacity is improved.

In the meanwhile, in the embodiment, the output power of the power supply 16 is distributed to the plural sets of coils 15, so that power in each set of coil 15 is relatively low, which can reduce strengths of effects such as recombination of active particles in the plasma in an area surrounded by the dielectric window 12, ion bombardment on the dielectric window 12, optical radiation, and the like, and lower both temperature rise of the dielectric window 12 and temperature gradient of a surface of the dielectric window 12, so as to prevent the dielectric window 12 from cracking, thereby prolonging service life of the dielectric window 12.

In the reaction chamber provided by the embodiment, the outer surface of the dielectric window 12 is provided thereon with plural sets of coils 15, which are arranged at an interval in the vertical direction, and wound around the dielectric window 12, so that process gas is ionized sequentially by the electromagnetic fields generated by the plural sets of coils 15 after being introduced into the reaction chamber 10, and moreover, during the process, the generated plasma diffuses in both horizontal direction and vertical direction, so that the plasma is distributed evenly in the reaction chamber 10, thereby improving uniformity of the process; in the meanwhile, by using the plural sets of coils 15 to ionize the process gas for plural times, ionization efficiency of the process can also be improved. In addition, in the

reaction chamber provided by the embodiment, power for exciting plasma is applied to the plural sets of coils 15, respectively, so that the power in each set of coil 15 is relatively low, as a result, influence of skin currents in the plural sets of coils 15 can be reduced, and more of the power applied to the plural sets of coils 15 can be used for exciting plasma, thereby improving effective power applied to the coils 15; also, strengths of effects such as recombination of active particles in the plasma, ion bombardment on the dielectric window 12, optical radiation, and the like can be reduced, temperature rise and temperature gradient of the dielectric window 12 during the process can be lowered, so as to prevent the dielectric window 12 from cracking, and service life of the dielectric window 12 can thus be prolonged.

In the embodiment, the number of turns of each set of coil 15 is plural; and a spacing between two adjacent sets of coils 15 is at least twice as long as that between two adjacent turns of the coil in each set of coil 15, in this way, there is enough space for the plasma in an area having a high generation rate of plasma to diffuse, so that the generation rate of plasma counterbalances the diffusion rate of plasma in the area, and thus the plasma is distributed evenly in the reaction chamber 10.

In the embodiment, for each of the plural sets of coils 15, a cross section of each turn of the coil in a plane parallel to the axial direction of the coil may be in the shape of rectangle, ring or circle.

In the embodiment, a position of the first connection member 101 where the first connection member 101 is connected with the third connection member 103 and a position of the second connection member 102 where the second connection member 102 is connected with the fourth connection member 104 are set according to currents required by the plural sets of coils 15. In a practical application, the position of the first connection member 101 where the first connection member 101 is connected with the third connection member 103 and/or the position of the second connection member 102 where the second connection member 102 is connected with the fourth connection member 104 may be determined according to practical requirements of a circuit. In the case where the position at which the first connection member 101 is connected with the third connection member 103 is different from the position at

which the second connection member 102 is connected with the fourth connection member 104, the circuits in which the plural sets of coils 15 are respectively arranged have different resistances, and thus have different currents. In the embodiment, by setting the position at which the first connection member 101 and the third connection member 103 are connected and the position at which the second connection member 102 and the fourth connection member 104 are connected, the currents in the circuits in which the plural sets of coils 15 are respectively positioned can be changed, further strengths of the electromagnetic fields generated by the plural sets of coils 15 can be changed, and ultimately, plasma excitation efficiency of the plural sets of coils 15 can be adjusted. Preferably, in the embodiment, one end of the third connection member 103 is connected to a middle position of the first connection member 101; and one end of the fourth connection member 104 is connected to a middle position of the second connection member 102.

It should be noted that, in the embodiment, the power supply unit includes one power supply 16, the plural sets of coils 15 are connected in parallel and connected to the power supply 16, but the present invention is not limited thereto. In practical applications, the number of the power supplies 16 may be plural, and the number of the matchers 17 corresponds to the number of the power supplies 16, and each power supply 16 is electrically connected to more than one set of coil 15 via one matcher 17. Moreover, for each power supply 16, the more than one set of coil 15 corresponding thereto has a same winding direction, so that the current direction in each set of coil 15 is the same when the power supply 16 supplies power to the more than one set of coil 15, so as to generate an electromagnetic field having a same direction.

As another technical solution, an embodiment of the present invention provides a plasma processing apparatus, including a reaction chamber, which is the reaction chamber provided by the above embodiments of the present invention.

In the plasma processing apparatus provided by the embodiment, by adopting the above reaction chamber provided by the present invention, plasma is distributed evenly in the reaction chamber, and density of plasma in the reaction chamber is improved, thereby improving both uniformity and efficiency of the process;

meanwhile, effective power for exciting plasma can be improved, and both temperature rise and temperature gradient of the dielectric window during the process can be lowered, so as to prevent the dielectric window from cracking, thereby prolonging the service life of the dielectric window.

It could be understood that the above implementations are exemplary implementations used for describing the principle of the present invention only, but the present invention is not limited thereto. For those skilled in the art, various variations and modifications may be made without departing from the spirit and substance of the present invention, and these variations and modifications are also considered as falling into the protection scope of the present invention.

CLAIMS:

1. A reaction chamber, comprising a chamber body, a dielectric window and a power supply unit, the dielectric window being provided above and hermetically connected with the chamber body, characterized in that, an outer side of the dielectric window is provided with a plurality of sets of coils arranged at an interval in a vertical direction and wound around the dielectric window, and the power supply unit supplies power to the plurality of sets of coils.

2. The reaction chamber according to claim 1, characterized in that, the power supply unit comprises a power supply and a matcher, and the plurality of sets of coils are connected to the power supply via the matcher.

3. The reaction chamber according to claim 2, characterized in that, the number of the power supply is one; the plurality of sets of coils are connected in parallel and electrically connected to the power supply; and winding directions of the plurality of sets of coils are the same, so that a current in each set of coil has a same direction when the power supply supplies power to the plurality of sets of coils.

4. The reaction chamber according to claim 2, characterized in that, the number of the power supplies is plural, the number of the matchers corresponds to the number of the power supplies, and each power supply is electrically connected to one set of coil via one matcher; currents in the plurality of sets of coils have a same direction when the power supplies supply power to the coils.

5. The reaction chamber according to claim 2, characterized in that, the number of the power supplies is plural, the number of the matchers corresponds to the number of the power supplies, and each power supply is electrically connected to more than one set of coil via one matcher; and

for each power supply, a winding direction of the more than one set of coil

corresponding thereto is the same, so that a current in each set of coil has a same direction when the power supply supplies power to the more than more set of coil.

6. The reaction chamber according to claim 3, characterized in that, the reaction chamber further comprises a first connection member, a second connection member, a third connection member and a fourth connection member;

the first connection member and the second connection member are arranged in a vertical direction, and the plurality of sets of coils have first ends connected to the first connection member, and second ends connected to the second connection member; and

the third connection member have two ends respectively connected to the power supply and the first connection member; and the fourth connection member has one end connected to the second connection member and the other end grounded.

7. The reaction chamber according to claim 6, characterized in that, a position of the first connection member at which the first connection member is connected to the third connection member and a position of the second connection member at which the second connection member is connected to the fourth connection member are set according to currents required by the plurality of sets of coils.

8. The reaction chamber according to claim 6, characterized in that, one end of the third connection member is connected to a middle position of the first connection member; and one end of the fourth connection member is connected to a middle position of the second connection member.

9. The reaction chamber according to claim 1, characterized in that, the number of turns in each set of coil is plural; and

a spacing between two adjacent sets of coils is at least twice as long as that between two adjacent turns of the coil in each set of coil.

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