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(54) **PLASMA PROCESSING APPARATUS**

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(57) **ABSTRACT**

A plasma processing apparatus is disclosed in which a wafer mounted on a sample stage arranged in a processing chamber in a vacuum vessel is processed using a plasma formed in the processing chamber. A dielectric bell jar makes up the upper part of the vacuum vessel and surrounds processing chamber. A coil-shaped antenna wound on the outer periphery of the bell jar is supplied with the high-frequency power to form the plasma. A Faraday shield of a conductive material is formed of double layers including inner and outer layers arranged in spaced relation to each other between the antenna and the bell jar, each layer having a plurality of slits and set at a predetermined potential. The slits of the inner and outer layers of the Faraday shield are arranged in staggered fashion.

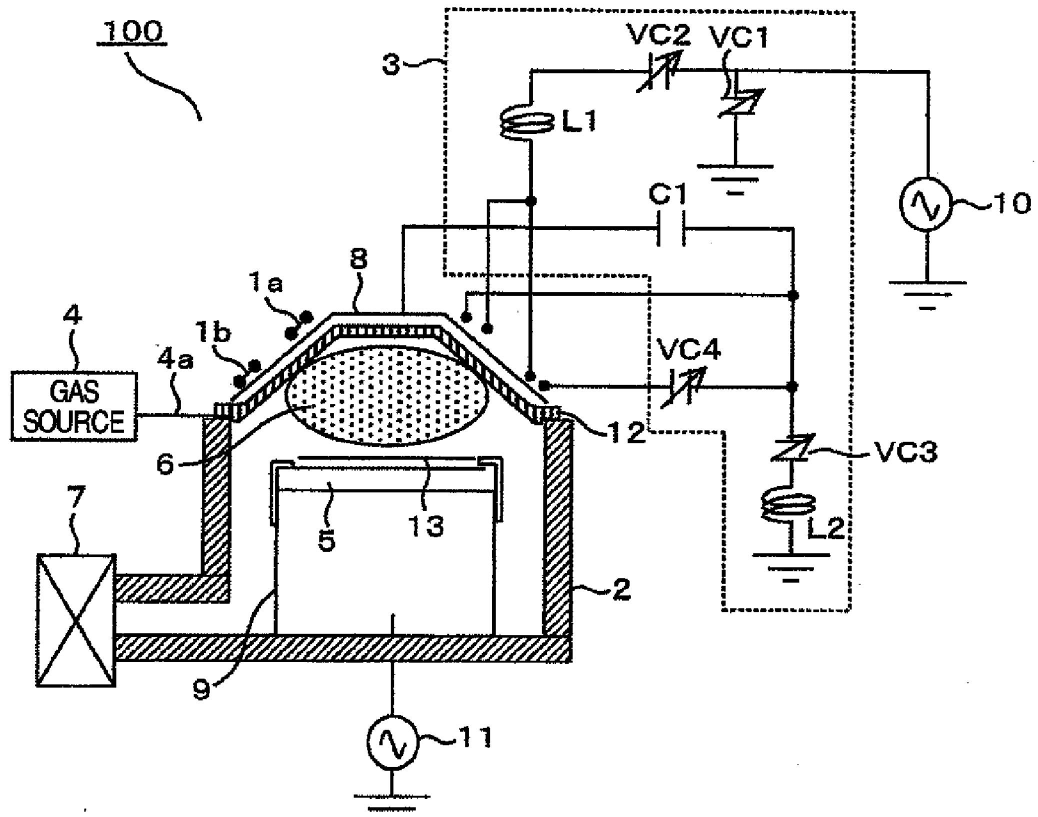


FIG.1

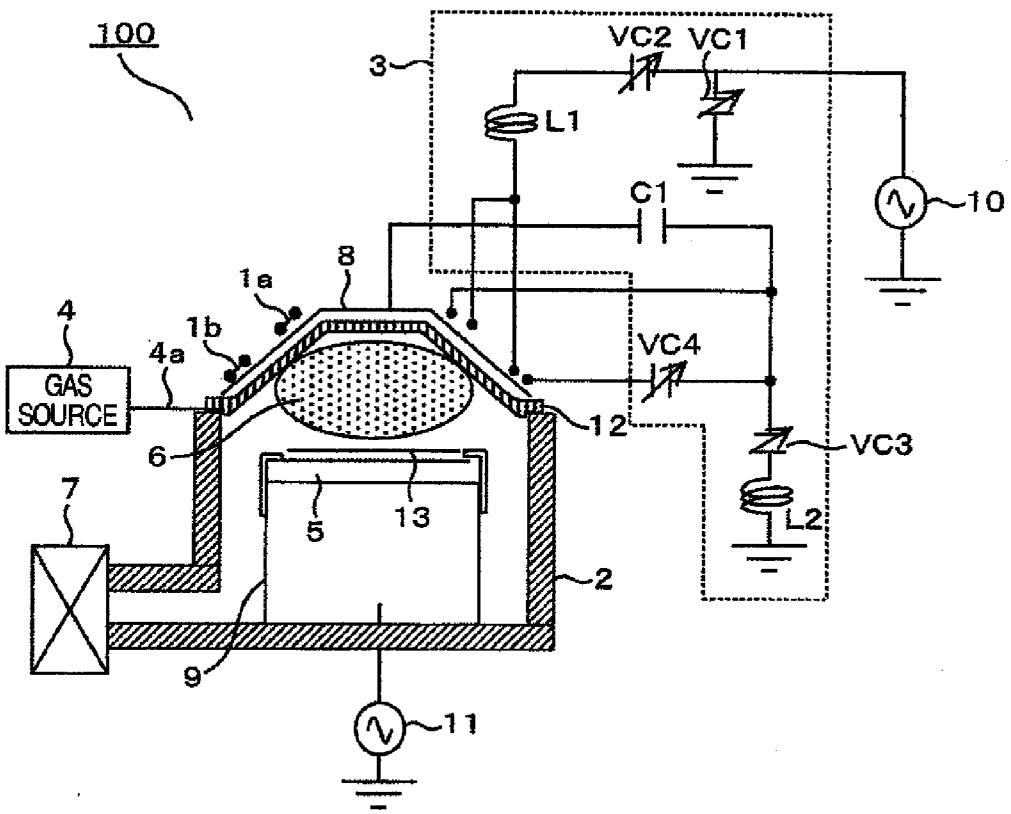

100
3
VC2
VC1
L1
10
C1
8
1a
1b
4
GAS SOURCE
4a
VC4
12
6
VC3
7
5
13
L2
2
9
11

FIG.2

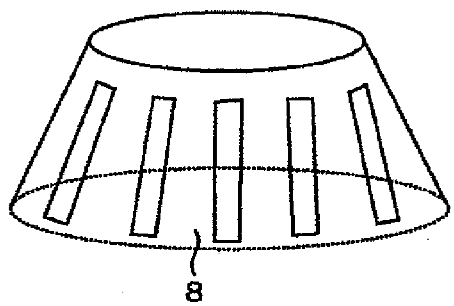

8

FIG.3

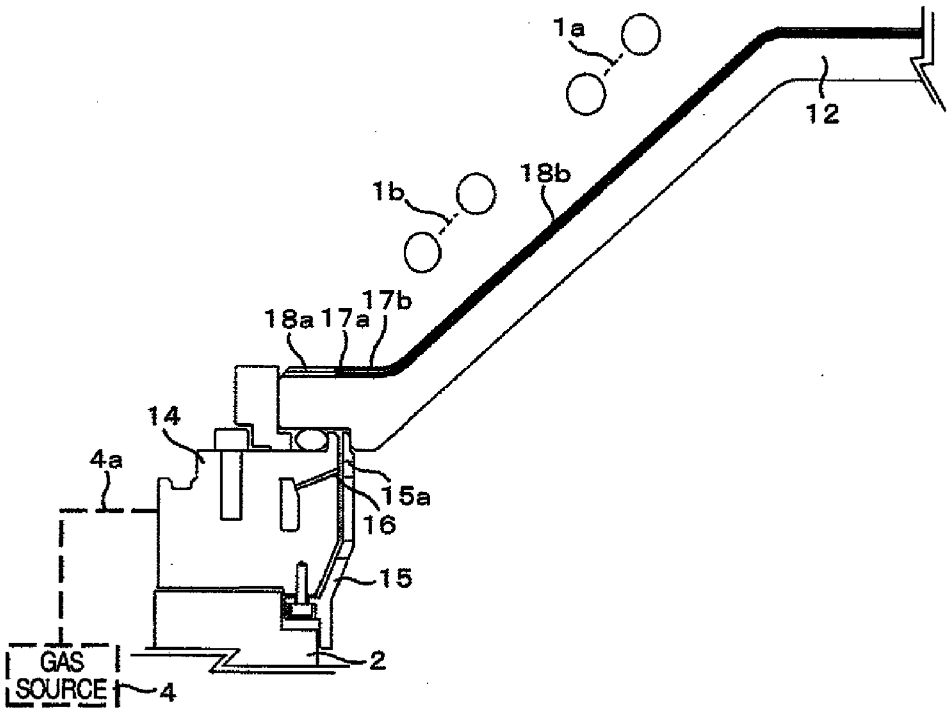

1a
12
1b
18b
18a
17a
17b
14
4a
15a
16
15
2
GAS SOURCE
4

FIG.4

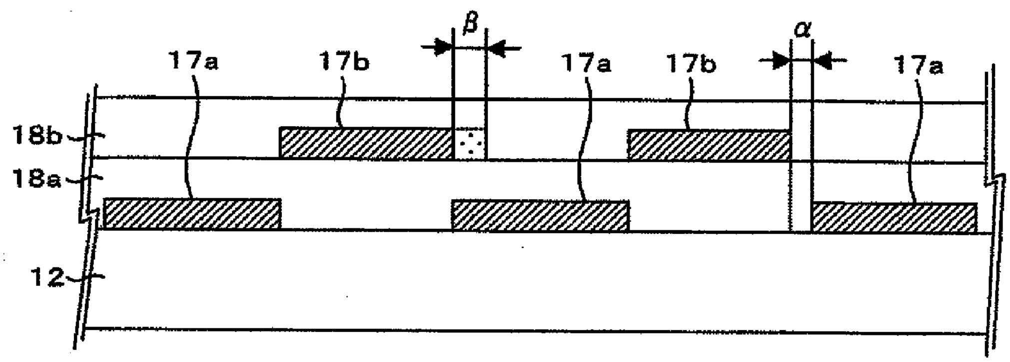

β
α
17a
17b
17a
17b
17a
18b
18a
12

FIG.5

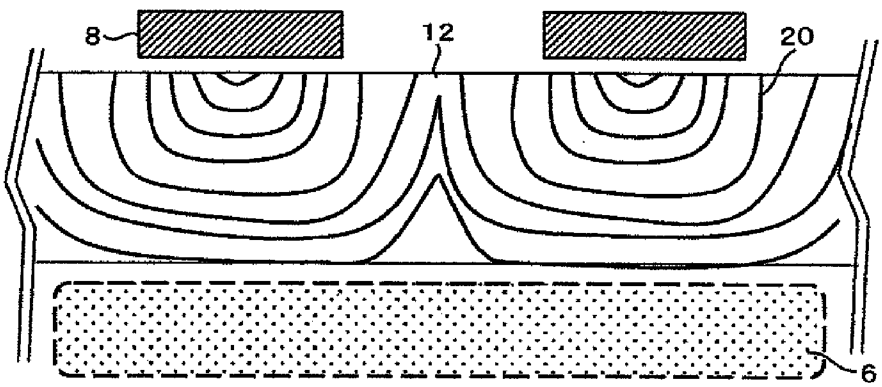
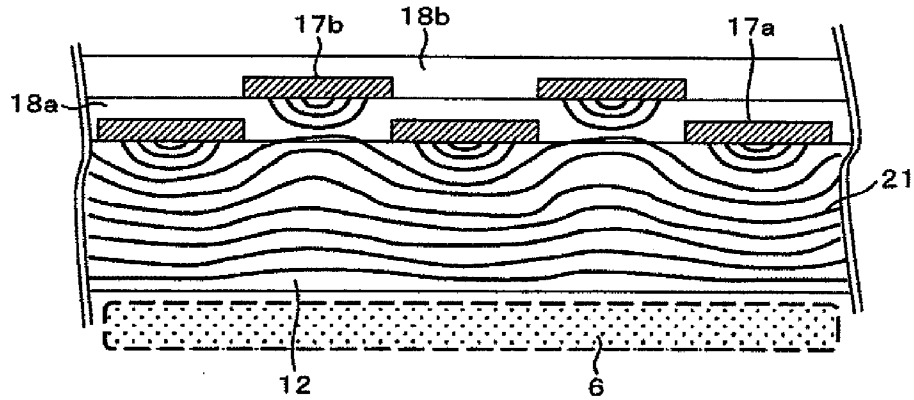


FIG.6



PLASMA PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

[0001] This invention relates to a plasma processing apparatus, or in particular, to a plasma processing apparatus for etching or otherwise processing a sample using a plasma formed in a processing chamber by supplying a high frequency to a coil-shaped antenna wound on the outer periphery of a processing chamber.

[0002] Generally, in the etching apparatus described above, a reaction product formed from a certain type of the processing gas and the material of the film arranged on the surface of a substrate-like sample such as a semiconductor wafer to be etched is attached to the inner wall surface of the processing chamber in the processing chamber. It is known that such a product deposited on the inner wall surface, if increased in amount, is peeled off or separated from the wall surface and, by attaching again to the sample surface, produces the contaminating matter which pollutes the sample surface.

[0003] Also, the deposition of such a product is known to deteriorate the stability of the process of etching, for example, Al_2O_3 with Cl_2 or SiO_2 with CF as a processing gas. In view of this, the conventional techniques are known to reduce the product attached to the inner wall surface of the processing chamber.

[0004] As an example of the conventional techniques, a Faraday shield is arranged between a plasma and a coil-shaped antenna wound on the outer periphery of a vacuum vessel and supplied with high-frequency power to suppress or remove the deposition on inner wall of the vacuum vessel. Such a conventional technique is disclosed, for example, in JP-A-2000-323298. According to the technique disclosed in JP-A-2000-323298, a plasma is formed in a processing chamber of an insulating material due to an induction field or a magnetic field formed by the high-frequency power supplied to a coil-shaped antenna. With the power supplied to the Faraday shield, the charged particles forming the plasma are attracted and impinged on the product on the inner wall surface of the processing chamber by the potential difference with the potential of a predetermined magnitude maintained on the inner wall of the processing chamber thereby to remove the product.

[0005] Another method using the Faraday shield is known in which the film of a specified metal is arranged on the outer wall surface of the processing chamber to function as a Faraday shield. For example, JP-A-2004-235545 discloses a technique of forming by spraying a tungsten film on the outer wall surface of a processing chamber of an insulating material.

SUMMARY OF THE INVENTION

[0006] The conventional techniques described above have posed a problem for lack of full consideration of the following points.

[0007] Specifically, in the case where a film is formed on the outer surface of the vacuum vessel as disclosed in JP-A-2004-235545, the gap between the filmy Faraday shield and the outer wall surface of the vacuum vessel is removed, so that the electrostatic capacitance between the Faraday shield and the plasma can be reduced to a minimum. As compared with the prior art, therefore, the deposition can be suppressed or removed with a higher effect on the one hand, while the fact that, as in the prior art configured of a tabular member, the Faraday shield has a planar shape with a slit portion extending in longitudinal (vertical) direction leads to the disadvantage that the electrostatic field formed by the power supplied to the Faraday shield fails to work on the portion of the processing chamber immediately under the slit portion (the inner wall surface of the processing chamber corresponding to the internal space of the slit portion).

[0008] Specifically, in the slit portion, the charged particles are not attracted to the inner wall surface of the vacuum vessel or so attracted considerably less than in the left and right non-slit portions (the inner wall surface having the outer periphery covered with a tabular or filmy member), thereby reducing the sputtering effect. As a result, a large difference develops in the amount of the attached product or deposition between the respective inner wall surface portions of the vacuum vessel corresponding to the slit and non-slit portions, and therefore, it is difficult to remove the attached product uniformly. This poses the problem that the processing operation along the peripheral direction of the sample (the peripheral direction of the processing chamber in the shape of a cylinder or a cone (truncated cone)) becomes disuniform and unstable with the result that the configuration of the Faraday shield makes it impossible to realize a uniform process.

[0009] An object of this invention is to provide a plasma processing apparatus capable of realizing a more uniform process. Another object of the invention is to provide a plasma processing apparatus which suppresses the generation of the contaminating matter for an improved yield.

[0010] In order to solve the problem described above, according to one aspect of this invention, there is provided a plasma processing apparatus in which a wafer placed on a sample stage arranged in a processing chamber inside a vacuum vessel is processed using the plasma formed in the particular processing chamber, comprising a dielectric bell jar making up the upper part of the vacuum vessel and surrounding the processing chamber, a coil-shaped antenna wound on the outer periphery of the bell jar and supplied with the high-frequency power to form the plasma, and a Faraday shield of a dielectric material formed in double layers including inner and outer layers in spaced relation to each other between the antenna and the bell jar, wherein the slits of one of the inner and outer layers of the Faraday shield are arranged to cover the film portions between the slits of the other of the inner and outer layers in staggered fashion.

[0011] According to another aspect of the invention, there is provided a plasma processing apparatus, wherein the Faraday shield is formed of a plurality of film layers arranged on the outer peripheral wall surface of the bell jar.

[0012] According to still another aspect of the invention, there is provided a plasma processing apparatus, wherein the high-frequency power is supplied to the Faraday shield.

[0013] According to yet another aspect of the invention, there is provided a plasma processing apparatus, wherein each member between the adjacent slits of the outer Faraday shield portion is arranged to cover the whole gaps of the slits of the inner Faraday shield portion in the peripheral direction of the wafer.

[0014] According to a further aspect of the invention, there is provided a plasma processing apparatus, wherein an insulating film is arranged between the inner and outer Faraday shield portions.

[0015] According to a still further aspect of the invention, there is provided a plasma processing apparatus, wherein the inner or outer Faraday shield portion is formed by spraying.

[0016] Other objects, features and advantages of the invention will become apparent from the following description of the embodiments of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a diagram for explaining a general configuration of a plasma processing apparatus according to an embodiment of the invention.
[0018] FIG. **2** is a perspective view schematically showing the configuration of a typical Faraday shield according to the prior art.
[0019] FIG. **3** is an enlarged general view of the configuration of the upper part of the apparatus according to the embodiment shown in FIG. **1**.
[0020] FIG. **4** is an enlarged view schematically showing the cross section of the Faraday shield and the bell jar **12** shown in FIG. **3**.
[0021] FIG. **5** is a diagram schematically showing the processing vessel and the distribution of the electrostatic or magnetic field therein of the plasma processing apparatus using the conventional Faraday shield.
[0022] FIG. **6** is a diagram schematically showing the processing vessel and the distribution of the electrostatic or magnetic field therein according to the embodiment shown in FIG. **1**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0023] The plasma processing apparatus according to an embodiment of the invention is explained below with reference to the drawings.

Embodiment 1

[0024] FIG. **1** is a diagram for explaining a general configuration of a plasma processing apparatus according to an embodiment of the invention. A plasma processing apparatus **100** according to this embodiment includes a vessel having a vacuum vessel **2** configured to surround a vacuum processing chamber, a radio wave source or a magnetic field source arranged on the exterior of the vacuum vessel **2** to supply the electric field or the magnetic field, respectively, into the vacuum processing chamber, and an exhaust means for decompressing by exhausting the interior of the vessel.
[0025] The vessel includes the cylindrical vacuum vessel **2** and a bell jar **12** formed of an insulating material (such as quartz, ceramic or other nonconductive material) arranged above the cylindrical vacuum vessel **2** and coupled to the vacuum vessel **2** to enclose the internal cylindrical space. The bell jar **12**, having a trapezoidal longitudinal section, is in the shape of a truncated cone symmetric about the vertical center axis passing through the circular cross section thereof. The vacuum processing chamber providing a space in the bell jar **12** is surrounded by the inner wall surface of the vacuum vessel **2** and the bell jar **12**, which are coupled to each other in such a manner that the interior of the plasma processing apparatus **100** can be sealed hermetically against the external atmospheric environment.
[0026] The vacuum processing chamber providing the internal space of the vessel has therein a sample stage **5** on which a substrate-like sample **13** is mounted in parallel to the inner wall surface of the top flat portion of the bell jar **12**. The internal space of the vacuum processing chamber above the sample stage **5** forms an area where, as described later, the pressure is reduced to a predetermined vacuum degree to generate a plasma **6** and the sample **13** is processed using the plasma **6**. Also, the sample stage **5** makes up the upper part of a cylindrical sample holder **9** including the sample stage **5**. The space between the outer periphery of the sample holder **9** and the cylindrical inner wall of the vacuum vessel **2** makes up the vacuum processing chamber as a passage through which a gas, containing the particles of the products generated by processing the plasma **6** formed above the sample **13**, the processing gas supplied and the sample **13**, is discharged by flowing down.
[0027] The coil-shaped antenna **1** is wound in a plurality of layers on the outer periphery of the outer inclined wall surface of the bell jar **12**. The antenna **1** according to this embodiment, divided into a plurality of positions of different heights, has an upper antenna portion **1***a* and a lower antenna portion **1***b*. Further, a filmy Faraday shield **8** is arranged along the exterior of the inclined outer wall surface of the bell jar **12** in such a manner as to cover the particular inclined surface.
[0028] The bell jar **12** according to this embodiment is mounted on and coupled hermetically to the upper part of the vacuum vessel **2**, and arranged with the circular lower end thereof located above the upper sample mounting surface of the sample stage **5** to surround the sample **13** circumferentially above it. The Faraday shield **8** arranged to cover the outer periphery of the bell jar **12** and the coil-shaped antenna **1** wound on the outside of the Faraday shield **8** are arranged to surround the outer periphery of the vacuum processing chamber to form the plasma **6** above the sample stage **5** or the sample **13** mounted thereon.
[0029] The Faraday shield **8** according to this embodiment is arranged to cover the outer wall surface including the inclined surface and the top flat portion of the bell jar **12**. The Faraday shield **8** is connected in series to a high-frequency power supply (first high-frequency power supply) **10** through a matching box **3**. While the sample **13** is processed, the Faraday shield **8** is maintained at a predetermined potential in its entirety and capacitively coupled to the plasma **6** having a specified potential as a dielectric material. The upper antenna portion **1***a*, the lower antenna portion **1***b* and the Faraday shield **8** are also connected with a series resonant circuit (a variable capacitor VC**3** and a reactor L**2**) having the impedance variable magnitude in parallel between the Faraday shield **8** and the earth.
[0030] The potential of the Faraday shield **8** is adjusted to a predetermined level by the matching box **3** including the series resonant circuit. Especially, the potential of the Faraday shield **8** according to this embodiment is adjustable to an arbitrary positive or negative value as well as the earth potential. This value can be set, for example, to attract the charged particles in the plasma in the vacuum processing chamber toward the Faraday shield **8** and impinge them on the surface of the bell jar **12**. By the impingement of the charged particles, the product deposited is released again physically or chemically into the internal space of the vacuum processing chamber thereby to reduce the deposition.
[0031] A gas feed pipe **4***a* connecting the vacuum vessel **2** and a gas source **4** of the processing gas supplied into the vacuum processing chamber is coupled to the upper end portion of the vacuum vessel **2**. The processing gas flowing in the gas feed pipe **4***a* from the gas source **4** is supplied into the vacuum processing chamber from an opening facing it. Also, by the operation of an exhaust unit **7** arranged under and

coupled to the vacuum vessel **2**, the gas in the vacuum processing chamber is discharged from an opening at the lower part of the vacuum processing chamber communicating with the exhaust unit **7**, so that the internal pressure of the vacuum processing chamber is reduced to a predetermined level.

[0032] The exhaust unit **7** includes an exhaust pump such as a turbo molecular pump generally used in the technical field of the invention, and an opening communicating between the exhaust pump and the interior of the vacuum processing chamber is formed at a designed horizontal distance from the center axis of the sample stage **5** under the vacuum vessel **2**. On the path communicating between this opening and the inlet of the exhaust pump, there are horizontally arranged a plurality of exhaust valves adapted to increase or decrease the open area of the particular path by rotating around the axis thereof. The pressure is regulated by rotating these exhaust valves to adjust the flow area of the path and the exhaustion rate.

[0033] The processing gas supplied into the vacuum processing chamber through the gas feed pipe **4***a* is converted into a plasma by the operation of the electric field or the magnetic field generated by the power supplied to the upper antenna portion **1***a* and the lower antenna portion **1***b*. The electrode arranged in the sample stage **5** is connected with a substrate bias power supply (second high-frequency power supply) **11**, from which power is supplied to the electrode thereby to form the bias potential above the sample stage **5** and the sample **13** placed thereon. In accordance with the potential difference between this bias potential and the potential of the plasma **6**, the charged particles such as ions existing in the plasma **6** can be attracted onto the sample **13** so that the sample **13** can be processed at a high processing rate as desired.

[0034] Incidentally, the power supplied from the high-frequency power supply **10** is the high-frequency power of, for example, 13.56 MH or a higher frequency in VHF band. By supplying this high frequency power to the antenna **1** or the Faraday shield **8**, an induction field or a magnetic field is formed to generate the plasma **6** in the vacuum processing chamber. In the process, the impedance of the antenna **1** is rendered to coincide with the output impedance of the high-frequency power supply **10** using the matching box **3**, thereby making it possible to suppress the power reflection. According to this embodiment, variable capacitors VC**1**, VC**2** connected in the form of an inverted L as shown, for example, are used as the matching box **3**.

[0035] According to this embodiment, the sample **13** such as a semiconductor wafer is transported through a carrier chamber (held by a vacuum robot arm not shown) coupled to the outer side wall of the internally decompressed vacuum vessel **2**, and after being delivered onto a plurality of pins on the sample stage **5** in the vacuum processing chamber, placed on the circular upper surface of the sample stage **5** and held there by adsorption. With a heat transmission gas supplied between the back of the sample **13** and the sample stage **5**, the particles of the processing gas supplied into the vacuum processing chamber above the sample **13** are dissociated by the induction or magnetic field supplied from the antenna **1**. In this way, a plasma due to the inductive coupling, i.e. the plasma **6** of what is called the induction type is formed. At the same time, the substrate bias is formed above the sample **13** and the sample is processed by the power supplied to the electrode in the sample stage **5**.

[0036] A predetermined process of the sample **13** is started and, after detection of the end of the process, the adsorption is ceased and the sample **13** is retrieved in the reverse order of the delivery steps.

[0037] According to this embodiment, the Faraday shield **8** exhibits a crucial effect in generating the plasma **6**. In the absence of the Faraday shield **8**, each part of the coil of the antenna **1** impressed with a voltage by the high-frequency power supplied to the antenna **1** would have an arbitrary potential. As a result, the electrostatic coupling would occur between the coil of the antenna **1** and the plasma **6** having a potential in the vacuum processing chamber. Therefore, the inner wall surface of the bell jar **12** in the neighborhood of the antenna **1** wound on the outer periphery of the inclined surface portion would be locally scraped off by the impingement of the charged particles from the plasma **6**, and the inner wall surface of the vacuum processing chamber would be consumed unevenly.

[0038] Further, this change in the wall surface state changes the coupling between the antenna **1** and the plasma **6** in the bell jar **12**, resulting in the adverse effect of changing the etching characteristic such as the etching rate, uniformity or the processing verticality on the surface of the sample **13**. To alleviate this problem, the plasma **6** and the Faraday shield **8** are arranged and a predetermined potential is applied to the Faraday shield **8** to reduce the potential difference between the inner wall surface of the bell jar **12** and the plasma **6**. Furthermore, as in this invention, the potential supplied to and formed in the Faraday shield **8** is adjusted in such a manner as to remove the deposits attached on the inner wall surface of the bell jar **12** by the impingement of the charged particles from the plasma **6**. In this way, the consumption of the inner wall surface of the bell jar **12** can be suppressed while at the same time preventing the change in uniformity and the secular variation of the process for an improved yield.

[0039] FIG. **2** is a perspective view schematically showing the configuration of the conventional Faraday shield. In FIG. **2**, the upper part represents the bell jar **12**. The Faraday shield made of a metal or the like conductor is covered on the upper surface and the inclined surface of the bell jar **12** through a predetermined gap. The portion of the Faraday shield **8** covering the inclined surface has a plurality of slits formed radially of the center axis of the circular upper surface and extending vertically to cross the direction in which the coil of the antenna **1** is wound insulatively on the outer periphery of the Faraday shield **8**. These slits are arranged in order not to shield the entire electric or magnetic field formed by the antenna **1** but to introduce a part of the electric or magnetic field into the vacuum processing chamber in preparation for ignition of the plasma **6**.

[0040] In the conventional processing apparatus using the Faraday shield **8** described above, a large difference occurs in the amount of deposits between the inner wall surface of the bell jar **12** immediately under the slits and the material between the slits of the Faraday shield **8**. Specifically, a large amount of deposits are attached on the inner wall surface of the bell jar **12** just inside the slits, whereas the deposits just inside the material between the slits are small in amount. Thus, the deposits on the inner wall of the vacuum processing chamber are attached unevenly along the periphery of the sample **13** or the cylindrical periphery of the vacuum processing chamber, with the result that the sample is processed unevenly along the peripheral direction.

[0041] FIG. **3** is a longitudinal sectional view showing, in enlarged form, the essential parts of the embodiment shown in FIG. **1**. As shown in FIG. **3**, the bell jar **12** is formed of an insulating material (for example, quartz, ceramics such as aluminum oxide or the like non-conductive material) having a trapezoidal longitudinal section. The antenna **1** (including the upper antenna portion **1***a* and the lower antenna portion **1***b*) is wound on the outer periphery of the inclined portion of the bell jar **12**. The Faraday shield **8** is located between the upper and lower antenna portions **1***a*, **1***b* and the outer peripheral wall surface of the bell jar **12**.

[0042] A gas ring **14** is an annular member arranged under the circular lower end of the bell jar **12** around the outer periphery of the vacuum processing chamber. This gas ring **14** is a member arranged at a point where at least one opening through which the processing gas supplied as described above is introduced into the vacuum processing chamber faces the vacuum processing chamber. The gas ring **14** has formed therein a gas passage, not shown, through which the processing gas (for example, Cl_2, BCl_3, CO or carbon fluoride such as C_4F_8, C_5F_8 or CF_4) supplied from the gas feed pipe **4***a* flows. The processing gas, after passing through the gas passage, flows out into the vacuum processing chamber from a gas outlet **16** formed on the surface of the gas ring **14** facing the interior of the vacuum processing chamber.

[0043] According to this embodiment, an annular anti-deposition plate **15** covers, through a gap, the internal wall surface of the gas ring **14** facing the vacuum processing chamber to prevent the products or other attached substances from being deposited on the surface of the gas ring **14**, or especially, the gas outlet **16**. The processing gas introduced from the gas outlet **16** into the vacuum processing chamber, after passing through an outlet opening **15***a* formed on the anti-deposition plate **15**, flows into and diffuses in the space above the sample **13**. Incidentally, according to this embodiment, the anti-deposition plate **15** has the upper end thereof arranged between the lower end surface of the bell jar **12** and the upper end surface of the gas ring **14**. Nevertheless, the anti-deposition plate **15** may alternatively be arranged in such a manner that the upper end portion thereof extends to cover the inner wall surface of the lower end portion of the bell jar **12**.

[0044] According to this embodiment, the Faraday shield **8** is configured of a conductive thin film **17** covering the outer peripheral wall surface of the bell jar **12**. Especially, as shown in FIG. **3**, the conductive thin film **17** is formed of a plurality of film layers. A plurality of insulating layers **18** of Al_2O_3, for example, insulate conductive films **17***a* forming lower layers and conductive films **17***b* (tungsten (W), for example) forming upper layers from each other, and the bell jar **12**. The plurality of the insulating layers **18** configured to insulate the plurality of the conductive films **17***a*, **17***b* include a lower insulating layer **18***a* and an upper insulating layer **18***b* stacked alternately with the conductive films **17***a*, **17***b*.

[0045] These layers are formed by a specified method on the outer surface of the bell jar **12**. Especially, according to this embodiment, the layers are formed by spraying. As the result of forming the Faraday shield **8** and the insulating layers **18** by spraying as thin films, the accurate thickness of the films can be secured in both peripheral and vertical directions. As a result, the distance between the Faraday shield **8** and the plasma **6** can be accurately controlled on the one hand, and the uniformity of the amount of the substances deposited on the inner wall surface of the bell jar **12** is improved so that the deposits on the inner wall surface of the bell jar can be removed uniformly on the other hand.

[0046] Further, the configuration in which the Faraday shield **8** is formed of a plurality of layers arranged at a predetermined distance from each other makes it possible to remove the deposits with a lower voltage (Faraday shield voltage; FSV) applied to the Faraday shield **8**. As a result, the consumption of the inner wall surface of the bell jar **12** by the Faraday shield **8** having the slits is alleviated. Incidentally, the principle of cleaning the inner wall surface of the bell jar **12** by the Faraday shield **8** and the method of optimizing the FSV are described in detail in JP-A-2004-235545.

[0047] FIG. **4** is a sectional view schematically showing a general configuration of the Faraday shield and the vacuum vessel according to the embodiment shown in FIG. **1**. As shown in FIG. **4**, according to this embodiment, a plurality of the conductive films **17***a*, **17***b* making up the Faraday shield **8** are arranged in staggered fashion with the insulating layers **18***a*, **18***b* inserted therebetween to form the slit portion of the Faraday shield **8** three-dimensionally.

[0048] Specifically, the conductive films **17***a* of tungsten, the insulating layer **18***a* as a thin film of alumina, the conductive films **17***b* of tungsten and the insulating layer **18***b* of alumina are arranged in that order upward (outward) from the outer peripheral surface of the bell jar **12**. The conductive films **17***b* on the upper side and the conductive films **17***a* on the lower side are arranged to cover the whole of the inclined surface and the top of the bell jar **12**, respectively, and have a plurality of slits extending vertically, i.e. in the direction crossing the direction (horizontal direction in this embodiment) in which the antenna **1** is wound.

[0049] These slits are arranged to prevent the situation in which the reverse electromotive current generated in the Faraday shield **8** by the induction or magnetic field of the plasma **6** or the antenna **1** flows in the direction hampering the formation of the electric or magnetic field, as the case may be. For this purpose, the slits are arranged at many points over as wide a range as possible covered by the electric or magnetic field. In short, the configuration shown in FIG. **2** is held.

[0050] Also, the film portions of the upper conductive films **17***b* between the slits are arranged to cover the outside (upper portion) of the slits of the lower conductive films **17***a*. Specifically, the slits of one of the conductive films **17***a*, **17***b* are covered by the material between the slits of the other of the conductive films **17***a*, **17***b*. In other words, the conductive films **17***a*, **17***b* of the Faraday shield **8** arranged in multiple layers are formed with the plurality of the slits and the material therebetween in staggered fashion.

[0051] The relative positions of the horizontal ends of the film portions between the slits of the conductive films **17***a*, **17***b*, as shown in FIG. **4**, may be such that a gap is formed as viewed from the outer direction (radial direction) or the film portions may be retreated from the end portion into the interior and overlapped. According to this embodiment, the end points of the film portions between the slits are overlapped on a straight line or to a degree not having an extremely adverse effect on the operation and effects.

[0052] In the case where a large gap is developed between the end points of the film portion between the slits of the upper and lower conductive films **17***a*, **17***b* as indicated by character a in FIG. **4**, a large amount of the product would be deposited on the inner wall surface of the bell jar **12** immediately inside the gap portion α as compared with the surrounding portion thereof. In the case where the tungsten films are overlapped considerably as indicated by β, on the other hand, a circumferential current is more liable to be generated through a stray capacitance between the conductive films **17***a*, **17***b* with the increase in the overlapped area. In the process, the induction or magnetic field generated by the conductive antenna **1** is offset by the circumferential current and it may become difficult to secure the density or distribution of the plasma **6** as desired. In order to satisfy the specification, therefore, it is desirable to overlap the film portions in an appropriate amount.

[0053] To realize the layer structure of the Faraday shield **8** according to this embodiment, each film is formed as described below. Specifically, the conductive films **17***a*, **17***b* each have the thickness of 100 μm and the insulating layers **18***a*, **18***b* each have the thickness of 150 μm. This invention, however, is not limited to these thickness values, but the thickness of each film is set appropriately in such a way as not to generate the circumferential current in the conductive films **17***a*, **17***b* as a whole. Further, the widths of each slit and each film portion between the slits are appropriately selected in accordance with the specification including the magnitude of the supplied power, the frequency, the material of the bell jar **12** and the thickness.

[0054] Also, according to this embodiment, the lower layers and the insulating layer **18***b* are both arranged to cover the whole of the top portion and the inclined surface portion of the bell jar **12**, so that the conductive films **17***a*, **17***b* are not exposed to the atmosphere. At the time of cleaning by removing the bell jar **12** from the plasma processing apparatus **100** proper, therefore, the conductive films **17***a*, **17***b* are corroded less in contact with the atmosphere or the cleaning material, thereby facilitating the handling for an improved cleaning efficiency.

[0055] Next, the operation of the electrostatic or magnetic field according to this embodiment is explained with reference to FIGS. **5** and **6**. FIG. **5** is a diagram schematically showing the processing vessel and the electrostatic or magnetic field therein of the conventional plasma processing apparatus using the Faraday shield, and FIG. **6** is a diagram schematically showing the processing vessel according to the embodiment shown in FIG. **1** and the distribution of the electrostatic or magnetic field in the processing vessel. In FIGS. **5** and **6**, the thick contour lines connect the points of equal strength of the electrostatic or magnetic field supplied from the Faraday shield **8** or the conductive films **17***a*, **17***b*. The greater the flatness of the contour lines, the greater the flatness of the magnitude of the operation to attract the charged particles in the plasma **6**. In other words, the uniformity with which the charged particles impinge on the inner wall surface of the bell jar **12** is increased.

[0056] In the configuration of the conventional Faraday shield **8** shown in FIG. **5**, the electrostatic field **20** generated by the supplied power, as described above, develops a point in the slit portion where the strength of the electrostatic field **20** is reduced and the contour lines lack uniformity. Therefore, the electrostatic field **20** reaches the plasma **6** in the state lacking uniformity on the inner wall surface of the bell jar **12**. As a result, the density, the amount and the deposition of ions reaching the inner wall surface of the bell jar **12** become extremely uneven along the peripheral direction on the inner wall surface of the bell jar **12**.

[0057] According to this embodiment, on the other hand, as shown in FIG. **6**, the slits of the multiple conductive films **17***a*, **17***b* making up the Faraday shield **8** are arranged in staggered fashion with the insulating later **18***a* therebetween. In this configuration, the slit portion of the conductive film **17***a* making up the lower film of the insulating layer **18***a* and the upper part thereof are supplied with the electrostatic or magnetic field from the film portion between the slits of the upper conductive film **17***b*. This electric or magnetic field increases the strength of the electrostatic or magnetic field of the conductive film **17***a* in the slit portion (between the film end portions of the lower conductive film **17***a*). Thus, coupled with the electrostatic or magnetic filed **21** generated from the conductive film **17***b*, the reduction in the electrostatic or magnetic field **21** in the slit portion of the lower conductive film **17***a* is suppressed. As a result, the electrostatic or magnetic field **21** that has reached the inner wall surface of the bell jar **12** can face the plasma **6** with a greater flatness. For this reason, the deposits can be removed more uniformly than in the conventional technique.

[0058] On the other hand, although the slits of the upper and lower conductive films **17***a*, **17***b* are covered by the film portions, the induction field or the magnetic field from the antenna **1** passes through the vertically stacked insulating layers **18***a*, **18***b* between the conductive films **17***a*, **17***b*, and an electric or magnetic field can be formed in the vacuum processing chamber through the bell jar **12** from the slit portion of the conductive film **17***a*. As a result, the electric or magnetic field required to maintain the ignition of the plasma **6** is prevented from extremely deteriorating the Faraday shield **8** having the configuration according to this embodiment as compared with the conventional technique.

[0059] As described above, according to this embodiment, the amount of consumption of or deposition on the inner wall surface of the vacuum processing chamber with the outer peripheral wall surface thereof covered by the Faraday shield **8** is uniformized along the peripheral direction of the sample **13** or the vacuum processing chamber, thereby realizing a plasma processing apparatus improved in reliability and service life. Also, the sample is processed uniformly along the peripheral direction on the one hand, and the generation of contaminating matter is suppressed while at the same time assuring the uniform distribution of the contaminating matter on the other hand, resulting in an improved processing efficiency and yield.

[0060] The configuration of the invention described above is not limited to this embodiment, but can be appropriately selected in accordance with the required specification without adversely affecting the operation and effects with the improved reliability and efficiency. For example, according to this embodiment, the high-frequency power is supplied to the Faraday shield **8**, and by forming a bias potential on the inner wall surface of the bell jar **12**, the charged particles are attracted. As in the conventional technique, however, the grounding potential may alternatively be employed and the supplied power may be adjusted to attach the deposits appropriately and maintain a uniform amount of the deposits.

[0061] It should be further understood by those skilled in the art that although the foregoing description has been made on embodiments of the invention, the invention is not limited thereto and various changes and modifications may be made without departing from the spirit of the invention and the scope of the appended claims.

1. A plasma processing apparatus in which a wafer placed on a sample stage arranged in a processing chamber in a vacuum vessel is processed using the plasma formed in the processing chamber, comprising:

a bell jar of an insulating material making up the upper part of the vacuum vessel and surrounding the processing chamber;

a coil-shaped antenna wound on the outer periphery of the bell jar and supplied with the high-frequency power to form the plasma; and

a Faraday shield of a conductive material arranged in double layers inside and outside with a gap between the antenna and the bell jar, each layer having a plurality of slits and set at a predetermined potential;

wherein the slits of the outer and inner layers of the Faraday shield are arranged in staggered fashion so that the slits of one of the outer and inner layers of the Faraday shield cover the film portions of the other of the outer and inner layers of the Faraday shield.

2. The plasma processing apparatus according to claim **1**, wherein the Faraday shield is formed of a plurality of film layers arranged on the outer peripheral wall surface of the bell jar.

3. The plasma processing apparatus according to claim **1**, wherein the high-frequency power is supplied to the Faraday shield.

4. The plasma processing apparatus according to claim **1**, wherein the film portions between the adjacent slits of the outer layer of the Faraday shield are arranged to cover the whole gap of the slits of the inner layer of the Faraday shield along the peripheral direction of the wafer.

5. The plasma processing apparatus according to claim **1**, wherein an insulative film is arranged between the inner and outer layers of the Faraday shield.

6. The plasma processing apparatus according to claim **1**, wherein selected one of the inner and outer layers of the Faraday shield is formed by spraying.

7. A plasma processing apparatus comprising:

a sample stage arranged in a processing chamber in an internally decompressed processing vessel and having a circular wafer mounted thereon;

a bell jar of an insulating material making up the upper part of the processing vessel and surrounding the outer periphery of the sample stage above the sample stage;

a coil-shaped antenna wound to surround the sample stage on the outside of the outer wall surface of the bell jar;

a power supply for supplying the high-frequency power to the antenna;

a filmy Faraday shield arranged between the bell jar and the antenna and set to a predetermined potential; and

an exhaust means coupled to the lower part of the processing vessel and arranged to communicate with the processing chamber;

wherein the Faraday shield includes inner and outer layers arranged in spaced relation to each other, each layer having a plurality of slits, and the film portions between the plurality of the slits of the inner and outer layers of the Faraday shield are arranged in staggered fashion so that the film portions between the slits of one of the inner and outer layers cover the slits of the other layer of the Faraday shield.

8. The plasma processing apparatus according to claim **7**, wherein the high-frequency power is supplied to the Faraday shield.

9. The plasma processing apparatus according to claim **7**, wherein the film portions between the adjacent slits of the outer layer of the Faraday shield are arranged to cover the slits of the inner layer of the Faraday shield over the whole peripheral gap of the wafer.

10. The plasma processing apparatus according to claim **7**, wherein a film of an insulating material is arranged between the inner and outer layers of the Faraday shield.

11. The plasma processing apparatus according to claim **7**, wherein selected one of the inner and outer layers of the Faraday shield is formed by spraying.

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