

FARADAY SHIELD AND REACTION CHAMBER

TECHNICAL FIELD

The present disclosure relates to the field of semiconductor manufacturing technology, and in particular, to a Faraday shield and a reaction chamber.

BACKGROUND

In the process of manufacturing an integrated circuit and a MEMS device using an Inductive Coupled Plasma Emission Spectrometer (hereinafter referred to as ICP) device, the generated plasma includes a large amount of active particles such as electrons, ions, excited atoms, molecules, free radicals and the like, and these active particles interact with the substrate to cause various physical and chemical reactions on a surface of the material, thereby changing the surface properties of the material.

Fig.1 is a cross-sectional view of an existing ICP device. Referring to Fig. 1, the ICP device includes a reaction chamber 1, a dielectric cylinder 3 disposed on a side wall 2 of the reaction chamber 1. A radio frequency coil 4 is disposed around the outside of the dielectric cylinder 3, and is electrically connected to an upper radio frequency power source 6 through an upper adapter 5, the upper radio frequency power source 6 is configured to supply radio frequency power to the radio frequency coil 4, and an electromagnetic field generated by the radio frequency coil 4 can pass through the dielectric cylinder 3 to be fed into the reaction chamber 1, so as to excite a process gas in the reaction chamber 1 to form a plasma. Moreover, a base 9 is further disposed in the reaction chamber 1, and is electrically connected to a lower radio frequency power source 8 through a lower adapter 7, and the lower radio frequency power source 8 is configured to supply a radio frequency negative bias to the base 9, so as to attract the plasma to etch a surface of a substrate. In addition, a Faraday shield 10 is disposed around the inside of the dielectric cylinder 3 to protect the dielectric cylinder 3 from being etched by the plasma and prevent a residue that sputters from the surface of the substrate from adhering to an inner wall of the dielectric cylinder 3, thereby improving the energy coupling efficiency of the dielectric cylinder 3 and

reducing particle contamination in the reaction chamber 1.

Fig. 2 is a structural diagram of an existing Faraday shield. Referring to Fig. 2, the Faraday shield 10 is a annular body, and a slit 101 extending in an axial direction of the annular body is formed on the annular body, and the slit 101 extends from the upper end surface of the annular body to the lower end surface of the annular body to completely disconnect the annular body, that is, the annular body is discontinuous in a circumferential direction thereof, so that the Faraday shield 10 can be prevented from generating eddy current loss and heat.

In the structure of the Faraday shield 10 mentioned above, as the slit 101 is along the axial direction of the annular body, as shown in Fig. 3, only a magnetic field component A, in the axial direction of the annular body, of the electromagnetic field generated by the radio frequency coil 4 annular body can pass through the slit 101, whereas an electric field component B of the electromagnetic field in the circumferential direction of the annular body can hardly pass through the slit 101 to be coupled into the reaction chamber, thereby resulting in a relatively low coupling efficiency of the magnetic field. The relatively low magnetic coupling efficiency often requires a relatively high radio frequency power to be loaded to the radio frequency coil 4 in order to achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition to reduce damage to a base dielectric layer when the base dielectric layer is made of a low-k material. However, loading a relatively high radio frequency power to the radio frequency coil 4 will cause the temperature of Faraday shield 10 to be too high due to the increased eddy current loss and the strengthened ion bombardment, thereby increasing the risk of particle contamination in the reaction chamber 1.

SUMMARY

The present disclosure aims to solve at least one of the technical problems existing in the prior art, and provides a Faraday shield and a reaction chamber, which can increase the total coupling efficiency of an electromagnetic field, so that a radio frequency power required to be loaded to a radio frequency coil can be decreased.

In order to realize the object of the present disclosure, there is provided a Faraday shield, including a conductive annular body, a slit being formed on the conductive annular body, and in an unfolded view of the conductive annular body, a projection of the slit in an axial direction of the conductive annular body has a length greater than zero, and a projection of the slit in a circumferential direction of the conductive annular body has a length greater than zero.

In an embodiment, the slit includes a first sub-slit, and an absolute value of an angle between a projection of an axis of the conductive annular body in the unfolded view of the conductive annular body and an extending direction of the first sub-slit is greater than 0 degree and less than 90 degrees.

In an embodiment, the angle between the projection of the axis of the conductive annular body in the unfolded view of the conductive annular body and the extending direction of the first sub-slit is 45 degrees.

In an embodiment, the first sub-slit extends from an upper end surface of the conductive annular body to a lower end surface of the conductive annular body such that the conductive annular body is completely disconnected in the circumferential direction thereof.

In an embodiment, the slit further includes a second sub-slit, and in the unfolded view of the conductive annular body, an angle between an extending direction of the second sub-slit and an extending direction of the first sub-slit is greater than 0 degree.

In an embodiment, the slit includes a first sub-slit and a second sub-slit, and in the unfolded view of the conductive annular body, an angle between a projection of an axis of the conductive annular body and an extending direction of the first sub-slit is equal to 90 degrees; an angle between an extending direction of the second sub-slit and the extending direction of the first sub-slit is greater than 0 degree.

In an embodiment, the second sub-slit extends from an upper end surface of the conductive annular body to a lower end surface of the conductive annular body such that the conductive annular body is completely disconnected in the circumferential direction thereof, or the second sub-slit is between the upper end surface and the lower end surface of the conductive annular body but does not reach the upper end

surface or the lower end surface of the conductive annular body.

In an embodiment, the second sub-slit and the first sub-slit intersect each other.

In an embodiment, the slit includes one or a plurality of second sub-slits, and in a case of the plurality of second sub-slits, the plurality of second sub-slits are distributed at an interval along the extending direction of the first sub-slit.

In an embodiment, the slit includes a plurality of first sub-slits, and the plurality of first sub-slits is evenly distributed along the circumferential direction of the conductive annular body.

In an embodiment, the conductive annular body is divided into N first regions and M second regions in the circumferential direction thereof, and the first regions and the second regions alternate, where N and M are integers greater than or equal to 1; at least two first sub-slits are disposed in each first region, and the at least two first sub-slits are distributed at an interval along the axial direction of the conductive annular body; at least two second sub-slits are disposed in each second region, and the at least two second sub-slits are distributed at an interval along the circumferential direction of the conductive annular body.

In an embodiment, the N first regions and the M second regions are evenly distributed along the circumferential direction of the conductive annular body; for each first region, the at least two first sub-slits therein are evenly distributed; for each second region, the at least two second sub-slits therein are evenly distributed.

In an embodiment, a width of the first region in the circumferential direction of the conductive annular body is 50 mm to 200 mm.

In an embodiment, on a cross section obtained by cutting the slit along a plane perpendicular to an axis of the conductive annular body, the slit is presented as a tortuous passage.

In an embodiment, the slit is presented as a tortuous passage in such a form that none of straight lines L1, L2, L3, and L4 meets the following requirement: the straight line does not cut or intersect S1 and S2 except at an upper left corner, a lower left corner, an upper right corner, and a lower right corner of the slit, and the straight line is between S1 and S2; wherein, S1 is a section line of an outer side surface of the slit,

S2 is a section line of an inner side surface of the slit, L1 is a straight line connecting the upper right corner and the lower right corner of the slit, L2 is a straight line connecting the upper left corner and the lower right corner of the slit, L3 is a straight line connecting the upper right corner and the lower left corner of the slit, and L4 is a straight line connecting the upper left corner and the lower left corner of the slit.

In an embodiment, the tortuous passage is formed by disposing a blocking portion in the slit.

In an embodiment, there are two blocking portions, which are a first blocking portion and a second blocking portion, respectively, and the first blocking portion and the second blocking portion are respectively disposed on a first end surface and a second end surface of the conductive annular body at the slit. The first blocking portion extends from the first end surface toward the second end surface, and there is a first gap between the first blocking portion and the second end surface; the second blocking portion extends from the second end surface toward the first end surface, and there is a second gap between the second blocking portion and the first end surface; there is a third gap between the first blocking portion and the second blocking portion in a radial direction of the conductive annular body; and the first gap, the second gap, and the third gap constitute the tortuous passage.

In an embodiment, the slit is filled with a dielectric material.

A width of the slit is in a range of 2 mm to 10 mm.

As another aspect, the present disclosure also provides a reaction chamber, including a dielectric cylinder, a Faraday shield and a radio frequency coil, the radio frequency coil being disposed around an outer side of the dielectric cylinder; the Faraday shield being disposed around an inner side of the dielectric cylinder, wherein the Faraday shield uses the Faraday shield according to any one of aforesaid solutions.

In an embodiment, the radio frequency coil uses a cylindrical three-dimensional spiral coil formed by a winding wire having a rectangular section.

In an embodiment, a spacing in an axial direction between any two adjacent turns of the winding wire of the cylindrical three-dimensional spiral coil is 6 mm to 10 mm.

In an embodiment, the reaction chamber is a pre-cleaning chamber.

The present disclosure has the beneficial effects as follows.

The Faraday shield provided by the present disclosure includes a conductive annular body, a slit is formed on the conductive annular body, and in an unfolded view of the conductive annular body, a projection of the slit in an axial direction of the conductive annular body has a length greater than zero, and a projection of the slit in a circumferential direction of the conductive annular body has a length greater than zero, so as to increase the total coupling efficiency of an electromagnetic field by increasing the coupling efficiency of an electric field component of the electromagnetic field in the circumferential direction of the conductive annular body, thereby reducing the radio frequency power required to be loaded onto the radio frequency coil, that is, even if a relatively low radio frequency power is loaded, it also can achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition, so as to reduce the damage to a substrate dielectric layer when the substrate dielectric layer is made of a low-k material. In addition, loading a relatively low radio frequency power can also avoid the temperature of the Faraday shield from being too high, thereby reducing the risk of particle contamination in the reaction chamber.

The reaction chamber provided by the present disclosure, by using the Faraday shield provided by the present disclosure, can reduce the radio frequency power required to be loaded onto the radio frequency coil, as a result, even if a relatively low radio frequency power is loaded, it also can achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition, so as to reduce the damage to a substrate dielectric layer when the substrate dielectric layer is made of a low-k material. In addition, loading a relatively low radio frequency power can also avoid the temperature of the Faraday shield from being too high, thereby reducing the risk of particle contamination in the reaction chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of an existing ICP device;

Fig. 2 is a structural diagram of an existing Faraday shield;

Fig. 3 is a partial structural diagram of an existing Faraday shield;

Fig. 4A is a structural diagram of a Faraday shield provided by a first embodiment of the present disclosure;

Fig. 4B is a partial structural schematic diagram of an unfolded view of a Faraday shield provided by the first embodiment of the present disclosure;

Fig. 4C is a partial structural schematic diagram of an unfolded view of another Faraday shield provided by the first embodiment of the present disclosure;

Fig. 4D is a partial structural schematic diagram of an unfolded view of another Faraday shield provided by the first embodiment of the present disclosure;

Fig. 4E is a partial structural schematic diagram of the unfolded view of another Faraday shield provided by the first embodiment of the present disclosure;

Fig. 5 is a partial structural diagram of a Faraday shield provided by a second embodiment of the present disclosure;

Fig. 6 is a side view of a Faraday shield provided by a third embodiment of the present disclosure;

Fig. 7A is a radial sectional view of a Faraday shield provided by a fourth embodiment of the present disclosure;

Fig. 7B is an enlarged view of region I in Fig. 7A;

Fig. 8A is a partial enlarged top view of a conductive annular body, showing line L1 and line L2;

Fig. 8B is a partial enlarged top view of the conductive annular body shown in Fig. 8A, showing line L3 and line L4;

Fig. 8C is a partial enlarged top view of the conductive annular body shown in Fig. 8A, showing a movement path of a particle;

Fig. 8D is a partial enlarged top view of a conductive annular body, showing line L1 and line L2;

Fig. 8E is a partial enlarged view top view of the conductive annular body shown in Fig. 8D, showing line L3 and line L4;

Fig. 8F is a partial enlarged top view of a conductive annular body, showing line L1 and line L2;

Fig. 8G is a partial enlarged top view of the conductive annular body shown in

Fig. 8F, showing line L3 and line L4;

Fig. 9 is a cross-sectional view of a reaction chamber provided by an embodiment of the present disclosure;

Fig. 10 is a structural diagram of a radio frequency coil used in an embodiment of the present disclosure; and

Fig. 11 is a structural view of another radio frequency coil used in an embodiment of the present disclosure.

DETAILED DESCRIPTION

In order to enable one skilled in the art to better understand technical solutions of the present disclosure, a Faraday shield and a reaction chamber according to the present disclosure will be described in detail below in conjunction with the accompanying drawings.

Before describing the Faraday shield and the reaction chamber provided by the present disclosure in detail, a width of a slit is first defined as follows: in the present disclosure, the width of the slit refers to a perpendicular distance between two long sides of the slit. When the slit includes a first sub-slit only, the width of the slit refers to the width of the first sub-slit; and when the slit includes a first sub-slit and a second sub-slit, a limitation on the width of the slit is not only a limitation on the width of the first sub-slit, but also a limitation on the width of the second sub-slit, that is, both the width of each first sub-slit and the width of each second sub-slit should within a numerical range of the width of the slit in each embodiment.

Thereinafter, the technical solutions provided by the present disclosure will be described in detail. The present disclosure provides a Faraday shield, including a conductive annular body, a slit formed on the conductive annular body, in an unfolded view of the conductive annular body, a projection of the slit in an axial direction of the conductive annular body has a length greater than zero, and a projection of the slit in a circumferential direction of the conductive annular body has a length greater than zero. In fact, it can also be understood that in the unfolded view of the conductive annular body, the slit can be decomposed into a component along the axial direction of the

conductive annular body and a component along the circumferential direction of the conductive annular body. It should be noted that, in the present application, regardless of the width of the slit, in the length of the projection of the slit in the axial direction of the conductive annular body, a length contributed by the width of the slit is equal to zero, and in the length of the projection of the slit in the circumferential direction of the conductive annular body, a length contributed by the width of the slit is equal to zero; in other words, when discussing the projection of the slit in the axial direction of the conductive annular body and/or the projection of the slit in the circumferential direction of the conductive annular body, the width of the slit should be regarded as zero, that is, two long sides of the slit are considered to coincide.

Referring to Fig. 4A and Fig. 4B together, a Faraday shield provided by a first embodiment of the present disclosure includes a conductive annular body 11, and a slit is formed on the conductive annular body 11, the slit including a first sub-slit 111. In an unfolded view of the conductive annular body shown in Fig. 4B, an angle a is formed between the first sub-slit 111 and the circumferential direction of the conductive annular body 11, and an angle b is formed between the first sub-slit 111 and a projection Z (the straight line Z in Fig. 4B) of an axis of the conductive annular body 11 on the unfolded view, where $b=90-a$, $|b| = |90-a|$, and the absolute value of b should be greater than 0 degree and less than 90 degrees. In the unfolded view of the conductive annular body shown in Fig. 4B, the length of the projection of the first sub-slit 111 in the axial direction of the conductive annular body 11 is L_a , and the length of the projection of the first sub-slit 111 in the circumferential direction of the conductive annular body 11 is L_c . From Fig. 4B, it can be clearly seen that both L_a and L_c are greater than zero. The electromagnetic field generated by the radio frequency coil 13 surrounding the conductive annular body 11, can be divided into a magnetic field component A along the axial direction of the conductive annular body 11 and an electric field component B along the circumferential direction of the conductive annular body 11. With the first sub-slit 111, the magnetic field component A along the axial direction of the conductive annular body 11 has a sub-component in an inclination direction of the first sub-slit 111, and this sub-component can be fed

into the reaction chamber through the first sub-slit 111, meanwhile the electric field component B along the circumferential direction of the conductive annular body 11 has a sub-component in the inclination direction of the first sub-slit 111, and this sub-component can be fed into the reaction chamber through the first sub-slit 111.

Poynting vector refers to the directional energy flux density energy flux density of an electromagnetic field, represents the energy transfer per unit area per unit time, and has a unit of the watt per square meter (W/m^2). Assuming that at a certain point in space, the electric field strength is E and the magnetic field strength is H, the energy flux density of the electromagnetic field at this point is $S=E \times H$, and the direction is determined by E and H according to the right-handed screw rule. The energy flux density of the electromagnetic field at this point has a value $|S| = |E| |H| \sin \theta$, where θ is an angle between E and H.

Based on the above principle, in a case where a slit is provided along the axial direction of the conductive annular body 11 as in the prior art, $E \approx 0$, and therefore $S \approx 0$. Assuming that an angle b formed between the first sub-slit 111 and the axis of the conductive annular body 11 is 45° , $\theta=45^\circ$, and it is obtained by substituting to the above formula that $|S| = |E| \cos 45^\circ \times |H| \sin 45^\circ \times \sin 45^\circ$. It can be seen that the energy flux density passing through the first sub-slit 111 is larger than the energy flux density passing through the slit provided along the axial direction of the conductive annular body 11 in the prior art. Therefore, in the present disclosure, the total coupling efficiency of the electromagnetic field is increased, thereby the radio frequency power required to be loaded to the radio frequency coil 13 will be reduced. That is, even if a relatively low radio frequency power is loaded, it can also achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition to reduce damage to a substrate dielectric layer when the substrate dielectric layer is made of a low-k material. In addition, loading a relatively low radio frequency power can also avoid the temperature of the Faraday shield being too high, thereby reducing the risk of particle contamination in the reaction chamber.

Preferably, the angle b formed between the first sub-slit 111 and the axis of the conductive annular body 11 is 45° , in this way, the length of the first sub-slit 111 can

be maximized, thereby maximizing the energy flux density and in turn increasing the total coupling efficiency of the electromagnetic field to the largest extent.

It should be noted that, in the present embodiment, the first sub-slit 111 is linear, but the present disclosure is not limited thereto. In practical applications, the first sub-slit 111 may be also in the shape of a broken line or an arc or the like, as long as the coupling efficiency of the magnetic field component of the electromagnetic field in the circumferential direction of the conductive annular body 11 can be increased to achieve the purpose of increasing the total coupling efficiency of the electromagnetic field. For example, the angle between the projection of the axis of the conductive annular body 11 on the unfolded view of the conductive annular body 11 and an extending direction of first sub-slit 111 may be set to have an absolute value greater than 0 degree and less than 90 degrees. The extending direction of the first sub-slit 111 refers to a direction of a line connecting the lower end and the upper end of the first sub-slit 111 in the unfolded view of the conductive annular body 11.

As a preferable solution of the present embodiment, the slit may further include a second sub-slit, and in the unfolded view of the conductive annular body 11, an angle between an extending direction of the second sub-slit and the extending direction of the first sub-slit 111 is greater than 0 degree. That is, any slit whose extending direction is different from the extending direction of the first sub-slit 111 is referred to as the second sub-slit. There may be one or more second sub-slits, and the extending directions of a plurality of second sub-slits may be the same or different from each other.

For example, as shown in Fig 4C, the slit further includes a second sub-slit 112 in addition to the first sub-slit 111, and the second sub-slit 112 is provided along the axial direction of the conductive annular body 11, and intersects with the first sub-slit 111 to form an angle c therebetween. In the unfolded view of the conductive annular body shown in Fig. 4C, the length of the projection of the slit in the axial direction of the conductive annular body 11 is L_a , the length of the projection of the slit in the circumferential direction of the conductive annular body 11 is L_c , and it can be seen clearly from Fig. 4C that both L_a and L_c are greater than zero. In the present

embodiment, the slit includes a first sub-slit 111 and a second sub-slit 112, and with the second sub-slit 112, the coupling efficiency of the magnetic field component A can be further increased.

In the present embodiment, the first sub-slit 111 extends from the upper end surface of the conductive annular body 11 to the lower end surface of the conductive annular body 11 so as to completely disconnect the conductive annular body 11 to avoid eddy current loss and heat generation in the conductive annular body 11. Moreover, the second sub-slit 112 does not extend to the upper end surface or the lower end surface of the conductive annular body 11 but is between the two end surfaces, namely, the second sub-slit 112 does not completely disconnect the conductive annular body 11, so that the conductive annular body 11 remains as one whole.

In order to prevent, to the largest extent, parts (such as the dielectric cylinder) inside the Faraday shield from being corroded at the slit on the premise that the coupling efficiency of the magnetic field is not affected, the slit has a width (hw) in the range of 2 mm to 10 mm, preferably in the range of 5mm to 8mm. Corresponding to the above definition of the width of the slit, in the present embodiment, the width hw of the slit refers to the widths of the first sub-slit 111 and the second sub-slit 112, and the widths of the first sub-slit 111 and the first sub-slit 112 may be the same or different from each other.

As shown in Fig. 4D, in order to prevent the parts (such as the dielectric cylinder) inside the Faraday shield from being corroded at the slit, a dielectric material 12, such as a ceramic, may be filled in the slit,. The electromagnetic field can be fed into the reaction chamber through the dielectric material 12.

It should be noted that, in the present embodiment, there is only one second sub-slit 112, but the present disclosure is not limited thereto. In practical applications, as shown in Fig. 4E, there may be a plurality of second sub-slit 112, and the plurality of the second sub-slits 112 are spaced apart along the extending direction (inclination direction) of the first sub-slit 111. Moreover, in the unfolded view of the conductive annular body shown in Fig. 4E, the length of projection of the slit in the axial

direction of the conductive annular body 11 is L_a , the length of projection of the slit in the circumferential direction of the conductive annular body 11 is L_c , and it can be seen clearly from Fig. 4E that both L_a and L_c are greater than zero.

It should be noted that, in the present embodiment, the second sub-slit(s) 112 and the first sub-slit 111 intersect with each other, but the present disclosure is not limited thereto. In practical applications, the second sub-slit(s) 112 may be separated from the first sub-slit 111.

It should be noted that, in practical applications, there may be one or more first sub-slits, and in case of a plurality of first sub-slits, the plurality of first sub-slits are spaced apart and evenly distributed along the circumferential direction of the conductive annular body 11 to ensure process uniformity. It is easy to understand that the larger the number of the first sub-slits and/or the second sub-slits, the greater the total coupling efficiency of the electromagnetic field.

Referring to Fig. 5, a Faraday shield provided by a second embodiment of the present disclosure includes a conductive annular body 21, and a slit is formed on the conductive annular body 21, the slit including two first sub-slits 212 extending along a circumferential direction of the conductive annular body 21, and arranged at an interval along an axial direction of the conductive annular body 21. Moreover, an angle between a projection of an axis of the conductive annular body 21 in the unfolded view of the conductive annular body 21 and the extending direction of the first sub-slits 212 is 90° , so that an electric field component B in the circumferential direction of the conductive annular body 21 can be fed into the reaction chamber through the first sub-slits 212.

Moreover, the slit also includes a second sub-slit 211 extending along the axial direction of the conductive annular body 21, and the second sub-slit 211 intersect with the first sub-slits 212. As the second sub-slit 211 extends along the axial direction of the conductive annular body 21, it allows a magnetic field component A in the axial direction of the conductive annular body 11 to be fed into the reaction chamber.

It can be seen clearly from the unfolded view of the conductive annular body shown in Fig. 5 that a projection of the slit in the axial direction of the conductive

annular body 21 has a length of L_a , a projection of the slit in the circumferential direction of the conductive annular body 21 has a length of L_c , and both L_a and L_c are greater than zero. With the first sub-slits 212 and the second sub-slit 211, the electric field component B and the magnetic field component A can be fed into the reaction chamber, respectively. Compared with a case where only the magnetic component A can be fed in the prior art, the total coupling efficiency of the electromagnetic field can be increased, thereby reducing the radio frequency power required to be loaded onto the radio frequency coil. That is, even if a lower radio frequency power is loaded, it can also achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition to reduce damage to a substrate dielectric layer when the substrate dielectric layer is made of a low-k material. In addition, loading a relatively low radio frequency power can also avoid a too high temperature of the Faraday shield, thereby reducing the risk of particle contamination in the reaction chamber.

In the present embodiment, the second sub-slit 211 extends from an upper end surface of the conductive annular body 11 to a lower end surface of the conductive annular body 11 so as to completely disconnect the conductive annular body 11 to avoid eddy current loss and heat generation in the conductive annular body 11. Moreover, each first sub-slit 212 does not extend to the upper end surface or the lower end surface of the conductive annular body 11 but between the two end surfaces, that is, the first sub-slits 212 do not completely disconnect the conductive annular body 21 between the two end surfaces, so that the conductive annular body 11 remains as one whole.

In the present embodiment, the number of the first sub-slits 212 is two. However, the present disclosure is not limited thereto. In practical applications, the number of the first sub-slits 212 may be one, or more than three, and angles formed between a plurality of first sub-slits 212 and the axis of the conductive annular body 21 may be the same or different from one another.

Referring to Fig. 6, a Faraday shield provided by a third embodiment of the present disclosure includes a conductive annular body 41, the conductive annular

body 41 is divided into a plurality of first regions 411 and a plurality of second regions 412 in a circumferential direction thereof, and the plurality of first regions 411 and the plurality of second regions 412 alternates, that is, on the left and right sides of the first region 411 are the second regions 412, and on the left and right sides of the second region 412 are the first regions 411. At least two first sub-slits 42 extending along the circumferential direction of the conductive annular body 41 and arranged at an interval along the axial direction (namely, the Y direction shown in Fig. 6) of the conductive annular body 41 are provided in each of the plurality of first regions 411; at least two second sub-slits 43 extending along the axial direction of the conductive annular body 41 and arranged at an interval along the circumferential direction (namely, the X direction shown in Fig. 6) of the conductive annular body 41 are provided in each of the plurality of second regions 412. Moreover, in the unfolded view of the conductive annular body shown in Fig. 6, a projection of the slit in the axial direction of the conductive annular body 41 has a length of L_a , a projection of the slit in the circumferential direction of the conductive annular body 41 has a length of L_c , and it can be seen clearly from Fig. 6 that both L_a and L_c are greater than zero. With the first sub-slits 42 and the second sub-slits 43, the electric field component B and the magnetic field component A can also be fed into the reaction chamber, respectively, thereby increasing the total coupling efficiency of the electromagnetic field, and in turn reducing the radio frequency power required to be loaded onto radio frequency coil.

In order to ensure process uniformity, preferably, the plurality of first regions 411 and the plurality of second regions 412 are evenly distributed along the circumferential direction of the conductive annular body 41. Moreover, for each of the plurality of first regions 411, the first sub-slits 42 therein are evenly distributed; and for each of the plurality of second regions 412, the second sub-slits 43 therein are evenly distributed.

Preferably, a width of the first region 411 in the circumferential direction of the conductive annular body 41 is 50 mm to 200 mm to reduce eddy current to the largest extent. The width of the first region 411 in the circumferential direction of the

conductive annular body 41 refers to a width of the first region 411 in the circumferential direction of the conductive annular body 41 in the unfolded view of the conductive annular body 41.

Referring to Fig. 7A and Fig. 7B together, a Faraday shield is provided by a fourth embodiment of the present disclosure on the basis of the above first to third embodiments. Specifically, in the above first to third embodiments, each slit has an opening on an inner wall of the conductive annular body and an opening on an outer wall of the conductive annular body, and a projection, on the outer wall of the conductive annular body, of the opening of the slit on the inner wall of the conductive annular body completely coincides or partially overlaps with the opening of the slit on the outer wall of the conductive annular body. In other words, in the top view of the conductive annular body, the slit extends along a thickness direction of the conductive annular body. In the fourth embodiment, in the top view of the conductive annular body, the slit is configured to be in the form of a tortuous passage. The tortuous passage means that in the top view of the conductive annular body, an extending direction of the slit does not coincide with the thickness direction of the conductive annular body, but at a certain angle t with respect to the thickness direction of the conductive annular body.

Specifically, a blocking portion is provided in the slit and on the conductive annular body 31 such that a tortuous passage 34 is formed between the outer wall and the inner wall of the conductive annular body 31. An extending direction of the tortuous passage 34 is the extending direction of the slit, that is, the extending direction of the straight line 11, the thickness direction of the conductive annular body 31 is the extending direction of the straight line 12, and an angle between them is t . Forming the tortuous passage 34 can further prevent the parts (such as the dielectric cylinder) inside the Faraday shield from being corroded at the slit, without affecting the coupling efficiency of the magnetic field.

In the present embodiment, there are two blocking portions, namely, a first blocking portion 32 and a second blocking portion 33, which are respectively disposed on the first end surface 311 and the second end surface 312 of the conductive

annular body 31 at the slit. The first end surface 311 and the second end surface 312 are two sections opposite to each other and disconnected by the slit of the conductive annular body 31. The first blocking portion 32 extends from the first end surface 311 toward the second end surface 312, and there is a first gap 321 between the first blocking portion 32 and the second end surface 312. An extending direction of the first blocking portion 32 is preferably the circumferential direction of the conductive annular body 31. The second blocking portion 33 extends from the second end surface 312 toward the first end surface 311 and there is a second gap 331 between the second blocking portion 33 and the first end surface 311. A third gap 341 is formed between the first blocking portion 32 and the second blocking portion 33 in the radial direction of the conductive annular body 31. The first gap 321, the second gap 331, and the third gap 341 constitute the tortuous passage 34.

In practical applications, the blocking portions may adopt any other structure as long as the following design requirements can be satisfied: a labyrinthic tortuous passage can be formed in the radial direction of the conductive annular body 31, so as to prevent the parts inside the Faraday shield from being corroded due to the presence of the slit.

Thereinafter, a pattern of the tortuous passage that the slit is configured to have and can prevent particles inside the conductive annular body from directly passing through the slit to the outside of the conductive annular body is specifically described with reference to Figs. 8A to 8G.

Referring to Figs. 8A to 8C, in a partially enlarged top view of the conductive annular body 11, that is, in a view obtained by cutting a region where the first sub-slit 111 is located using a plane perpendicular to the axis of the conductive annular body 11, the first sub-slit 111 is in an arc shape, S1 is a section line of the outer side surface of the first sub-slit 111, S2 is a section line of the inner side surface of the first sub-slit 111, L1 is a straight line connecting the upper right corner and the lower right corner of the first sub-slit 111, L2 is a straight line connecting the upper left corner and the lower right corner of the first sub-slit 111, L3 is a straight line connecting the upper

right corner and the lower left corner of the first sub-slit 111, and L4 is a straight line connecting the upper left corner and the lower left corner of the first sub-slit 111. L1 only intersects S2 at the upper and lower endpoints (i.e., the upper right corner and the lower right corner of the first sub-slit 111) of S2, and L1 is on the right side of S2 rather than between S1 and S2; in addition to the upper endpoint of S1 and the lower endpoint of S2 (i.e., the upper left corner and the lower right corner of the first sub-slit 111), L2 also intersects S1 and S2 at point B of S2; in addition to the lower endpoint of S1 and the upper endpoint of S2 (i.e., the upper right corner and the lower left corner of the first sub-slit 111), L3 also intersects S1 and S2 at point C of S2; L4 only intersects S1 at the upper and lower endpoints (i.e., the upper left corner and the lower left corner of the first sub-slit 111) of S1. Since L4 does not cut or intersect S1 and S2 except at the upper and lower endpoints of S1 and is between S1 and S2, that is, L4 and the conductive annular body 31 do not have any intersection point other than the upper left corner, the lower left corner, the upper right corner and the lower right corner of the first sub-slit 111, as such, a region between L4 in the first sub-slit 111 and S2 becomes a passage that runs through an inside region and an outside region of the conductive annular body 31 in a straight line direction, so that particles inside the conductive annular body 31 can directly reach the outside of the conductive annular body 31 through the passage, and the dotted line arrow in Fig. 8C shows a path through which particles inside the conductive annular body 31 pass through the first sub-slit 111 to directly reach the outside of the conductive annular body 31. It can be seen that a plasma inside the conductive annular body 11 can directly pass through the first sub-slit 111 shown in Figs. 8A to 8C, that is, the first sub-slits adopting the configurations shown in Figs. 8A to 8C cannot prevent the plasma from passing through the first sub-slit 111 from the inside of the conductive annular body 11 to reach the outside of the conductive annular body 11, resulting in that a part (such as, the dielectric cylinder) inside the Faraday shield is corroded at the position of the first sub-slit 11.

Referring to Figs. 8D and 8E, in a partially enlarged top view of the conductive annular body 11, that is, in a view obtained by cutting a region where the first sub-slit

111 is located using a plane perpendicular to the axis of the conductive annular body 11, the first sub-slit 111 is in an arc shape. In the embodiment, the meanings of S1, S2, L1, L2, L3, and L4 are the same as those of the corresponding symbols in the aforesaid embodiments shown in Figs. 8A to 8C, and are not repeatedly described herein. L1 only intersects S2 at the upper and lower endpoints of S2 (i.e., the upper right corner and the lower right corner of the first sub-slit 111), and L1 is on the right side of S2 rather than between S1 and S2; in addition to the upper endpoint of S1 and the lower endpoint of S2 (i.e., the upper left corner and the lower right corner of the first sub-slit 111), L2 also intersects S1 and S2 at point B of S2; in addition to the lower endpoint of S1 and the upper endpoint of S2 (i.e., the upper right corner and the lower left corner of the first sub-slit 111), L3 also intersects S1 and S2 at point C of S2; in addition to the upper endpoint and lower endpoints of S1 (i.e., the upper left corner and the lower left corner of the first sub-slit 111), L4 also intersects S2 at points D1 and D2 of S2. None of the straight lines L1, L2, L3, and L4 meets the following requirement: it does not cut or intersect S1 and S2 except at the upper left corner and the lower left corner of the first sub-slit 111, and is between S1 and S2 (that is, none of the straight lines L1, L2, L3 and L4 has an intersection point with the conductive annular body 31 other than the upper left corner, the lower left corner, the upper right corner and the lower right corner of the first sub-slit 111). In this way, when the first sub-slit adopts the configuration shown in Fig. 8D or 8E, there is no passage (or path) that runs through the inner region and the outer region of the conductive annular body 31 along a straight line direction, so that particles inside the conductive annular body 31 can pass through this passage (or path) to directly reach the outside of the conductive annular body 31.

Referring to Figs. 8F and 8G, in a partially enlarged top view of the conductive annular body 11, that is, in a view obtained by cutting a region where the first sub-slit 111 is located using a plane perpendicular to the axis of the conductive annular body 11, the first sub-slit 111 is in an arc shape. In the embodiment, the meanings of S1, S2, L1, L2, L3, and L4 are the same as those of the corresponding symbols in the aforesaid embodiments shown in Figs. 8A to 8C, and are not repeatedly described

herein. In addition to the upper and lower endpoints of S1 (i.e., the upper right corner and the lower right corner of the first sub-slit 111), L1 also intersects S1 and S2 at the point A1 of S1 and the points A2 and A3 of S2; in addition to the lower endpoint of S1 and the upper endpoint of S2 (i.e., the upper left corner and lower right corner of the first sub-slit 111), L2 also intersects S1 and S2 at the points B1 and B2 of S1 and the points B3 and B4 of S2; in addition to the upper endpoint of S1 and the lower endpoint of S2 (i.e., the upper right corner and the lower left corner of the first sub-slit 111), L3 also intersects S1 and S2 at the point C1 of S1 and the point C2 of S2; in addition to the upper and lower two endpoints of S2 (i.e., the upper left corner and the lower left corner of the first sub-slit 111), L4 also intersects S1 and S2 at the points D1 and D2 of S1 and the point D3 of S2. None of the straight lines L1, L2, L3, and L4 meets the following requirement: it does not cut or intersect S1 and S2 except at the upper left corner and the lower left corner of the first sub-slit 111, and is between S1 and S2 (that is, none of the straight lines L1, L2, L3 and L4 has an intersection point with the conductive annular body 31 other than the upper left corner, the lower left corner, the upper right corner and the lower right corner of the first sub-slit 111). In this way, when the first sub-slit adopts the configuration shown in Fig. 8F or 8G, there is no passage (or path) that runs through the inner region and the outer region of the conductive annular body 31 along a straight line direction, so that particles inside the conductive annular body 31 can pass through this passage (or path) to directly reach the outside of the conductive annular body 31.

The following principle can be found through the above description: as long as any one of the straight lines L1, L2, L3, and L4 does not cut or intersect S1 and S2 except at the upper left corner, the lower left corner, the upper right corner, and the lower right corner of the slit and is between S1 and S2, particles inside the conductive annular body can directly pass through the slit to reach the outside of the conductive annular body, that is, the slit cannot prevent the particles inside the conductive annular body from directly passing through the slit to reach the outside of the conductive annular body, resulting in that a part (such as the dielectric cylinder) inside the Faraday shield is corroded at the slit. Preferably, the slit is configured to be such a

tortuous passage that in a top view of the conductive annular body, each of L1, L2, L3, and L4 fails to meet the following requirement: the line does not cut or intersect S1 and S2 except at the upper left corner, the lower left corner, the upper right corner, and the lower right corner of the slit and is between S1 and S2.

In summary, the Faraday shield provided by the embodiments of the present disclosure includes a conductive annular body, a slit is formed on the conductive annular body, and in an unfolded view of the conductive annular body, a projection of the slit in an axial direction of the conductive annular body has a length greater than zero, and a projection of the slit in a circumferential direction of the conductive annular body has a length greater than zero, so as to increase the total coupling efficiency of the electromagnetic field by increasing the coupling efficiency of the magnetic field component of the electromagnetic field in the circumferential direction of the conductive annular body, thereby reducing the radio frequency power required to be loaded onto the radio frequency coil, that is, even if a relatively low radio frequency power is loaded, it also can achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition to reduce the damage to a substrate dielectric layer when the substrate dielectric layer is made of a low-k material. In addition, loading a relatively low radio frequency power can also avoid a too high temperature of the Faraday shield, thereby decreasing the risk of particle contamination in the reaction chamber.

As another technical solution, as shown in Fig. 9, an embodiment of the present disclosure further provides a reaction chamber 201, and a dielectric cylinder 203 is disposed in a sidewall 202 of the reaction chamber 201. A radio frequency coil 204 is disposed around an outer side of the dielectric cylinder 203, and is electrically connected to an upper radio frequency power source 206 through an upper adapter 207. The upper radio frequency power source 206 is configured to supply a radio frequency power to the radio frequency coil 204, and an electromagnetic field generated by the radio frequency coil 204 can pass through the dielectric cylinder 203 to be fed into the reaction chamber 201 to excite a process gas in the reaction chamber 201 to form a plasma. Moreover, a base 9 is further disposed in the reaction chamber

201, and is electrically connected to a lower radio frequency power source 208 through a lower adapter 209, and the lower radio frequency power source 208 is configured to supply a radio frequency negative bias to the base 9 to attract the plasma to etch a surface of a substrate. In addition, a Faraday shield 210 is disposed around an inner side of the dielectric cylinder 203 for protecting the dielectric cylinder 203 from being etched by the plasma and meanwhile preventing a residue sputtering from the surface of the substrate from adhering to the inner wall of the dielectric cylinder 203, thereby improving the energy coupling efficiency of the dielectric cylinder 203 and reducing particle contamination in the reaction chamber 201. The Faraday shield 210 may be grounded or may have a floating potential.

The Faraday shield 201 is the Faraday shield provided by any of the above embodiments in the present disclosure.

As shown in Fig. 9, in the present embodiment, the radio frequency coil 204 is a cylindrical three-dimensional spiral coil, and a winding wire forming the cylindrical three-dimensional spiral coil has a section in the shape of a circle (in the embodiment of the present disclosure, the section is a section perpendicular to an axis of winding wire). However, the present disclosure is not limited thereto, and the winding wire may have a section in other shape. Preferably, as shown in Fig. 10, the winding wire of the radio frequency coil 204' has a section in the shape of a rectangle, and the radio frequency coil 204' formed by winding the winding wire extends upward and downward as shown in the figure to form a cylindrical three-dimensional spiral coil. the winding wire has a width W (i.e., the height of a single turn of the winding wire in the vertical direction) greater than a diameter of the winding wire having a circular section as shown in Fig. 9, so that a cross-sectional area of the winding wire having a rectangular section is larger than a cross-sectional area of the winding wire having a circular section.

Parasitic capacitance between the cylindrical three-dimensional spiral coil and the Faraday shield is proportional to the cross-sectional area of the cylindrical three-dimensional spiral coil. The smaller the parasitic capacitance, the weaker the capacitive coupling, and the weaker the electric field intensity fed into the reaction

chamber; conversely, the larger the parasitic capacitance, the stronger the capacitive coupling, and the stronger the electric field intensity fed into the reaction chamber, and thus the electric field intensity is sufficient to achieve the plasma ignition. Based on this theory, by using a cylindrical three-dimensional spiral coil formed by a winding wire having a rectangular section as the radio frequency coil 204', and making the cross-sectional area of the winding wire having the rectangular section larger than the cross-sectional area of the winding wire having a circular section, the parasitic capacitance can be increased, thereby strengthening the capacitive coupling, and in turn strengthening the electric field intensity fed into the reaction chamber.

Preferably, a spacing d , in the axial direction, between any two adjacent turns of winding wire of the cylindrical three-dimensional spiral coil formed by winding the winding wire with a rectangular section is 6 mm to 10 mm, and thus sparking phenomenon due to a potential difference between two adjacent turns of winding wire can be prevented.

In practical applications, the cylindrical three-dimensional spiral coil formed by the winding wire having a rectangular section has a thickness of 2 mm to 4 mm in a radial direction thereof. Moreover, the cylindrical three-dimensional spiral coil formed by the winding wire having a rectangular section has a height h_c that cannot exceed the height of the dielectric cylinder 203, that is, the cylindrical three-dimensional spiral coil formed by the winding wire having a rectangular section has an upper end lower than an upper end of the dielectric cylinder 203, and a lower end higher than a lower end of the dielectric cylinder 203.

In practical applications, the reaction chamber 201 may be a pre-cleaning chamber. In this case, a radio frequency power loaded onto the radio frequency coil 204 may have a frequency of 2 MHz, 13.56 MHz or 60 MHz or the like. Alternatively, a radio frequency power formed by a pulse may be loaded. A radio frequency power loaded onto the base 9 may have a frequency of 400 kHz, 2 MHz, 13.56 MHz, or 60 MHz or the like. Alternatively, a radio frequency power formed by a pulse may be loaded. Alternatively, the base 9 is not supplied with a radio frequency power.

The reaction chamber provided by the embodiments of the present disclosure, by using the Faraday shield provided by any of the above embodiments in the present disclosure, can reduce radio frequency power required to be loaded to the radio frequency coil, thereby even if a relatively low radio frequency power is loaded, it also can achieve plasma ignition, maintain a certain processing rate, and use an upper electrode alone for ignition to reduce damage to a substrate dielectric layer when the substrate dielectric layer is made of a low-k material. In addition, loading a relatively low radio frequency power can also avoid the temperature of the Faraday shield from being too high, thereby increasing the risk of particle contamination in the reaction chamber.

It should be understood that, the above implementations are only exemplary implementations for the purpose of explaining the principle of the present disclosure, and the present disclosure is not limited thereto. For one of ordinary skill in the art, various improvements and modifications can be made without departing from the spirit and essence of the present disclosure, and these improvements and modifications also fall within the protection scope of the present disclosure.

What is claimed is:

1. A Faraday shield, comprising a conductive annular body, a slit being formed on the conductive annular body, wherein in an unfolded view of the conductive annular body, a projection of the slit in an axial direction of the conductive annular body has a length greater than zero, and a projection of the slit in a circumferential direction of the conductive annular body has a length greater than zero.

2. The Faraday shield according to claim 1, wherein the slit comprises a first sub-slit, and an angle between a projection of an axis of the conductive annular body in the unfolded view of the conductive annular body and an extending direction of the first sub-slit has an absolute value greater than 0 degree and less than 90 degrees.

3. The Faraday shield according to claim 2, wherein the angle between the projection of the axis of the conductive annular body in the unfolded view of the conductive annular body and the extending direction of the first sub-slit is 45 degrees.

4. The Faraday shield according to claim 2 or 3, wherein the first sub-slit extends from an upper end surface of the conductive annular body to a lower end surface of the conductive annular body such that the conductive annular body is completely disconnected in the circumferential direction thereof.

5. The Faraday shield according to claim 4, wherein the slit further comprises a second sub-slit, in the unfolded view of the conductive annular body, an angle between an extending direction of the second sub-slit and the extending direction of the first sub-slit is greater than 0 degree.

6. The Faraday shield according to claim 1, wherein the slit comprises a first sub-slit and a second sub-slit, in the unfolded view of the conductive annular body, an angle between a projection of an axis of the conductive annular body and an

extending direction of the first sub-slit is equal to 90 degrees; and an angle between an extending direction of the second sub-slit and the extending direction of the first sub-slit is greater than 0 degree.

7. The Faraday shield according to claim 5 or 6, wherein the second sub-slit extends from an upper end surface of the conductive annular body to a lower end surface of the conductive annular body such that the conductive annular body is completely disconnected in the circumferential direction thereof, or

the second sub-slit is between the upper end surface and the lower end surface of the conductive annular body but does not reach the upper end surface or the lower end surface of the conductive annular body.

8. The Faraday shield according to claim 7, wherein the second sub-slit and the first sub-slit intersect with each other.

9. The Faraday shield according to claim 8, wherein a number of the second sub-slit is one or more, and in a case of a plurality of second sub-slits, the plurality of second sub-slits are distributed at an interval along the extending direction of the first sub-slit.

10. The Faraday shield according to claim 9, wherein a number of the first sub-slits is plural, and the plurality of first sub-slits are evenly distributed along the circumferential direction of the conductive annular body.

11. The Faraday shield according to claim 6, wherein the conductive annular body is divided into N first regions and M second regions in the circumferential direction thereof, and the first regions and the second regions alternate, where N and M are integers greater than or equal to 1;

at least two first sub-slits are disposed in each first region, and the at least two first sub-slits are distributed at an interval along the axial direction of the conductive

annular body; and

at least two second sub-slits are disposed in each second region, and the at least two second sub-slits are distributed at an interval along the circumferential direction of the conductive annular body.

12. The Faraday shield according to claim 11, wherein the plurality of first regions and the plurality of second regions are evenly distributed along the circumferential direction of the conductive annular body; and

the at least two first sub-slits in each first region are evenly distributed; and the at least two second sub-slits in each second region are evenly distributed.

13. The Faraday shield according to claim 11, wherein a width of the first region in the circumferential direction of the conductive annular body is 50 mm to 200 mm.

14. The Faraday shield according to claim 1, wherein on a cross section obtained by sectioning the slit along a plane perpendicular to an axis of the conductive annular body, the slit is in a form of a tortuous passage.

15. The Faraday shield according to claim 14, wherein the slit is in such a form of a tortuous passage that none of straight lines L1, L2, L3, and L4 meets a following requirement: the straight line does not cut or intersect S1 and S2 except at an upper left corner, a lower left corner, an upper right corner, and a lower right corner of the slit, and is between S1 and S2;

where S1 is a section line of an outer side surface of the slit, S2 is a section line of an inner side surface of the slit, L1 is a straight line connecting the upper right corner and the lower right corner of the slit, L2 is a straight line connecting the upper left corner and the lower right corner of the slit, L3 is a straight line connecting the upper right corner and the lower left corner of the slit, and L4 is a straight line connecting the upper left corner and the lower left corner of the slit.

16. The Faraday shield according to claim 15, wherein the tortuous passage is formed by disposing a blocking portion in the slit.

17. The Faraday shield according to claim 16, wherein there are two blocking portions, which are a first blocking portion and a second blocking portion, respectively, and are respectively disposed on a first end surface and a second end surface of the conductive annular body at the slit, wherein

the first blocking portion extends from the first end surface toward the second end surface, and there is a first gap between the first blocking portion and the second end surface;

the second blocking portion extends from the second end surface toward the first end surface, and there is a second gap between the second blocking portion and the first end surface;

there is a third gap between the first blocking portion and the second blocking portion in a radial direction of the conductive annular body; and

the first gap, the second gap, and the third gap constitute the tortuous passage.

18. The Faraday shield according to claim 1, wherein the slit is filled with a dielectric material.

19. The Faraday shield according to claim 1, wherein the slit has a width in a range of 2 mm to 10 mm.

20. A reaction chamber, comprising a dielectric cylinder, a Faraday shield and a radio frequency coil, the radio frequency coil being disposed around an outer side of the dielectric cylinder; and the Faraday shield being disposed around an inner side of the dielectric cylinder, wherein the Faraday shield is the Faraday shield according to any one of claims 1 to 19.

21. The reaction chamber according to claim 20, wherein the radio frequency coil uses a cylindrical three-dimensional spiral coil formed by a winding wire having a rectangular section.

22. The reaction chamber according to claim 21, wherein a spacing, in an axial direction, between any two adjacent turns of the winding wire of the cylindrical three-dimensional spiral coil is 6 mm to 10 mm.

23. The reaction chamber according to claim 18, wherein the reaction chamber is a pre-cleaning chamber.