PLASMA SYSTEM AND FILTER DEVICE

TECHNICAL FIELD

[001] The present disclosure generally relates to the semiconductor manufacturing field and, more particularly, to a plasma system and a filter device applied in the plasma system.

BACKGROUND

[002] Conventionally, before performing processes such as deposition on a workpiece (e.g., a wafer), pre-cleaning is performed on the workpiece to remove impurities of the workpiece. A specific pre-cleaning process includes ionizing process gas such as argon, helium, hydrogen, etc., to form plasma, and free radicals of the plasma reacting with oxide impurities of the workpiece for a reduction-oxidation reaction to remove the impurities.

[003] However, during the above-mentioned pre-cleaning process, ions from the plasma may have a negative impact on materials of the workpiece. For example, for low-k materials, if the plasma includes hydrogen ions, the hydrogen ions will enter the low-k materials, which results in degradation of the low-k materials. Thus, processing results do not meet the expectation.

SUMMARY

[004] Embodiments of the present disclosure are intended to solve at least one of the technical problems in the existing technology and disclose a plasma system and a filter device, which can prevent ions from the plasma from negatively affecting material on the workpiece to improve product performance.

[005] According to an embodiment of the present disclosure, a plasma system is disclosed. The plasma system includes a dielectric window, a first adapter, a lower electrode platform, and a filter device. An area surrounded by the dielectric window is set as a first chamber. The first

chamber is configured to accommodate plasma. The first adapter is arranged under the dielectric window. An area surrounded by the first adapter is set as a second chamber. The lower electrode platform is placed in the second chamber. The lower electrode platform is used to carry a workpiece. The filter device includes a filter member, a first extension member, and a second extension member. The filter member is placed at an intersection of the first chamber and the second chamber. The filter member includes a plurality of through-holes configured to filter out ions from the plasma during a process that the plasma in the first chamber enters the second chamber through the through-holes. The first extension member extends from the filter member in a first direction and is placed over the first adapter. The second extension member extends from a position of the filter member adjacent to the first extension member to an inner side of the first adapter in a second direction and is configured to support the filter member. The second direction is perpendicular to the first direction.

[006] The plasma system of the embodiment, with the filter member of the filter device, effectively filters out the ions from the plasma passed through in the process of the plasma in the first chamber entering the second chamber through the through-holes in the filter member. Thus, the ions may be prevented from entering low-k materials and causing degradation of the low-k material. In addition, by placing the first extension member of the filter device over the first adapter, the filter device is installed and positioned. By extending the second extension member to the inner side of the first adapter, the second extension member may support the filter member and protect the first adapter from being bombarded by the plasma. At the same time, since the filter device is integrally formed by the filter member, the first extension member, and the second extension member, no assembly gap exists among the filter member, the first extension member, and the second extension member. Under such a structure, the integrally formed filter

device may prevent the plasma from bombarding the gap where elements are assembled. Thus, the replacement frequency of the filter device may be greatly reduced, thereby reducing the cost.

[007] According to an embodiment of the present disclosure, a filter device applied to a plasma system is disclosed. The plasma system includes a dielectric window and an adapter arranged under the dielectric window. An area surrounded by the dielectric window is configured as a first chamber. The first chamber is configured to accommodate plasma. An area surrounded by the adapter is configured as a second chamber. The plasma system further includes a lower electrode platform placed in the second chamber. The lower electrode platform is used to carry a workpiece. The filter device includes a filter member, a first extension member, and a second extension member. The filter member is placed at an intersection of the first chamber and the second chamber. The filter member includes a plurality of through-holes and is configured to filter out ions from the plasma during the process that the plasma in the first chamber enters the second chamber through the through-holes. The first extension member extends from the filter member in a first direction and is placed over the first adapter. The second extension member extends from a position of the filter member adjacent to the first extension member to the inner side of the first adapter in a second direction and is configured to support the filter member. The second direction is perpendicular to the first direction.

[008] The plasma system may effectively filter out the ions from the plasma passed through with the filter device of the embodiment, which prevents the ions from entering the low-k material to cause deterioration of the low-k material. In addition, by placing the first extension member of the filter device over the first adapter, the filter device may be installed and positioned. By extending the second extension member to the inner side of the first adapter, the second extension member can support the filter device and protect the first adapter from being

bombarded by the plasma. At the same time, since the filter device is integrally formed by the filter member, the first extension member, and the second extension member, no assembly gap exists among the filter member, the first extension member, and the second extension member. Under such a structure, the integrally formed filter device can prevent the plasma from bombarding the gap where elements are assembled. Thus, the replacement frequency of the filter device may be greatly reduced, thereby reducing the cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[009] FIG. 1 is a schematic diagram of a plasma system according to an embodiment of the present disclosure.

[0010] FIG. 2 is a schematic diagram of a filter device according to an embodiment of the present disclosure.

[0011] FIGs. 3A and 3B are detailed structural diagrams showing a first extension member of the filter device according to an embodiment of the present disclosure.

[0012] FIGs. 4A and 4B are top views showing the first extension member of the filter device according to an embodiment of the present disclosure.

[0013] FIGs. 5A and 5B are side views showing a second extension member of the filter device according to an embodiment of the present disclosure.

[0014] FIGs. 6A to 6C are schematic diagrams showing thicknesses of a filter member and the first extension member of the filter device according to an embodiment of the present disclosure.

[0015] FIGs. 7A to 7F are simulation result diagrams according to an embodiment of the present disclosure.

[0016] FIG. 8 is a side view of a filter member according to an embodiment of the present disclosure.

[0017] FIGs. 9A to 9C are simulation result diagrams according to an embodiment of the present disclosure.

[0018] FIG. 10 is a side view of a plasma system according to another embodiment of the present disclosure.

[0019] FIG. 11 is a side view of a plasma system according to yet another embodiment of the present disclosure.

[0020] FIG. 12 is a side view showing an adapter and a shield according to an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0021] The following disclosure provides various embodiments or examples, which can be used to implement various features of the present disclosure. Specific examples of components and configurations described below are used to simplify the present disclosure. It can be noted, these descriptions are only exemplary and are not intended to limit the present disclosure. For example, in the following description, forming a first feature on or over a second feature may include, in some embodiments, the first and second features being in direct contact with each other, and in some embodiments, an additional assembly being formed between the first and second features, such that the first and second features are not in the direct contact with each other. In addition, in embodiments of the present disclosure, reference numerals and/or marks may be reused. Such reuse is for brevity and clarity, and does not represent a relationship between different embodiments and/or configurations discussed.

[0022] Further, spatially relative terms, such as “below,” “under,” “lower,” “above,” “over,” and the like, may be used to facilitate the description of a relationship between an assembly or feature shown in the drawings and another or a plurality of assemblies or features. These

spatially relative terms are intended to cover various orientations of the device in use or operation in addition to the orientation shown in the drawings. The device may be placed in another orientation (e.g., rotated 90° or at other orientations). These spatially relative terms should be interpreted accordingly.

[0023] Although a numerical range and a parameter used to set forth a broader scope of the present disclosure are approximate values, related values of specific embodiments have been presented as precisely as possible. However, any value inherently contains a standard deviation resulting from an individual test method. As used herein, "about" generally means that an actual value is within plus or minus 10%, 5%, 1%, or 0.5% of a particular value or range. Alternatively, the word "about" means that the actual value lies within an acceptable standard error of the mean, which can be determined by those of ordinary skill in the art of the present disclosure. It can be understood that, in addition to experimental examples, or unless otherwise specified, all ranges, quantities, values, and percentages used here (for example, to describe an amount of material, time length, temperature, operation condition, quantity ratio, and the like) are decorated by "about." Therefore, unless otherwise specified to the contrary, the numerical parameters disclosed in the specification and the accompanying claims are approximate values and may be changed as needed. These numerical parameters should be at least understood as the indicated significant digits and values obtained by applying ordinary rounding. The numerical range is represented herein as from one endpoint to the other endpoint or between the endpoints. Unless otherwise specified, the numerical range described here includes the endpoints.

[0024] When a workpiece (such as a wafer) is processed, especially when processes of through-silicon via and packaging are performed on the workpiece, a pre-cleaning chamber may be required. A function of the pre-cleaning chamber may include removing impurities of a surface

of a to-be-processed workpiece to facilitate an effective subsequent physical vapor deposition process. In a general pre-cleaning chamber, gases, such as argon, helium, hydrogen, etc., may be excited into plasma. The process of removing the impurities of the workpiece may be realized by using the plasma to physically bombard the impurities and chemically react with the impurities. For some oxide impurities, the plasma needs to be subject to a reduction-oxidation reaction with the oxide impurities at trenches or holes of the workpiece to remove the oxide impurities. Thus, the performance of the subsequent metal deposition process may not be affected. However, because some ions (such as hydrogen ions) may easily enter into the low-k material and degrade the low-k material to cause a process result not to meet the expectation, the hydrogen ions need to be prevented from such reaction. The embodiment discloses plasma system and a filter device applied to the plasma system, which can effectively reduce the reaction between the ions (e.g., hydrogen ions) and the low-k materials so as to avoid the above situation.

[0025] FIG. 1 is a schematic diagram of plasma system 1 according to an embodiment of the present disclosure. The plasma system 1 may include a pre-cleaning device and may be configured to react and remove impurities such as oxides in the trenches or the holes of the workpiece (e.g., the wafer). The plasma system 1 includes a dielectric window 11, a first adapter 12, a lower electrode platform 13, a radio frequency (RF) source 14, a matching circuit 15, an induction coil 16, a metal barrel 17, and a filter device 18. An area surrounded by the dielectric window 11 is set as a first chamber CH1. In the embodiment, the dielectric window 11 is illustrated in a hemispherical shape, however, the shape is not limited according to the embodiments of the present disclosure. In other embodiments, the dielectric window 11 may be in a different shape. Other changes regarding the dielectric window 11 may be explained in subsequent description. The first adapter 12 is arranged under the dielectric window 11 and is

grounded. An area surrounded by the first adapter 12 is set as a second chamber CH2. In the embodiment, the plasma system 1 may fill the reaction gas (such as helium, argon, hydrogen, etc.) into the first chamber CH1 in a side inletting method. For example, a first gas passage may be arranged in the first adapter 12 and configured to transfer the reaction gas into the first chamber CH1.

[0026] The lower electrode platform 13 is arranged in the second chamber CH2 and configured to carry the workpiece. In some embodiments, the lower electrode platform 13 may be an electrostatic chuck, which can individually adjust temperatures of different positions of the workpiece by using a multi-zone heating method to improve the temperature uniformity of the workpiece.

[0027] The RF source 14 may apply RF power to the induction coil 16 through the matching circuit 15. The matching circuit 15 may be configured to adjust and match an impedance behind the matching RF source 14, so that the loaded RF power may achieve the maximum coupling efficiency. The induction coil 16 may be in a barrel shape and surround the dielectric window 11, for example, a cylindrical three-dimensional helical coil. In some embodiments, in order to achieve better uniformity and symmetry of electromagnetic field distribution, the induction coil 16 may be a cylindrical three-dimensional helical coil with more than 2 turns of coils. Each turn of the coil includes of a horizontal segment of 3/4 circumference and a spiral rising segment of 1/4 circumference. A higher end of the spiral rising segment may be connected to one end of the horizontal segment of the adjacent and higher one-turn coil. The induction coil 16 is configured to couple the RF power into the first chamber CH1, and ionizing and coupling the reaction gas in the first chamber CH1 into plasma. The metal barrel 17 is disposed over the first adapter 12 and

surrounds the induction coil 16, and the metal barrel 17 is in contact with the first adapter 12 to achieve grounding and electromagnetic shielding.

[0028] The filter device 18 has an integral structure. The filter device 18 may include a conductive material. That is, the filter device 18 is made of a conductive material. In certain embodiments, the filter device 18 may be made of aluminum. The filter device 18 may be realized by the integral structure that can avoid the gap where the plasma bombards the elements to greatly reduce the replacement frequency of the filter device 18, and further reduce the cost. Referring to FIGS. 1 and 2 at the same time, the filter device 18 includes a filter member 181, a first extension member 182, and a second extension member 183. The filter member 181 is arranged at the intersection of the first chamber CH1 and the second chamber CH2 to isolate the first chamber CH1 and the second chamber CH2. The filter member 181 may have a plurality of through-holes. Two ends of the through-holes may communicate with the first chamber CH1 and the second chamber CH2. Thus, the plasma in the first chamber CH1 can enter the second chamber CH2 through the through-holes. At the same time, the filter member 181 may be configured to filter out ions of the plasma passing through the through-holes. The plurality of through-holes of the filter member 181 may filter out the ions of the plasma (e.g., argon ions, helium ions, hydrogen ions, etc.) to prevent the ions from entering the second chamber CH2 to react with the workpiece on the lower electrode platform 13. Thus, the workpiece may be degraded, and the processing results of the subsequent processing may not meet the expectation.

[0029] In some embodiments, an arrangement density of the plurality of through-holes of the filter member 181 may be within a range of 0.7 through-holes/square centimeter to 3 through-holes/square centimeter. The arrangement density of the through-holes may be changed according to the speed of the process efficiency. In detail, when a higher requirement is applied

to the process rate, the arrangement density of the through-holes may be appropriately increased, and vice versa.

[0030] FIGs. 3A and 3B illustrate detailed structural diagrams of the first extension member 182 according to an embodiment of the present invention. As shown in FIG. 3A, the first extension member 182 extends from the filter member 181 in the first direction and is placed over the first adapter 12 to be in contact with the first adapter 12 to form a good grounding. For example, the first extension member 182 extends from the circumferential side surface of the filter member 181 in the first direction shown in FIGs. 3A and 3B. The extended part overlaps the upper end surface of the first adapter 12 to realize a conductive contact.

[0031] In addition, as shown in FIG. 3A, the first adapter 12 is provided with a first gas passage. The first gas passage is connected to an external reaction gas source (not illustrated in the figure). A gas outlet end of the first gas passage is located on the upper surface of the first adapter 12 and is located at a position between the first extension member 182 and the dielectric window 11 to communicate with the inside of the first chamber CH1. The reaction gas (such as helium, argon, hydrogen, etc.) may directly enter the first chamber CH1 through the gas passage. The reaction gas entering the first chamber CH1 may be ionized to form the plasma. The plasma in the first chamber CH1 may enter the second chamber CH2 through the through-holes. At the same time, the filter member 181 may filter out the ions from the plasma passing through the through-holes to prevent the ions from entering the second chamber CH2 to react with the workpiece and degrade the workpiece, the process results of the subsequent processing thus may not meet the expectation. However, the gas inlet method is not a limitation of the embodiment.

[0032] Referring to FIG. 3B, the structure of the first extension member 182 shown in FIG. 3B is different from the structure of the first extension member in FIG. 3A. Except for the first

extension member, other structures are the same, which are not repeated here. In FIG. 3B, a portion of the first extension member 182 is attached to the upper surface of the first adapter 12. The remaining portion is arranged above the first adapter part 12 at an interval. The first extension member 182 may be in a stepped structure, for example, including a first lower surface 1821 and a second lower surface 1822. The first lower surface 1821 is arranged over the first adapter 12 and is attached to the upper surface of the first adapter 12 to form a good grounding. The second lower surface 1822 is located on a side of the first lower surface 1821 away from the filter member 181. The position of the second lower surface 1822 in an axial direction of the filter member 181 is higher than the position of the first lower surface 1821 in the axial direction of the filter member 181. Thus, an interval between the second lower surface 1822 and the upper surface of the first adapter 12 may form a second gas passage configured to let the gas to pass through. Specifically, as shown in FIG. 3B, the first adapter 12 is provided with the first gas passage. The first gas passage is connected to the external reaction gas source (not shown). The gas outlet end of the first gas passage is located on the upper surface of the first adapter 12 and is opposite to the second lower surface 1822. The second lower surface 1822 and the first adapter 12 form the second gas passage. Specifically, the interval between the second lower surface 1822 and the upper surface of the first adapter 12 may be the second gas passage. The second gas passage may communicate with the gas outlet end of the first gas passage. With such an arrangement, the reaction gas may enter the first chamber after passing through the first gas passage and the second gas passage. At the same time, the first extension member 182 may shield the gas outlet end of the first gas passage well, thereby reducing and even preventing the plasma from entering the first gas passage.

[0033] In some embodiments, the upper surface 1823 of the first extension member 182 may be coplanar with the upper surface 1811 of the filter member 181, which is beneficial to improve the uniformity of gas distribution.

[0034] The first extension member 182 may have various structures. For example, FIG. 4A is a top view of the first extension member 182 according to an embodiment of the present disclosure. As shown in FIG. 4A, the first extension member 182 extends from the edge of the filter member 181 in the first direction to form an annular structure. The ring structure surrounds along in the circumferential direction of the filter member 181. In this case, the upper surface 1823 of the first extension member 182 forms the ring structure in the top view. The extension direction of the first extension member 182 of the ring structure is the first direction shown in FIG. 4A. That is the direction along a radial direction of the filter member 181 and away from a central axis of the filter member 181.

[0035] For another example, FIG. 4B is a top view of the first extension member 182 according to another embodiment of the present disclosure. Referring to FIG. 4B, a plurality of the first extension members 182 are included and arranged at intervals along the circumferential direction of the filter member 181. Each first extension member 182 may extend from the edge of the filter member 181 in the first direction to form a protrusion structure. In this case, each upper surface 1823 of the first extension member 182 may form a protrusion structure, such as a protrusion shape or a claw shape, in a top view. The extending direction of the protrusion structure is the first direction shown in FIG. 4B. That is the direction along the radial direction of the filter member 181 and away from the central axis of the filter member 181.

[0036] Those of ordinary skill in the art should be able to easily understand after reading embodiments of FIGs. 4A and 4B that the first extension member 182 may also use any other

structure, as long as the filter device 18 can be stably arranged over the first adapter 12 and form a good grounding.

[0037] Referring to FIG. 5A and in connection with FIG. 1, the second extension member 183 extends from the position of the filter member 181 neighboring to the first extension member 182 in the second direction to the inner side of the first adapter 12 and may be configured to support the filter member 181. At the same time, the second extension member 183 may further be used as an inner lining to protect the first adapter 12 from being bombarded by the plasma. Thus, the service life of the first adapter 12 can be extended, and the plasma can be prevented from bombarding the first adapter 12 to form particles to contaminate the workpiece on the lower electrode platform 13. Specifically, the above-mentioned second direction is perpendicular to the first direction. For example, as shown in FIG. 5A, the second extension member 183 extends downward along the axial direction of the filter member 181. As shown in FIG. 5B, the second extension member 183 may have a barrel structure and surrounds along the circumferential direction of first adapter piece 12.

[0038] In some embodiments, different positions of the filter member 181 may have the same thickness in the axial direction. FIGs. 6A to 6C use the structure shown in FIG. 3B as an example. FIG. 6A is a detailed structural diagram of a filter device 18 according to an embodiment of the present disclosure. As shown in FIG. 6A, the thickness of the different positions of the filter member 181 in the axial direction is equal to thickness W1a. A thickness of the first extension member 182 in the axial direction of the filter member 181 (i.e., the interval between the upper surface 1823 and the first lower surface 1821) is equal to thickness W2a. Thickness W1a is greater than thickness W2a, however, which is not a limitation of embodiments of the present disclosure. In some embodiments, the thickness of the filter member

181 in the axial direction may be less than or equal to the thickness of the first extension member 182 in the axial direction of the filter member 181. As shown in FIG. 6B, the thickness of different positions of the filter member 181 in the axial direction is equal to thickness W1b. The thickness of the first extension member 182 in the axial direction of the filter member 181 (i.e., the interval between the upper surface 1823 and the first lower surface 1821) is equal to thickness W2b. Thickness W1b is equal to thickness W2b. In addition, as shown in FIG. 6C, the thickness of different positions of the filter member 181 in the axial direction is equal to thickness W1c. The thickness of the first extension member 182 in the axial direction of the filter member 181 (i.e., the interval between the upper surface 1823 and the first lower surface 1821) is equal to thickness W2c. Thickness W1c is smaller than thickness W2c.

[0039] Those skilled in the art should be able to easily understand after reading the embodiments in FIGs. 6A to 6C that embodiments of the present disclosure do not limit the relative relationship of the thicknesses of the filter member 181 and the first extension member 182 in the axial direction of the filter member 181. As long as the first extension member 182 can be placed over the first adapter 12 and form a good grounding to realize the shield function, it should belong to the scope of the present disclosure.

[0040] As mentioned above, in some embodiments, the thickness of different positions of the filter member 181 may be the same in the axial direction. In this design, a ratio of a through-hole depth of the filter member 181 to a through-hole diameter may range from 2 to 20. Preferably, the through-hole depth of the filter member 181 may be 10 mm, and the through-hole diameter may be 1 mm. In other words, the ratio of the through-hole depth to the through-hole diameter is 10. Preferably, the through-hole depth of the filter member 181 may be 7 mm, and the through-hole diameter may be 0.5 mm. In other words, the ratio of the through-hole depth to the through-

hole diameter is 14. Preferably, the through-hole depth of the filter member 181 may be 7 mm, and the through-hole diameter may be 1 mm. In other words, the ratio of the through-hole depth to the through-hole diameter is 7. The above-mentioned through-hole sizes are all smaller than plasma sheath, so that after the plasma of the first chamber CH1 passes through the through-holes of the filter member 181, a large number of ions from the plasma cannot pass through. Therefore, the filter device 18 of embodiments of the present disclosure can effectively filter out the ions. Thus, free radicals, atoms, and molecules may process the workpiece in the second chamber CH2, which avoids the reaction between the ions and the workpiece to cause the process result not to meet the expectation.

[0041] Applicants have simulated various conditions of the filter device 18 to obtain a device specification that are most effective in filtering the ions. It should be noted that, as shown in FIGs. 7A to 7F, an axial position is a position upward from the lower electrode platform 13, and a radial position is a position from the center axis of the lower electrode platform 13 outward to the edge. FIG. 7A shows the simulation of the electric field distribution in the plasma system 1 with and without the filter device 18. The solid line in FIG. 7A represents the electric field distribution when the filter device 18 is not installed in the plasma system 1. The dotted line represents the electric field distribution when the filter device 18 is installed in the plasma system 1. It can be clearly observed from FIG. 7A that the plasma system 1 with the filter device 18 installed effectively shields the diagonal electric field. In detail, when the filter device 18 is installed, the diagonal electric field can be effectively shielded within a certain distance from the lower electrode platform 13 to an upper portion of the lower electrode platform 13.

[0042] FIG. 7B shows simulations of ion concentration distribution in the plasma system 1 with or without the filter device 18. In FIG. 7B, the solid line represents the ion concentration

distribution above the lower electrode platform 13 when the filter device 18 is not installed in the plasma system 1. The dotted line represents the ion concentration distribution above the lower electrode platform 13 when the filter device 18 is installed in the plasma system 1. It can be clearly observed from FIG. 7B that, compared with the case that the filter device 18 is not installed, the plasma system 1 with the filter device 18 installed can effectively filter the ions.

[0043] FIG. 7C shows simulations of ion concentration distribution when the through-holes of the filter member 181 have the same depth but different diameters. In detail, in the simulations shown in FIG. 7C, the measurement is performed at a certain fixed position above the lower electrode platform 13 (e.g., the position of the workpiece). In addition, in the simulations shown in FIG. 7C, the through-hole depths of the filter member 181 is fixed at 10 mm, and the simulations are performed with the through-hole diameter being 0.5 mm, 1 mm, and 2 mm, respectively. It can be clearly observed from FIG. 7C that the smaller the through-hole diameter is, the lower the ion concentration is at the fixed position. In other words, the smaller the through-hole size is, the more ions can be filtered out to be prevented from reacting with the workpiece.

[0044] FIG. 7D shows simulations of free radical concentration distribution when the through-holes of the filter member 181 have the same depth but different diameters. In detail, in the simulations shown in FIG. 7D, the measurement is performed at a certain fixed position above the lower electrode platform 13 (e.g., the position of the workpiece). In addition, in the simulations shown in FIG. 7D, the through-hole depth of the filter member is fixed at 10 mm, and the simulations were performed for the through-hole diameters of 0.5 mm, 1 mm, and 2 mm, respectively. It can be clearly observed from FIG. 7D that the smaller the through-hole diameter is, the more consistent the free radical concentration is in the radial direction of the lower

electrode platform 13. In other words, the smaller the through-hole diameter, the better the uniformity of free radical concentration is.

[0045] FIG. 7E shows simulations of the ion density distribution when the through-holes of the filter member 181 have the same diameter but different depths. In detail, in the simulations shown in FIG. 7E, the measurement is performed at the certain fixed position above the lower electrode platform 13 (e.g., the position of the workpiece). In addition, in the simulations shown in FIG. 7E, the through-hole diameter is fixed at 0.5 mm, and the simulations are performed for the through-hole depths of 1 mm, 2 mm, 7 mm, and 10 mm, respectively. It can be clearly observed from FIG. 7E that the deeper the through-hole depth is, the lower the ion density is at the fixed position. In other words, the deeper the through-hole depth is, the more ions can be filtered out to be prevented from reacting with the workpiece.

[0046] FIG. 7F shows simulations of electric field distribution when the filter device 18 is realized with different materials. More specifically, in the simulations shown in FIG. 7F, the simulations were performed when the filter device 18 is realized by ceramics and aluminum, and when the filter device 18 is not installed. It can be clearly observed from FIG. 7F that when the filter device 18 is realized with a ceramic material, similar to the case when the filter device 18 is not installed, the shield effect for the diagonal electric field is less significant. On the contrary, when the filter device 18 is realized with an aluminum material, the diagonal electric field can be effectively and completely shielded within a certain distance from the lower electrode platform 13 to a position above the lower electrode platform 13.

[0047] In some embodiments, the filter member 181 may be thicker at the edges than at the center. Referring to FIG. 8, FIG. 8 is a side view of the filter member 181 according to an embodiment of the present disclosure. The thickness of the filter member 181 at the edges is

W1d, and the thickness of the filter member 181 at the center is W1e. Thickness W1d is greater than thickness W1e. Preferably, the through-hole diameter of the filter member 181 may be 0.5 mm, and the through-hole depth may be gradually changed from 15 mm at the edge to 6 mm at the center. In other words, the ratio of the depth to the through-hole diameter of the filter member 181 may range from 12 to 30. Preferably, the through-hole diameter of the filter member 181 may be 1 mm, and the through-hole depth may be gradually changed from 18 mm at the edge to 8.5 mm at the center. In other words, the ratio of the depth to the through-hole diameter of the filter member 181 may range from 8.5 to 18.

[0048] Applicants have performed simulations with various conditions of the filter device 18 to obtain the device specifications that are most effective in filtering the ions. As shown in FIGs. 9A to 9C, the axial position represents the position upward from the lower electrode platform 13, and the radial position represents the position from the center axis of the lower electrode platform 13 outward to the edge. FIG. 9A shows the simulations of the electric field distribution when the through-hole size of the filter member 181 is 0.5 mm and 1 mm, respectively, and the thickness is gradually changed. In detail, in the simulations shown in FIG. 9A, the measurement is performed at a certain fixed position above the lower electrode platform 13 (e.g., the position of the workpiece). It can be clearly observed from FIG. 9A, with the improved design that the thickness is gradually changed, the filter member 181 with the through-hole diameter of 0.5 mm or 1 mm can effectively and completely shield the diagonal electric field.

[0049] FIG. 9B shows the simulations of the ion concentration distribution when the through-hole diameter of the filter member 181 is 0.5 mm and 1 mm, respectively, and the thickness is fixed or is gradually changed. In detail, in the simulations shown in FIG. 9B, the measurement is performed at a certain fixed position above the lower electrode platform 13 (e.g., the position of

the workpiece). It can be clearly observed from FIG. 9B that when the through-hole diameter of the filter member 181 is 0.5 mm, the ions can be filtered more effectively with the improved design that the thickness is gradually changed to be prevented from reacting with the workpiece. Similarly, when the through-hole diameter of the filter member 181 is 1 mm, with the improved design that the thickness is gradually changed, the ions can be filtered more effectively to be prevented from reacting with the workpiece.

[0050] FIG. 9C shows a simulation diagram for the free radical concentration distribution when the through-hole diameter of the filter member 181 is 0.5 mm and 1 mm, respectively, and the thickness is fixed or is gradually changed. In detail, in the simulations shown in FIG. 9C, the measurement is performed at a certain fixed position above the lower electrode platform 13 (e.g., the position of the workpiece). It can be clearly observed from FIG. 9C that when the through-hole diameter of the filter member 181 is 0.5 mm, with the improved design that the thickness is gradually changed, the uniformity of the free radical concentration may be improved more effectively in the radial direction of the lower electrode platform 13. Similarly, when the through-hole diameter of the filter member 181 is 1 mm, with the improved design that the thickness is gradually changed, the uniformity of the free radical concentration may be improved more effectively in the radial direction of the lower electrode platform 13.

[0051] According to the embodiments of FIGs. 7A to 7F and FIGs. 9A to 9C, it can be clearly observed that the filter device 18 of the present disclosure has a good shield effect on the RF electric field. Thus, the vacuum chamber can be divided into plasma generation area and plasma diffusion area. The filter device 18 made of the aluminum material can almost completely shield the diagonal electric field to prevent glow phenomenon below of the filter device 18 (i.e., the second chamber CH2). In addition, with the improved design by changing the ratio of the

through-hole depth to the through-hole diameter of the filter member 181 and gradually changing the thickness of the filter member 181 from thicker at the edge to thinner at the center, the ion concentration above the lower electrode platform 13 may be reduced, and the uniformity of the free radicals in the radial direction of the lower electrode platform 13 may be improved.

[0052] It should be noted that, compared with the conventional plasma system, the plasma system 1 of embodiments of the present disclosure does not have a lower RF source and a matching circuit. Since the filter device 18 of the present disclosure can effectively reduce the ion concentration above the lower electrode platform 13, when there is no lower RF source and matching circuit, the free radicals may reach the workpiece on the lower electrode platform 13 in a diffusion method. As such, compared with the conventional plasma system, the plasma system 1 can reduce power consumption more effectively.

[0053] The dielectric window 11 in the plasma system 1 may have a hemispherical shape, however, which is not a limitation of embodiments of the present disclosure. FIG. 10 is a side view of plasma system 2 according to an embodiment of the present disclosure. The plasma system 2 may process the workpiece by plasma. For example, the plasma system 2 may be a pre-cleaning device and configured to remove oxide impurities in the trenches or holes of the workpiece by performing an oxidization reaction on the oxide impurities. The plasma system 2 includes a dielectric window 21, a first adapter 22, a lower electrode platform 23, an RF source 24, a matching circuit 25, an induction coil 26, a metal barrel 27, a filter device 28, and a top cover 29. The plasma system 2 is substantially similar to the plasma system 1. The only difference exists in the dielectric window 21 and the top cover 29 of plasma system 2. In detail, unlike the dielectric window 11, which is hemispherical, the dielectric window 21 has a barrel-shaped structure and is arranged over the first adapter 22. In the embodiment, the dielectric

window 21 may include an insulation material. For example, the dielectric window 21 may be made of materials such as quartz or ceramic. The top cover 29 is arranged above the dielectric window 21. In the embodiment, the top cover 29 may include a conductive material. For example, the top cover 29 may be made of aluminum. Those skilled in the art should be able to easily understand the functions and purposes of other assemblies in the plasma system 2 after reading the embodiments in FIGs. 1 to 9C. The detailed description is omitted here to save space.

[0054] FIG. 11 is a side view of plasma system 3 according to an embodiment of the present disclosure. The plasma system 3 may process the workpiece by plasma. For example, the plasma system 3 may be a pre-cleaning device configured to remove oxide impurities in trenches or holes of the workpiece by performing a reduction reaction on the oxide impurities. The plasma system 3 includes a dielectric window 31, a first adapter 32, a lower electrode platform 33, an RF source 34, a matching circuit 35, an induction coil 36, a metal barrel 37, a filter device 38, a top cover 39, a second adapter 40, and a shield 41. The plasma system 3 is substantially similar to the plasma system 2. The only difference includes that the plasma system 3 additionally includes a second adapter 40 and a shield 41. Structures, shapes, and functions of the second adapter 40 and the shield 41 are described in detail below.

[0055] Referring to FIG. 12, FIG. 12 is a side view of the second adapter 40 and the shield 41 according to an embodiment of the present disclosure. The second adapter 40 has an annular bottom 401 and an annular top 402. The annular bottom 401 represents an annular structure in a top view. The annular bottom 401 is arranged over the dielectric window 31 and protrudes oppositely to an inner peripheral wall of the annular top 402. An upper surface of the annular top 402 is attached to a lower surface of the top cover 39. In other words, the top cover 39 is arranged on the second adapter 40.

[0056] The shield member 41 includes an annular main body 412 and an annular extension member 411. The annular main body 412 surrounds at an inner side of the dielectric window 31 along a circumferential direction of the dielectric window 31. The annular extension member 411 may represent an annular structure in a top view. The annular extension member 411 extends from the annular main body 412 and is arranged over the annular bottom 401. Specifically, the annular extension member 411 extends from an outer peripheral wall of the annular main body 412 along a radial direction of the annular main body 412. The extended portion overlaps the portion of the annular bottom 401 protruding from the inner peripheral wall of the annular top 402 to fix the shield member 41. By surrounding the annular main body 412 at the inner side of the dielectric window 31 along the circumferential direction of the dielectric window 31, the represented barrel-like structure may form a good grounding and a Faraday shield barrel. Thus, regular maintenance and replacement of the dielectric window 31 may be reduced. In addition, an inner surface of the shield member 41 may be performed with surface roughening treatment such as sandblasting, thermal spraying, etc., and has a function similar to an inner lining to reduce falling of particles. In addition, a barrel surface of the barrel-shaped structure formed by the shield member 41 has a plurality of gaps. A gap length may be greater than 70% of a barrel-shaped structure height. A gap width may be greater than 0.5 mm. Thus, the plasma in the first chamber CH1 may be prevented from generating Eddy current loss on the barrel-shaped structure.

[0057] To briefly summarize embodiments of the present disclosure, the filter device of embodiments of the present disclosure can have a good shield effect on the RF electric field to divide the vacuum chamber into the plasma generation area and the plasma diffusion area. The filter device made of the aluminum material can almost completely shield the diagonal electric

field, which can prevent the glow phenomenon below the filter device. In addition, with the improved design by changing the ratio of the through-hole depth to the through-hole diameter of the filter member and by gradually changing the thickness of the filter member from thicker at the edges to thinner at the center, the ion concentration above the lower electrode platform may be reduced, and the uniformity of the free radicals may be improved in the radial direction of the lower electrode platform.

CLAIMS

WHAT IS CLAIMED IS:

1. A plasma system, comprising:

a dielectric window, an area surrounded by the dielectric window defining a first chamber and the first chamber being configured to accommodate plasma;

a first adapter, arranged immediately under the dielectric window, and an area surrounded by the first adapter defining a second chamber;

a lower electrode platform placed in the second chamber, the lower electrode platform being used to carry a workpiece; and

a filter device, wherein

a filter member of the filter device is placed at an intersection of the first chamber and the second chamber, and the filter member has a plurality of through-holes configured to filter the plasma in the first chamber, such that the filtered plasma enters the second chamber;

a first extension member of the filter device extends from the filter member in a first direction and is placed over the first adapter;

the filter device has a second extension member at a position adjacent to the first extension member and extending in a second direction perpendicular to the first direction, the second extension member being arranged immediately adjacent to the first adapter and surrounding the second chamber to support the filter member.

2. The plasma system of claim 1, wherein the first extension member extends from the filter member in the first direction to form an annular structure.

3. The plasma system of claim 1, wherein the first extension member extends from the filter member in the first direction, and extends from an edge of the filter member to form a claw-shaped structure.

4. The plasma system of any one of claims 1-3, wherein the first extension member comprises a first lower surface and a second lower surface, wherein the first lower surface is arranged immediately over the first adapter, a position of the second lower surface in an axial direction is higher than a position of the first lower surface in the axial direction.

5. The plasma system of claim 4, wherein the first adapter is provided with a first gas passage through which reaction gas passes, and a second gas passage, through which the reaction gas passes, is formed between the second lower surface and the first adapter, wherein the reaction gas enters the first chamber after passing through the first gas passage and the second gas passage.

6. The plasma system of any one of claims 1-3, wherein in an axial direction, a thickness of the filter member is greater than a thickness of the first extension member.

7. The plasma system of any one of claims 1-3, wherein in an axial direction, a thickness of the filter member is less than or equal to a thickness of the first extension member.

8. The plasma system of any one of claims 1-3, wherein an upper surface of the first extension member is coplanar with an upper surface of the filter member.

9. The plasma system of claim 1, wherein the second extension member extends from the position adjacent to the first extension member in the second direction to form a barrel-shaped structure and surround the second chamber.

10. The plasma system of claim 1, wherein the first direction is a direction along a radial direction of the filter member and away from a center axis of the filter member, and the second direction is a downward direction along the center axis of the filter member.

11. The plasma system of claim 1, wherein the filter member has a same thickness in an axial direction.

12. The plasma system of claim 11, wherein ratios of depths to diameters of the plurality of through-holes of the filter device range from 2 to 20.

13. The plasma system of claim 12, wherein the ratios of the depths to the diameters of the plurality of through-holes of the filter device are 14.

14. The plasma system of claim 12, wherein the ratios of the depths to the diameters of the plurality of through-holes of the filter device are 10.

15. The plasma system of claim 12, wherein the ratios of the depths to the diameters of the plurality of through-holes of the filter device are 7.

16. The plasma system of claim 1, wherein a thickness of an edge portion of the filter member is greater than a thickness of a center portion of the filter member.

17. The plasma system of claim 16, ratios of depths to diameters of the plurality of through-holes of the filter device range from 12 to 30.

18. The plasma system of claim 16, wherein ratios of depths to diameters of the plurality of through-holes of the filter device range from 8.5 to 18.

19. The plasma system of claim 1, wherein a density of the plurality of through-holes of the filter device ranges from 0.7 through-hole/cm^2 to 3 through-holes/cm^2.

20. The plasma system of claim 1, wherein the dielectric window has a hemispherical shape.

21. The plasma system of claim 1, wherein the dielectric window has a barrel shape.

22. The plasma system of claim 21, further comprising:

a second adapter, the second adapter having an annular bottom, wherein the annular bottom is arranged immediately over the dielectric window;

a top cover arranged immediately over the second adapter, the top cover including a conductive material; and

a shield member, the shield member having an annular extension member, wherein the annular extension member is placed immediately over the annular bottom, and the shield member has a third extension member extending downward at an inner edge of the annular extension member, the third extension member being immediately adjacent to the dielectric window and surrounding the first chamber.

23. The plasma system of claim 1, wherein the filter device includes a conductive material.

24. The plasma system of claim 23, wherein the filter device includes aluminum.

25. A filter device applicable to a plasma system, wherein the plasma system includes a dielectric window and an adapter arranged immediately under the dielectric window, and an area surrounded by the dielectric window defines a first chamber, the first chamber is used to accommodate plasma, an area surrounded by the adapter defines a second chamber, and the plasma system further includes a lower electrode platform placed in the second chamber, the lower electrode platform is used to carry a workpiece, wherein a filter member of the filter device is placed at an intersection of the first chamber and the second chamber, and the filter member has a plurality of through-holes configured to filter the plasma in the first chamber, such that the filtered plasma enters the second chamber; a first extension member of the filter device extends from the filter member in a first direction and is placed over the adapter; the filter device has a second extension member at a position adjacent to the first extension member and extending in a second direction perpendicular to the first direction, the second extension member being arranged immediately adjacent to the adapter and surrounding the second chamber to support the filter member.