APPARATUS FOR GAS PROCESSING

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an apparatus for gas processing a substrate by using a processing gas.

Disclosure of the prior art

Recently, as one method for conducting a film-forming process or an etching process by using a plasma, attention is focused on an ECR (Electron Cyclotron Resonance) plasma processing method, which generates a microwave discharge by utilizing a resonance phenomenon between an electron cyclotron movement and a microwave in a magnetic field. According to the method, a plasma having a higher density can be generated in a higher vacuum by electrodeless discharge. Thus, a surface processing can be achieved at a higher speed. In addition, there is less fear that a semiconductor wafer or the like may be contaminated or polluted.

An example of a conventional plasma processing unit for conducting such an ECR plasma process is explained with reference to Fig.9, about a case of a film-forming process. A microwave of for example 2.45 GHz is supplied into a plasma generating chamber 1A through a wave guide not shown. At the same time, an electromagnetic coil 10 generates a magnetic field of a predetermined strength such as 875 gauss. Then, by an interaction (a resonance) of the microwave and the magnetic field, a plasma-generating gas such as Ar gas, which can be supplied from an upper portion of the plasma generating chamber 1A, can be changed into a plasma with a higher density. A reactive film-forming gas, which can be introduced from a side portion of a film-forming chamber 1B through gas holes of a circular gas-supplying member 18, can be activated by the plasma in the film-forming chamber 1B to make an activating seed. Thus, a spatter-etching process and an accumulating process can be conducted to a surface of a silicon wafer W placed on a stage 11 connected to a high-frequency power source 12 at the same time. The spatter-etching process and the accumulating process are

counter to each other. In the case, they are controlled in such a manner that the accumulating process is superior to the spatter-etching process in a macroscopic view. That is, as a whole, the accumulating process is conducted.

SUMMARY OF THE INVENTION

Recently, semiconductor devices are required to be minute and to operate at a higher speed. In such a situation, attention is being focused on a CF film as an effective insulation film having a small dielectric constant. In a case of accumulating a CF film on a surface of a wafer, a CF gas (a carbon fluoride gas) such as C_4F_8 gas is used as a reactive gas. However, when the CF film is accumulated on the surface of the wafer by using the conventional processing unit shown in Fig.9, a peripheral area of the accumulated CF film has a greater thickness, and a central area thereof has a smaller thickness. The problem is more remarkable when the wafer has a larger size.

The reason of such uneven distribution of the film thickness has not been solved clearly. However, inventors of this invention guess the reason as follows.

As shown in Fig.9, the plasma-generating gas is supplied from gas nozzles 13, whose number may be 8 to 16, arranged at an upper side portion of the tubular plasma generating chamber 1A toward a central area thereof in a radial direction thereof. Then, the plasma-generating gas flows downward in the plasma-generating chamber 1A to an ECR point near to a border between the plasma generating chamber 1A and the film forming chamber 1B.

In general, as shown in Fig.10, a gas flow in a pipe 15 has a greatest velocity at a central area of the pipe 15. On the contrary, the gas flow has a smaller velocity at an area nearer to an inside surface 16 of the pipe 15. In Fig.10, respective velocities of the gas flow at respective areas are represented by vector arrows 17. A vector arrow in a central area of the pipe is longest. A vector arrow in an area nearer to a side end is shorter.

As described about Fig.10, it can be thought that the gas

flow flowing downward in the pipe has a larger velocity at a central area of the plasma generating chamber 1A, and a smaller velocity at an area nearer to the inside surface. Thus, it can be thought that the gas flow at the ECR point has a greatest velocity at a central area as shown by the vector arrows 14 in Fig.9. A difference of the velocities between the central area and the peripheral area at the ECR point may be larger when the wafer has a larger size.

Ar ions generated in the plasma process are charged particles. Thus, they are supplied onto the wafer W while bound by the magnetic field. At that time, the supply of the Ar ions onto the wafer W depends on the velocity distribution of the gas flow at the ECR point. That is, a volume of the supplied Ar ions (charged particles) per unit time and unit area is larger at a central area of the wafer. Thus, in the area, the CF gas may be easily decomposed to generate F (fluorine). The generated F operates to etch the CF film accumulated on the surface of the wafer. Thus, the etching effect is greater in the central area of the wafer than in the peripheral area thereof. That is, the CF film is thinner in the central area of the wafer.

This invention is intended to solve the above problem effectively. The object of this invention is to provide a gas processing unit, which can conduct a uniform process to a surface of a substrate such as a wafer by using a process gas.

The invention is a gas processing unit comprising: a stage on which a substrate can be placed; a vacuum container surrounding the stage, whose inside can be produced a vacuum; and a gas-supplying member having a plurality of gas holes for supplying a process gas toward the substrate placed on the stage; wherein an opening density of the gas holes of the gas-supplying member is greater in an area for a peripheral area of the substrate than in an area mainly for a central area of the substrate.

For example, an opening size of each of the gas holes in the area for the peripheral area of the substrate may be larger than an opening size of each of the gas holes in the area for the central area of the substrate. Alternatively, a number of the gas holes may be larger in the area for the peripheral area

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of the substrate than in the area for the central area of the substrate.

Preferably, a gas processing unit according to the invention further includes a gas-holes obstructing member for obstructing the gas holes.

Preferably, the gas-holes obstructing member is adapted to obstruct the gas holes of the gas-supplying member in the area mainly for the peripheral area of the substrate. In addition, preferably, the gas-holes obstructing member is exchangeable. In addition, preferably, the gas-holes obstructing member can be adjusted to change the gas holes obstructed thereby. For example, the gas-holes obstructing member may have a plurality of blade-like members overlapping in an adjustable manner.

In addition, a gas processing unit according to the invention further includes: a microwave penetrable window hermetically arranged in an opening formed in the vacuum container, the window facing the substrate placed on the stage; a wave guide connected to the vacuum container via the microwave penetrable window for introducing a microwave into the vacuum container; and a magnetic-field forming means for generating a magnetic field in the vacuum container; wherein the gas processing unit is adapted to generate an electron cyclotron resonance in the vacuum container by an interaction of the microwave introduced through the wave guide and the magnetic field, to change the process gas into a plasma and to process the substrate by the plasma.

In the case, the gas-supplying member may be made of a microwave penetrable material. In addition, the gas processing unit may further include a gas-holes obstructing member made of an electric conductor for obstructing the gas holes.

The gas holes may be arranged in a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate. Alternatively, the gas holes may be arranged in a substantially peripheral area of a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a schematic view of an example of a gas processing unit used for an embodiment according to the invention;

Fig.2 is a plan view of a gas-supplying member in the gas processing unit shown in Fig.1;

Fig.3 is a plan view of a situation wherein a part of gas holes of the gas-supplying member shown in Fig.1 is obstructed by a gas-holes obstructing member;

Fig.4 is an explanatory view for explaining a state of a gas flow at an ECR point of a gas processing unit using a gas-supplying member in which an opening area of gas holes per unit area is uniform;

Fig.5 are explanatory views for explaining operations of the gas-holes obstructing member;

Fig.6 is a schematic view of another example of a gas processing unit used for an embodiment according to the invention;

Fig.7 is a plan view of a gas-supplying member in the gas processing unit shown in Fig.6;

Fig.8 is a schematic view of a main part of the gas processing unit shown in Fig.6 provided with a gas-holes obstructing member;

Fig.9 is a schematic view of a film-forming unit using conventional plasma; and

Fig.10 is an explanatory view for explaining a state of a gas flow flowing in a pipe.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Embodiments of the invention will now be described with reference to drawings.

At first, an example of a gas processing unit used for an embodiment according to the invention is shown in Fig.1. The unit includes a vacuum container 2 made of for example aluminum or the like. The vacuum container 2 consists of a first cylindrical vacuum chamber 21 located in an upper portion thereof for generating plasma; and a second cylindrical vacuum chamber 22 located under and connected to the first vacuum chamber 21, having a diameter larger than that of the first vacuum chamber 21. In

addition, the vacuum container 2 is grounded to be in zero potential.

An upper end of the vacuum container 2 has an opening. A penetrable window 23 made of a microwave penetrable material such as a crystal is sealingly fitted in the opening. Thus, an inside of the vacuum container 2 can be maintained at a vacuum. A wave guide 25 is provided outside of the penetrable window 23. The wave guide 25 is connected to a high-frequency power source 24, which can generate a microwaver of for example 2.45 GHz. Then, the microwave generated by the high-frequency power source 24 is introduced into the wave guide 25 by for example a TE mode. Alternatively, the microwave guided by the TE mode is converted to a TM mode in the wave guide 25. Then, the microwave can be introduced into the first vacuum chamber 21 through the penetrable window 23.

A showerhead 32 as a gas-supplying member for supplying a plasma-generating gas (for example Ar gas) into the first vacuum chamber 21 is arranged for example near to an upper end of the first vacuum chamber 21, that is, just below the penetrable window 23. The showerhead 32 is adapted to face a wafer W as a substrate to be processed placed on a stage 4 described below. The showerhead 32 is connected to gas nozzles 31 piercing through a side wall defining the first vacuum chamber 21. The other ends of the gas nozzles 31 are connected to a gas source such as an Ar gas source not shown.

The showerhead 32 is a disk-like hollow box made of a crystal. A plurality of through gas holes 33 are formed in a base plate thereof. A circular gas-holes obstructing member 34 for controlling to open and close the gas holes 33 is arranged below the showerhead 32. The invention has a feature in distribution of opening area of the gas holes of the showerhead 32. The feature is described in detail as below.

The stage 4 for the wafer is arranged in the second vacuum chamber 22 to face the first vacuum chamber 21. The stage 4 has an electrostatic chuck 41 in a surface portion thereof. Electrodes of the electrostatic chuck 41 are connected to a direct-current power source (not shown) to stick to the wafer

and to a high-frequency power source 42 for applying a bias voltage to draw ions up to the wafer.

A circular film-forming-gas supplying member 51 is provided at an upper portion of the second vacuum chamber 22, that is, at a connecting portion of the second vacuum chamber 22 and the first vacuum chamber 21. The film-forming-gas supplying member 51 include for example gas supplying pipes 52, 53 and gas holes 54 formed in an inside surface thereof. For example, two kinds of film-forming gases are supplied through the respective gas supplying pipes 52, 53. Then, a mixed gas from the two kinds of film-forming gases is supplied into the vacuum container 2 via the gas holes 54.

A magnetic-field forming means such as a circular main electromagnetic coil 26 is arranged around and near to the side wall defining the first vacuum chamber 21. A circular assistant electromagnetic coil 27 is arranged below the second vacuum chamber 22. Exhausting pipes 28 are connected to a base plate of the second vacuum chamber 22 for example at two positions symmetric with respect to a central axis of the vacuum chamber 22.

Fig.2 shows the base plate of the showerhead 32. In the showerhead 32, an open area of the gas holes 33 per unit area is larger in a peripheral area of the head than in a central area thereof. In detail, as shown in Fig.2, the gas holes 33 having the same open size are arranged more densely in a more peripheral area. A relationship between a distance from a central axis of the showerhead 32 and an open area of the gas holes 33 per unit area is such a relationship that, as shown by vector arrows (that represent velocities of a gas flow) with a numeral sign 30 in Fig.1, velocities of a gas flow of the plasma-generating gas at an ECR point are uniform with respect to the wafer. In general, an area where the gas holes are arranged densely is located outside of a projection W' (shown by a dotted line in Fig.2) of the wafer W. However, the area may partly overlap with the projection W' of the wafer W. In the case, a diameter of each of the gas holes 33 is 0.2 to 0.5 mm, because an abnormal discharge may tend to be easily generated if the diameter is over the range. In addition,

a distance from the showerhead 32 to the ECR point is 220 mm.

If using a showerhead wherein an open area of the gas holes 33 per unit area is uniform, as shown by vector arrows 36 in Fig.4, it may be thought that the plasma-generating gas at the ECR point has a greatest velocity in a central area thereof. Thus, spatter-etching operation in the central area of the wafer becomes so strong that an accumulated film has an uneven thickness. The embodiment prevents the velocity of the plasma-generating gas from becoming not uniform.

Alternatively, as another example, diameters of the gas holes 33 may gradually increase in the range of 0.2 to 0.5 mm from the central area of the showerhead 32 to the peripheral area thereof. In the case, the number of the gas holes 33 per unit area may be the same everywhere in the showerhead 32 or may increase from the central area of the showerhead 32 to the peripheral area thereof.

Fig.3 shows a situation wherein a part of gas holes 33 of the showerhead 32 is obstructed by the gas-holes obstructing member 34. The gas-holes obstructing member 34 consists of a plurality of blade-like members, each adjacent two of which overlap with each other a little, just like a diaphragm mechanism in a camera. By adjusting the overlapping condition, a size of an opening defined by the plurality of blade-like members can be changed. Thus, in the example shown in Fig.3, although the gas-holes obstructing member 34 obstructs gas holes arranged on a most outside circumference, the gas-holes obstructing member 34 may obstruct no gas holes by enlarging the opening thereof or may obstruct gas holes arranged on a second or third outside circumference as well by narrowing the opening thereof.

As described above, by controlling a pattern defined by the gas holes 33, an effective area for blowing the plasma-generating gas may be adjusted. In general, when a kind of the plasma-generating gas is changed, a distribution of plasma density may be changed at the ECR point. In addition, it may be necessary to change a distribution of the gas flow velocity of the plasma-generating gas, based on characteristics of a formed film. In the case, the distribution of the gas flow velocity may

be revised by not changing the showerhead 32 but adjusting the pattern of the gas holes by means of the gas-holes obstructing member 34. Thus, a planned distribution of plasma density may be obtained at the ECR point. In detail, when the gas holes 33 near to the outside periphery of the showerhead 32 are not obstructed, as shown by vector arrows 37 in Fig.5(b), the gas flow of the plasma-generating gas at the ECR point may have a too great velocity at an area near to the periphery rather than at a central area. Then, a thickness of a film accumulated on the wafer W may be uneven. In the case, if the gas holes 33 near to the outside periphery of the showerhead 32 are suitably obstructed by the gas-holes obstructing member 34, as shown in Fig.5(a), a gas flow having an uniform velocity at the ECR point may be obtained.

In addition, when the gas-holes obstructing member 34 is made of an electric conductor such as a metal, the gas-holes obstructing member 34 may also have a function to adjust a penetrable area of the microwave that has penetrated through the penetrable window 23.

Alternatively, in another example, the gas-holes obstructing member 34 may be arranged in such a manner the size of the opening thereof may not be adjusted freely. In the case, the gas-holes obstructing member 34 can be attached to and removed from the first vacuum chamber 21. In addition, a plurality of gas-holes obstructing members 34 whose opening sizes are different from each other may be prepared. Then, one gas-holes obstructing member may be suitably chosen from the plurality of gas-holes obstructing members and attached to the first vacuum chamber 21.

Then, a method for forming a interlayer dielectric film consisting of a CF film onto a wafer W as a substrate to be processed by using the unit described above is explained. At first, a gate valve (not shown) provided at the side wall of the vacuum container 2 is opened. A conveying arm (not shown) conveys a wafer W, which has for example an aluminum circuit on an upper surface thereof, from the load-lock chamber (not shown) onto the stage 4. The wafer 4 conveyed onto the stage 4 is electrostaticly

stuck to the electrostatic chuck 41.

Then, the gate valve is closed, that is, the inside of the vacuum container 2 is hermetically closed. Then, gas in the inside of the vacuum container 2 is exhausted from the exhausting pipes 28, and the inside of the vacuum container 2 is produced to a predetermined vacuum. After that, a plasma-generating gas such as Ar gas is introduced into the first vacuum chamber 21 through the plasma-gas nozzle 31 and a CF film-forming gas is introduced from the film-forming gas supplying member 51 into the second vacuum chamber 22 at a predetermined flow rate. The pattern of the gas holes, which is determined by a distribution of the gas holes 33 in the showerhead 32 and an arrangement of the gas-holes obstructing member 34, is adjusted most suitably in advance, based on preparatory experiments and/or process data in the past and so on.

Then, the inside of the vacuum container 2 is maintained at a predetermined process pressure. The high-frequency power source 42 applies a bias voltage of 13.56 MHz and 1500 W to the stage 4. In addition, a temperature of the upper surface of the stage 4 is set to about 400 ℃.

The high-frequency wave (microwave) of 2.45 GHz from the high-frequency power source 24 is introduced into the first vacuum chamber 21 through the wave guide 25 and through the penetrable window 23 at a ceiling of the vacuum container 2. In the container 2, the electromagnetic coils 26 and 27 form a magnetic field in a direction from an upper portion of the first vacuum chamber 21 toward a lower portion of the second vacuum chamber 22. For example, a strength of the magnetic field at a lower portion of the first vacuum chamber 21 is 875 gauss. Then, an electric cyclotron resonance is generated by an interaction between the magnetic field and the microwave. The resonance causes the Ar gas to become plasma and to be much dense. A plasma flow flowing from the first vacuum chamber 21 into the second vacuum chamber 22 activates the CF gas supplied thereinto to make activated seeds and to form a CF film on the wafer W.

In a case of manufacturing actual devices, after that, the CF film may be etched with a predetermined pattern by means of

a predetermined etching means such as O_2 (plasma). For example, W films may be buried in etched grooves to form a W circuit.

According to the above embodiment, since the showerhead 32 is arranged in such a manner that the open area of the gas holes 33 per unit area is larger in the peripheral area of the head than in the central area thereof, it may be prevented that the gas flow of the plasma-generating gas become slow at an area near to the inside surface of the first vacuum chamber 21. Thus, the flow velocity of the plasma-generating gas at the ECR point can be uniform with respect to the wafer W. Thus, a gas flow rate per unit time and per unit area can be uniform above the wafer W, spatter-etching effect on the surface of the wafer W can be uniform, and the thickness of the film accumulated on the wafer W can be uniform in a radial direction of the wafer W.

In addition, according to the above embodiment, even when a material of an accumulated film or a kind of the plasma-generating gas is changed, a gas flow having a uniform flow velocity can be obtained by adjusting the pattern of the gas holes by means of the gas-holes obstructing member 34. Thus, there is no need to prepare a plurality of showerhead which have various patterns of the gas holes. Thus, films of various materials can be accumulated by using various kinds of plasma-generating gas at small cost.

Another example of an embodiment according to the invention is shown in Figs.6 to 8. The plasma processing unit is different from the unit shown in Figs.1 to 3, in that a gas-ring 62 is provided as a ring-like gas supplying member instead of the showerhead 32 and that the gas-holes obstructing member 34 is omitted. Other structure is the same as the example shown in Figs.1 to 3 and described above. Thus, the same numeral references correspond to the same elements as the example shown in Figs.1 to 3. The detailed explanation of the same elements is not repeated.

As shown in Fig.7, the gas-ring 62 consists of a hollow ring-like box surrounding an effective area of the penetrable window 23 (an area designated by a diameter d in Fig.6). A plurality of gas holes 63 are formed in a base plate of the gas-ring

62. The plurality of gas holes 63 are arranged just below the penetrable window 23 to face a plane including an upper surface of the wafer W. The gas-ring 62 is connected to a gas source of Ar gas or the like through the gas nozzles 31. The gas-ring 62 is made of a metal or an insulation such as a crystal. A dimension of the diameter d may be about 190 mm, for example if an inside diameter D of the first vacuum chamber 21 is 250 mm. That is, in the case, the inside diameter and the outside diameter of the gas-ring 62 are about 190 mm and about 250 mm, respectively.

The gas holes 63 may be arranged in such a manner that an open area of the gas holes 63 per unit area is larger in a peripheral area, that is, in an outside area than in a central area, that is, an inside area. Alternatively, the gas holes 63 may be arranged in such a manner that an open area of the gas holes 63 per unit area is the same everywhere in the gas-ring 62.

By supplying the plasma-generating gas into the first vacuum chamber 21 by means of the gas-ring 62, the plasma-generating gas flows downward from a peripheral area of the first vacuum chamber 21. Thus, a gas density at a central area near to the gas-ring 62 is small. Combination of this fact and the fact that a gas flow tends to have a larger velocity in a central area than in a peripheral area at the ECR point causes the flow velocity of the plasma-generating gas at the ECR point to be uniform with respect to the wafer W, as shown by vector arrows 60 (which represent velocities of the gas flow) in Fig.6.

As shown in Fig.8, a ring-like gas-holes obstructing member 64 may be arranged below the gas-ring 62 in order to control to open and close the gas holes 63. The gas-holes obstructing member 64 is the same as the gas-hole obstructing member 34 described above. Thus, a pattern of the gas holes 63 can be adjusted, based on a material of an accumulated film or a kind of the plasma-generating gas. Then, a distribution of the gas flow velocity may be revised, and a planned distribution of plasma density may be obtained at the ECR point.

According to the embodiment shown in Figs.6 to 8, a gas flow rate per unit time and per unit area can be uniform above

the wafer W, spatter-etching effect on the surface of the wafer W can be uniform, and the thickness of the film accumulated on the wafer W can be uniform in a radial direction of the wafer W. In addition, since the gas-ring 62 is arranged outside the penetrable window 23, the microwave may not pass through the gas supplying member. Thus, it may be prevented that a film is formed in the gas supplying member.

In the above embodiments, the exhausting pipes may be connected to a bottom portion of the side wall of the vacuum container, and the electromagnetic coil for forming the magnetic field may be provided in a side area of the wave guide. In addition, this invention may be applied to not only the unit for conducting a film-forming process but also various units for processing a substrate with plasma such as an etcher for etching a substrate with plasma made of CF gas. In addition, this invention may be applied to not only the case of processing a substrate with plasma but also a case of decomposing a process gas with heat to form activated seeds and to form films by using the activated seeds.

In addition, this invention is not limited to the manner of generating plasma by ECR. For example, this invention may be applied to a case of generating plasma by a method called ICP (Inductive Coupled Plasma) wherein a coil wound around a dome-like container gives an electric field and a magnetic field to a process gas. This invention may also be applied to a case of generating plasma by an interaction of a helicon wave of for example 13.56 MHz and a magnetic field by formed by a magnetic coil, which plasma is called helicon-wave plasma. This invention may also be applied to a case of generating plasma by applying a magnetic field to two parallel cathodes in a substantially parallel manner, which plasma is called magnetron plasma. This invention may also be applied to a case of generating plasma by applying a high-frequency electric power between electrodes facing with each other, which are called parallel-plates.

In this invention, a substrate is not limited to the wafer, but may be a glass substrate for a liquid crystal display.

As described above, according to a feature of the invention, the process gas is supplied more in the outside area than in the

central area from the gas supplying member which is arranged at a position to face the substrate or a plane extended from the substrate. Thus, a surface of the substrate can undergo a uniform process.

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CLAIMS:

1. A gas processing unit comprising;

a stage on which a substrate can be placed,

a vacuum container surrounding the stage, whose inside can be produced a vacuum, and

a gas-supplying member having a plurality of gas holes for supplying a process gas toward the substrate placed on the stage,

wherein an opening density of the gas holes of the gas-supplying member is greater in an area for a peripheral area of the substrate than in an area for a central area of the substrate.

2. A gas processing unit according to claim 1, wherein:

an opening size of each of the gas holes in the area for the peripheral area of the substrate is larger than an opening size of each of the gas holes in the area for the central area of the substrate.

3. A gas processing unit according to claim 1, wherein:

a number of the gas holes is larger in the area for the peripheral area of the substrate than in the area for the central area of the substrate.

4. A gas processing unit according to claim 1, further comprising:

a gas-holes obstructing member for obstructing the gas holes.

5. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member is adapted to obstruct the gas holes of the gas-supplying member in the area for the peripheral area of the substrate.

6. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member is exchangeable.

7. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member can be adjusted to change the gas holes obstructed thereby.

8. A gas processing unit according to claim 7, wherein:

the gas-holes obstructing member has a plurality of blade-like members overlapping in an adjustable manner.

9. A gas processing unit according to claim 1, further

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comprising:

a microwave penetrable window hermetically arranged in an opening formed in the vacuum container, the window facing the substrate placed on the stage,

a wave guide connected to the vacuum container via the microwave penetrable window for introducing a microwave into the vacuum container, and

a magnetic-field forming means for generating a magnetic field in the vacuum container,

wherein the gas processing unit is adapted to generate an electron cyclotron resonance in the vacuum container by an interaction of the microwave introduced through the wave guide and the magnetic field, to change the process gas into a plasma and to process the substrate by the plasma.

10. A gas processing unit according to claim 9, wherein:

the gas-supplying member is made of a microwave penetrable material.

11. A gas processing unit according to claim 9, further comprising:

a gas-holes obstructing member made of an electric conductor for obstructing the gas holes.

12. A gas processing unit according to claim 9, wherein:

the gas holes are arranged in a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate.

13. A gas processing unit according to claim 9, wherein:

the gas holes are arranged in a substantially peripheral area of a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate.

14. A gas processing unit according to claim 1, wherein:

the stage is adapted to be placed a substantially circular substrate,

the gas holes are arranged in a plane parallel to the substrate, and

the vacuum container has a substantially cylindrical shape at least at a portion provided with the gas holes.

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15. A gas processing unit according to claim 1, further comprising:

an etching processing mechanism.

16. A gas processing unit according to claim 1, further comprising:

a film-forming processing mechanism.

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ABSTRACT

In a gas processing unit according to the invention, a showerhead 32 having gas holes 33, which are arranged in such a manner that the opening density per unit area is larger in the peripheral area than in the central area, is arranged just below a penetrable window 23 to face a wafer W. A gas-holes obstructing member 34 is arranged below the showerhead 32 for controlling to open and close the gas holes 33. Thus, a uniform process can be conducted to a surface of a substrate such as a wafer by using plasma.

flow flowing downward in the pipe has a larger velocity at a central area of the plasma generating chamber 1A, and a smaller velocity at an area nearer to the inside surface. Thus, it can be thought that the gas flow at the ECR point has a greatest velocity at a central area as shown by the vector arrows 14 in Fig.9. A difference of the velocities between the central area and the peripheral area at the ECR point may be larger when the wafer has a larger size.

Ar ions generated in the plasma process are charged particles. Thus, they are supplied onto the wafer W while bound by the magnetic field. At that time, the supply of the Ar ions onto the wafer W depends on the velocity distribution of the gas flow at the ECR point. That is, a volume of the supplied Ar ions (charged particles) per unit time and unit area is larger at a central area of the wafer. Thus, in the area, the CF gas may be easily decomposed to generate F (fluorine). The generated F operates to etch the CF film accumulated on the surface of the wafer. Thus, the etching effect is greater in the central area of the wafer than in the peripheral area thereof. That is, the CF film is thinner in the central area of the wafer.

This invention is intended to solve the above problem effectively. The object of this invention is to provide a gas processing unit, which can conduct a uniform process to a surface of a substrate such as a wafer by using a process gas.

The invention is a gas processing unit comprising: a stage on which a substrate can be placed; a vacuum container surrounding the stage, whose inside can be produced a vacuum; a plasma-generating-gas supplier having a plurality of gas holes, which can introduce a gas for generating a plasma in the vacuum container, and a process-gas supplier that can introduce a process gas for conducting a predetermined plasma process to the substrate in the vacuum container; wherein an opening density of the gas holes of the plasma-generating-gas supplier is greater in an area for a peripheral area of the substrate than in an area mainly for a central area of the substrate.

For example, an opening size of each of the gas holes of the plasma-generating-gas supplier in the area for the peripheral

area of the substrate may be larger than an opening size of each of the gas holes of the plasma-generating-gas supplier in the area for the central area of the substrate. Alternatively, a number of the gas holes of the plasma-generating-gas supplier may be larger in the area for the peripheral area

of the substrate than in the area for the central area of the substrate.

Preferably, a gas processing unit according to the invention further includes a gas-holes obstructing member for obstructing the gas holes of the plasma-generating-gas supplier.

Preferably, the gas-holes obstructing member is adapted to obstruct the gas holes of the gas-supplying member in the area mainly for the peripheral area of the substrate. In addition, preferably, the gas-holes obstructing member is exchangeable. In addition, preferably, the gas-holes obstructing member can be adjusted to change the gas holes obstructed thereby. For example, the gas-holes obstructing member may have a plurality of blade-like members overlapping in an adjustable manner.

In addition, a gas processing unit according to the invention further includes: a microwave penetrable window hermetically arranged in an opening formed in the vacuum container, the window facing the substrate; a wave guide connected to the vacuum container via the microwave penetrable window for introducing a microwave into the vacuum container; and a magnetic-field forming means for generating a magnetic field in the vacuum container; wherein the gas processing unit is adapted to generate an electron cyclotron resonance between the plasma-generating-gas supplier and the process-gas supplier in the vacuum container by an interaction of the microwave introduced through the wave guide and the magnetic field, to change the process gas into a plasma and to process the substrate by the plasma.

In the case, the plasma-generating-gas supplier may be made of a microwave penetrable material. In addition, the gas processing unit may further include a gas-holes obstructing member made of an electric conductor for obstructing the gas holes of the plasma-generating-gas supplier.

The gas holes of the plasma-generating-gas supplier may be arranged in a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate. Alternatively, the plasma-generating-gas supplier may be formed by a ring-like hollow box arranged in a

substantially peripheral area of a space between the microwave penetrable window and the substrate placed on the stage, and may have the plurality of gas holes facing the substrate in a base portion thereof.

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CLAIMS:

1. (Amended) A gas processing unit comprising;

a stage on which a substrate can be placed,

a vacuum container surrounding the stage, whose inside can be produced a vacuum,

a plasma-generating-gas supplier having a plurality of gas holes, which can introduce a gas for generating a plasma in the vacuum container, and

a process-gas supplier that can introduce a process gas for conducting a predetermined plasma process to the substrate in the vacuum container,

wherein an opening density of the gas holes of the plasma-generating-gas supplier is greater in an area for a peripheral area of the substrate than in an area for a central area of the substrate.

2. (Amended) A gas processing unit according to claim 1, wherein:

an opening size of each of the gas holes of the plasma-generating-gas supplier in the area for the peripheral area of the substrate is larger than an opening size of each of the gas holes of the plasma-generating-gas supplier in the area for the central area of the substrate.

3. (Amended) A gas processing unit according to claim 1, wherein:

a number of the gas holes of the plasma-generating-gas supplier is larger in the area for the peripheral area of the substrate than in the area for the central area of the substrate.

4. (Amended) A gas processing unit according to claim 1, further comprising:

a gas-holes obstructing member for obstructing the gas holes of the plasma-generating-gas supplier.

5. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member is adapted to obstruct the gas holes of the gas-supplying member in the area for the peripheral area of the substrate.

6. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member is exchangeable.

7. A gas processing unit according to claim 4, wherein:

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the gas-holes obstructing member can be adjusted to change the gas holes obstructed thereby.

8. A gas processing unit according to claim 7, wherein:

the gas-holes obstructing member has a plurality of blade-like members overlapping in an adjustable manner.

9. (Amended) A gas processing unit according to claim 1, further comprising:

a microwave penetrable window hermetically arranged in an opening formed in the vacuum container, the window facing the substrate,

a wave guide connected to the vacuum container via the microwave penetrable window for introducing a microwave into the vacuum container, and

a magnetic-field forming means for generating a magnetic field in the vacuum container,

wherein the gas processing unit is adapted to generate an electron cyclotron resonance between the plasma-generating-gas supplier and the process-gas supplier in the vacuum container by an interaction of the microwave introduced through the wave guide and the magnetic field, to change the process gas into a plasma and to process the substrate by the plasma.

10. (Amended) A gas processing unit according to claim 9, wherein:

the plasma-generating-gas supplier is made of a microwave penetrable material.

11. (Amended) A gas processing unit according to claim 9, further comprising:

a gas-holes obstructing member made of an electric conductor for obstructing the gas holes of the plasma-generating-gas supplier.

12. (Amended) A gas processing unit according to claim 9, wherein:

the gas holes of the plasma-generating-gas supplier are arranged in a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate.

13. (Amended) A gas processing unit according to claim 9, wherein:

the plasma-generating-gas supplier is formed by a

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ring-like hollow box arranged in a substantially peripheral area of a space between the microwave penetrable window and the substrate placed on the stage, and has the plurality of gas holes facing the substrate in a base portion thereof.

14. A gas processing unit according to claim 1, wherein:

the stage is adapted to be placed a substantially circular substrate,

the gas holes are arranged in a plane parallel to the substrate, and

the vacuum container has a substantially cylindrical shape at least at a portion provided with the gas holes.

15. A gas processing unit according to claim 1, further comprising:

an etching processing mechanism.

16. A gas processing unit according to claim 1, further comprising:

a film-forming processing mechanism.

17. (Added) A gas processing unit according to claim 1, wherein:

the plasma-generating-gas supplier is formed by a ring-like hollow box, and has the plurality of gas holes facing the substrate in a base portion thereof.



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CLAIMS:

1. (Twice Amended) A gas processing unit comprising;

a stage on which a substrate can be placed,

a vacuum container surrounding the stage, whose inside can be produced a vacuum,

a plasma-generating-gas supplier having a plurality of gas holes, which can introduce a gas for generating a plasma in the vacuum container, and

a process-gas supplier that can introduce a process gas for conducting a predetermined plasma process to the substrate in the vacuum container,

wherein an opening density of the gas holes of the plasma-generating-gas supplier is greater in an area for a peripheral area of the substrate than in an area for a central area of the substrate, and the plasma-generating-gas supplier and the process-gas supplier are separately arranged.

2. (Amended) A gas processing unit according to claim 1, wherein:

an opening size of each of the gas holes of the plasma-generating-gas supplier in the area for the peripheral area of the substrate is larger than an opening size of each of the gas holes of the plasma-generating-gas supplier in the area for the central area of the substrate.

3. (Amended) A gas processing unit according to claim 1, wherein:

a number of the gas holes of the plasma-generating-gas supplier is larger in the area for the peripheral area of the substrate than in the area for the central area of the substrate.

4. (Amended) A gas processing unit according to claim 1, further comprising:

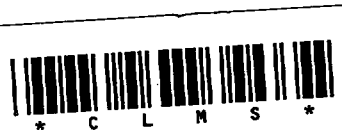
a gas-holes obstructing member for obstructing the gas holes of the plasma-generating-gas supplier.

5. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member is adapted to obstruct the gas holes of the gas-supplying member in the area for the peripheral area of the substrate.

6. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member is exchangeable.



7. A gas processing unit according to claim 4, wherein:

the gas-holes obstructing member can be adjusted to change the gas holes obstructed thereby.

8. A gas processing unit according to claim 7, wherein:

the gas-holes obstructing member has a plurality of blade-like members overlapping in an adjustable manner.

9. (Amended) A gas processing unit according to claim 1, further comprising:

a microwave penetrable window hermetically arranged in an opening formed in the vacuum container, the window facing the substrate,

a wave guide connected to the vacuum container via the microwave penetrable window for introducing a microwave into the vacuum container, and

a magnetic-field forming means for generating a magnetic field in the vacuum container,

wherein the gas processing unit is adapted to generate an electron cyclotron resonance between the plasma-generating-gas supplier and the process-gas supplier in the vacuum container by an interaction of the microwave introduced through the wave guide and the magnetic field, to change the process gas into a plasma and to process the substrate by the plasma.

10. (Amended) A gas processing unit according to claim 9, wherein:

the plasma-generating-gas supplier is made of a microwave penetrable material.

11. (Amended) A gas processing unit according to claim 9, further comprising:

a gas-holes obstructing member made of an electric conductor for obstructing the gas holes of the plasma-generating-gas supplier.

12. (Amended) A gas processing unit according to claim 9, wherein:

the gas holes of the plasma-generating-gas supplier are arranged in a space between the microwave penetrable window and the substrate placed on the stage and in a plane parallel to the substrate.

13. (Amended) A gas processing unit according to claim 9, wherein:

the plasma-generating-gas supplier is formed by a ring-like hollow box arranged in a substantially peripheral area of a space between the microwave penetrable window and the substrate placed on the stage, and has the plurality of gas holes facing the substrate in a base portion thereof.

14. A gas processing unit according to claim 1, wherein:

the stage is adapted to be placed a substantially circular substrate,

the gas holes are arranged in a plane parallel to the substrate, and

the vacuum container has a substantially cylindrical shape at least at a portion provided with the gas holes.

15. A gas processing unit according to claim 1, further comprising:

an etching processing mechanism.

16. A gas processing unit according to claim 1, further comprising:

a film-forming processing mechanism.

17. (Added) A gas processing unit according to claim 1, wherein:

the plasma-generating-gas supplier is formed by a ring-like hollow box, and has the plurality of gas holes facing the substrate in a base portion thereof.

