

SUBSTRATE PROCESSING APPARATUS

FIELD OF THE INVENTION

The present invention belongs to the field of semiconductor technology and relates to a substrate processing apparatus.

BACKGROUND

A semiconductor substrate processing apparatus is used for processing a semiconductor substrate through techniques including plasma-enhanced chemical vapor deposition (PECVD), atomic layer deposition (ALD), plasma-enhanced atomic layer deposition (PEALD), and plasma-enhanced pulsed deposition layer (PEPDL). One type of semiconductor substrate processing apparatus is a plasma processing apparatus including a reaction chamber having an upper electrode and a lower electrode, wherein radio frequency (RF) power is applied between the electrodes to excite a process gas into plasma for processing the semiconductor substrate in the reaction chamber.

During substrate processing, for example, in PECVD, ion bombardment is an important factor exerting stress on the substrate. Excessively strong local stress on the substrate often leads to high warpage of the substrate. In addition, non-uniformities in gas flow, temperature, plasma distribution, and the like result in non-uniform film quality or film thickness, leading to poor uniformity of the film on the substrate surface. Such problems cannot be precisely controlled and adjusted by known substrate processing apparatuses.

Therefore, it is desirable to provide a novel substrate processing apparatus.

SUMMARY

In view of the above-mentioned drawbacks of the prior art, the object of the present invention is to provide a substrate processing apparatus for solving the problem that conventional substrate processing apparatuses cannot realize precise control and adjustment.

To achieve the above object and other related objects, a substrate processing apparatus is provided, comprising:

an RF power supply, including a high-frequency RF power supply and a low-frequency RF power supply;

an upper electrode, coupled to the RF power supply;

a lower electrode, including a plurality of electrode segments, the RF power supply applying power to the plurality of electrode segments via the upper electrode, respectively;

a power measurement module, configured to measure the high-frequency power and the low-frequency power applied by the high-frequency RF power supply and the low-frequency RF power supply to each electrode segment;

an electrode impedance adjustment module, configured to adjust the high-frequency impedance and the low-frequency impedance from each electrode segment to a ground terminal according to a measurement signal of the power measurement module.

Optionally, during different processes of substrate processing by the substrate processing apparatus or different stages of the same process, the electrode impedance adjustment module is configured to adjust the impedance value of the high-frequency impedance and/or the low-frequency impedance from the lower electrode to the ground terminal, so that a first current applied by the RF power supply to the upper electrode is switched to a second current.

Optionally, the electrode impedance adjustment module is configured to adjust the impedance value of the high-frequency impedance or the low-frequency impedance from at least one electrode segment to the ground terminal.

Optionally, the electrode impedance adjustment module is configured to separately adjust the impedance values of the high-frequency impedance and the low-frequency impedance from at least one electrode segment to the ground terminal.

Optionally, the electrode impedance adjustment module includes a high-frequency impedance adjustment circuit and a low-frequency impedance adjustment circuit, wherein each of the high-frequency impedance adjustment circuit and the low-frequency impedance adjustment circuit includes a capacitor and/or an inductor.

Optionally, the capacitor and/or the inductor is adjustable.

Optionally, each electrode segment is coupled to the electrode impedance adjustment module via a switch, respectively, wherein the switch is used for controlling the on and off of each electrode segment.

Optionally, the lower electrode is equally divided.

Optionally, the lower electrode includes an internal electrode and at least one external electrode surrounding the internal electrode, wherein the internal electrode and the external electrode serve as the electrode segments.

Optionally, a plurality of external electrodes are provided, and the plurality of external electrodes are spaced apart and arranged radially outward from the outer edge of the internal electrode in order.

Optionally, the internal electrode and/or at least one external electrode is equally divided.

Optionally, the electrode impedance adjustment module includes a plurality of impedance adjustment circuits, each of the impedance adjustment circuits includes a high-frequency impedance circuit and a low-frequency impedance circuit connected in parallel with each other, and is configured to adjust the high-frequency impedance and the low-frequency impedance from each electrode segment to the ground terminal, respectively.

Optionally, the power measurement module includes a voltage sensor and a current sensor.

As described above, in the substrate processing apparatus of the present invention,

the lower electrode is divided into electrode segments so that RF power can be individually applied to each electrode segment corresponding to a local region of the substrate, and the high-frequency power and the low-frequency power applied to each electrode can be separately adjusted by adjusting the high-frequency impedance and the low-frequency impedance from each electrode segment to the ground terminal, thereby achieving more precise adjustment of the substrate processing apparatus, further enabling adjustable film-forming properties of the local region of the substrate, and optimizing uniformity of the film on the substrate surface.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present invention will be further described by the following embodiments and the accompanying drawings of the embodiments.

FIG. 1 is a schematic structural view of an embodiment of the substrate processing apparatus in the present invention.

FIG. 2 is a schematic structural view of another embodiment of the substrate processing apparatus in the present invention.

FIGS. 3(a) to 3(c) are schematic views of one, two, and three annular external electrodes in the present invention, respectively.

FIGS. 4(a) to 4(c) are schematic views of specific embodiments in which the internal electrode is divided into two, three, and four equal parts in the present invention, respectively.

FIG. 5 is a schematic view of another embodiment in which the internal electrode is divided into three equal parts in the present invention.

FIG. 6 is a schematic view of the lower electrode divided into two equal parts in the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

The embodiments of the present invention are described below with specific

examples, and those skilled in the art can easily understand other advantages and efficacies of the present invention from the content disclosed in the present specification. The present invention may also be implemented or applied through other specific embodiments, and various details in the present specification may be modified or changed based on different viewpoints and applications without departing from the spirit of the present invention.

In the following detailed description of embodiments of the present invention, for ease of illustration, the cross-sectional views showing the device structures are not partially enlarged in accordance with the general scale, and the schematic views are merely examples, which should not limit the protection scope of the present invention herein. In addition, actual fabrication should include three-dimensional dimensions of length, width, and depth.

For convenience of description, spatially relative terms such as "under," "below," "lower," "beneath," "underneath," "above," "upper," and "on" may be used herein to describe the relationship of one element or feature shown in the accompanying drawings to another element or feature. It will be understood that these spatially relative terms are intended to encompass other orientations of the device in use or operation in addition to the orientation depicted in the accompanying drawings. Furthermore, when a layer is referred to as being "between" two layers, the layer may be the only layer between the two layers, or one or more intervening layers may also be present. The term "between" as used herein includes both endpoints.

In the context of the present application, a structure in which a first feature is "on" a second feature may include an embodiment in which the first feature and the second feature are formed in direct contact, and may also include an embodiment in which an additional feature is formed between the first feature and the second feature, so that the first feature and the second feature may not be in direct contact.

It should be noted that the drawings provided in the present embodiment illustrate the basic concept of the present invention in a schematic manner, so the drawings only show the components related to the present invention instead of being drawn according to the number, shape, and size of the components in actual implementation. The shape, number, and proportion of each component may be changed arbitrarily in actual

implementation, and the component layout may be more complicated. Although the substrate processing apparatus is described below in plasma-enhanced chemical vapor deposition (PECVD), the substrate processing apparatus and the method for controlling power in a segmented manner can be applied to other types of plasma processing chambers, such as plasma systems for processing semiconductor substrates using atomic layer deposition (ALD), plasma-enhanced atomic layer deposition (PEALD), plasma-enhanced pulsed deposition layer (PEPDL) techniques, and other plasma systems requiring plasma tuning.

As shown in FIG. 1, the present embodiment provides a substrate processing apparatus for performing PEALD on a substrate. The substrate processing apparatus comprises an RF power supply 100, an upper electrode 200 coupled to the RF power supply 100, and a substrate support 800 for supporting a substrate W. In one embodiment, the upper electrode 200 is also used as a showerhead for supplying a process gas, and the process gas enters the substrate processing apparatus through the showerhead. The substrate support 800 may be formed of a ceramic material, the upper surface of the substrate support 800 is used for carrying the substrate W, and a lower electrode 300 is embedded in the substrate support 800 (for the specific design of the lower electrode 300, refer to FIGS. 3 to 5 in detail). The RF power supply 100 outputs a current to the upper electrode 200, and the lower electrode 300 is coupled to the upper electrode 200 to form an RF electric field between the upper electrode and the lower electrode, and the RF electric field is used for exciting the process gas to form plasma so as to deposit a thin film on the substrate surface. The lower electrode 300 includes a plurality of electrode segments, each electrode segment is coupled to an electrode impedance adjustment module via a power measurement module, and the electrode impedance adjustment module is grounded. The power measurement module includes a plurality of sensors 500, and the electrode impedance adjustment module includes a plurality of impedance adjustment circuits 400. The plurality of impedance adjustment circuits 400 are respectively used for adjusting the impedance from each electrode segment to the ground terminal so as to adjust the RF power applied to each electrode segment.

The RF power supply 100 applies power to the lower electrode 300 via the upper electrode 200 to generate and maintain plasma between the upper electrode and the

lower electrode. The RF power supply 100 includes a high-frequency RF power supply 111 and a low-frequency RF power supply 121. FIG. 1 shows a specific embodiment in which the RF power supply 100 includes the high-frequency RF power supply 111 and the low-frequency RF power supply 121. The high-frequency RF power supply 111 is coupled to the upper electrode 200 via a matching network 112, and the low-frequency RF power supply 121 is coupled to the upper electrode 200 via a matching network 122. Such an arrangement of the RF power supply allows the high-frequency RF power supply and the low-frequency RF power supply to apply power to the upper electrode 200 via matching networks of corresponding frequencies according to process requirements, so as to excite the process gas to form plasma. The frequency applied by the high-frequency RF power supply is higher than the frequency applied by the low-frequency RF power supply, and preferably, the frequency ranges of the high-frequency power supply and the low-frequency power supply do not overlap during operation. That is, the low-frequency RF power supply 121 always operates at a frequency lower than the frequency of the high-frequency RF power supply 111. For example, common frequencies of the high-frequency RF power supply are 13.56 MHz and 27.12 MHz, and common frequencies of the low-frequency RF power supply are 370 kHz and 400 kHz.

The lower electrode 300 is disposed in the substrate support 800. For specific details of the lower electrode structure, see FIGS. 3 to 6. The lower electrode 300 is a metal mesh, and the lower electrode 300 may be formed of aluminum, copper, or other conductive metal materials. The lower electrode is divided into a plurality of regions according to different regions spaced apart from each other, so that the lower electrode is divided into a plurality of electrode segments, and the plurality of electrode segments are spaced apart and insulated from each other. Illustratively, in one embodiment, the lower electrode is equally divided to form the plurality of electrode segments, as shown in FIG. 6, where the lower electrode is divided into two equal parts. In other embodiments not shown, the lower electrode can be divided in other equal parts, such as three equal parts, four equal parts, and the like. In another embodiment, the lower electrode is divided into an internal electrode and an external electrode according to regions of the internal electrode and the external electrode, and further, in other embodiments, the internal electrode and/or at least one external electrode is further equally divided into a plurality of internal electrode segments and a plurality of

external electrode segments according to different regions. Illustratively, the lower electrode 300 includes the internal electrode and at least one external electrode surrounding the internal electrode. The external electrode includes at least one of a first external electrode and a second external electrode, wherein the first external electrode is an unequally divided external electrode, and the second external electrode is an equally divided external electrode. As shown in FIGS. 3 to 5, for example, the lower electrodes 310, 320, 330, 340, 350, 360, and 370 include first external electrodes 312, 322, 332, 342, 351, 361, and 371, respectively. According to FIG. 5, a second external electrode 374 is equally divided into a plurality of external electrode segments. The number of the first external electrodes is at least one. If a plurality of first external electrodes are provided, the plurality of first external electrodes may be spaced apart and arranged radially outward from the outer edge of the internal electrode in order. For example, in the lower electrode 310 in FIG. 3(a), one first external electrode 312 is arranged radially outward from the outer edge of an internal electrode 311, and a gap (not labeled) is reserved between the first external electrode 312 and the internal electrode 311. In another embodiment, as shown in the lower electrodes 320 and 330 in FIGS. 3(b) to 3(c), a plurality of first external electrodes 322 and 332 are spaced apart and arranged radially outward from the outer edge of the internal electrode in order. The first external electrode and the second external electrode may be freely combined in the same lower electrode, including at least one first external electrode and/or at least one second external electrode. Illustratively, in one embodiment, for example, as shown in FIG. 5, the lower electrode 370 has one first external electrode 371 and one second external electrode 374. In other embodiments not shown, the first external electrode and the second external electrode may also have other combinations. In one combination, for example, the lower electrode includes a plurality of first external electrodes 371 and one second external electrode 374, and the plurality of first external electrodes are spaced apart and arranged radially outward from the outer edge of the second external electrode in order. In another combination, the lower electrode includes a plurality of second external electrodes and excludes the first internal electrode, and at this time, the plurality of second external electrodes are spaced apart and arranged radially outward from the outer edge of the internal electrode in order. In yet another combination, the lower electrode includes a plurality of first external electrodes and a plurality of second external electrodes, the plurality of first external electrodes are spaced apart and arranged radially outward from the outer edge of the

internal electrode in order, and the plurality of second external electrodes are spaced apart and arranged radially outward from the outermost outer edge of the plurality of first external electrodes in order. Other combinations will not be listed one by one. The internal electrode may be equally divided or unequally divided. For example, the internal electrodes 311, 321, and 331 in FIG. 3 are unequally divided, and the internal electrodes 341, 352, 362, and 372 in FIGS. 4 and 5 are equally divided into internal electrode segments. The gap between the respective electrode segments of the lower electrodes 310, 320, and 330 in FIGS. 3 and 5 are schematically shown in the figures, and the gap between the respective electrode segments of the lower electrodes 340, 350, and 360 in FIG. 4 is not schematically shown in the figure.

The lower electrode is further provided with a connecting portion, and the connecting portion passes through the gap formed by the spacing between adjacent internal electrode segments and extends to the inner edge of the external electrode. As shown in FIG. 4(a), a connecting portion 343 passes through a gap (not shown) between two internal electrode segments of the internal electrode 341, and both ends of the connecting portion 343 extend to the inner edge of the external electrode 342 without contacting the internal electrode 341. As shown in FIG. 4(b), a connecting portion 353 starts from a central region 354, respectively passes through a gap (not shown) formed by the spacing between three adjacent internal electrode segments, and extends to the inner edge of the external electrode 351. As shown in FIG. 4(c), a connecting portion 364 starts from a central region 363, respectively passes through a gap formed by the spacing between four adjacent internal electrode segments of the internal electrode 362, and extends to the inner edge of the external electrode 361. As shown in FIG. 5, a first connecting portion 375 starts from a central region 376, respectively passes through a gap formed by the spacing between three adjacent internal electrode segments, and extends to the inner edge of the first external electrode 371, and a second connecting portion 373 starts from the central region 376, respectively passes through a gap formed by the spacing between three adjacent internal electrode segments, and extends to the inner edge of the second external electrode 374. The central region may be specifically described as a region not exceeding one-third of the radius of the circle defined by the outer edge of the internal electrode. The provision of the connecting portion connected from the central region to the inner edge of the external electrode facilitates electrical connection of the

internal electrode and the external electrode to the impedance adjustment circuits 400 within a limited space of the central region.

In one embodiment, the lower electrode is equally divided to form a plurality of electrode segments, so that an electrostatic chuck (ESC) voltage can be simultaneously applied to the plurality of electrode segments to generate an electrostatic adsorption effect on the substrate. As shown in FIG. 6, a lower electrode 380 includes two equally divided electrode segments, and the ESC voltage is simultaneously applied to the two electrode segments to generate an electrostatic adsorption effect on the substrate. In another embodiment, the lower electrode includes the internal electrode and the external electrode, the external electrode includes at least one first external electrode and/or at least one second external electrode, and the internal electrode is a whole or equally divided into a plurality of internal electrode segments. The ESC voltage can be applied to the internal electrode without being applied to the external electrode to generate an electrostatic adsorption effect on the substrate. When the internal electrode is equally divided into a plurality of internal electrode segments that are spaced apart, the ESC voltage is simultaneously applied to the plurality of internal electrode segments to generate an electrostatic adsorption effect on the substrate. As shown in FIG. 4(a), the lower electrode 340 includes two internal electrode segments, and an ESC voltage application circuit 700 simultaneously applies the ESC voltage to the two internal electrode segments, as schematically shown in FIG. 2. In another embodiment, the internal electrode is a whole, and the ESC voltage application circuit 700 applies the ESC voltage to one internal electrode to generate an electrostatic adsorption effect on the substrate. For example, as shown in FIG. 3(a), the ESC voltage is applied to the internal electrode 311 of the lower electrode 310, as schematically shown in FIG. 1. The ESC voltage application circuit 700 is coupled between the internal electrode and the ground terminal. In one embodiment, the ESC voltage application circuit 700 may be connected between the internal electrode and the impedance adjustment circuits. In another embodiment, the ESC voltage application circuit 700 may also be connected to the impedance adjustment circuits 400, which will be described in detail below.

The impedance adjustment circuit module includes at least one impedance adjustment circuit 400 for regulating the impedance between at least one of the plurality of electrode segments of the lower electrode and the ground terminal, so as to

adjust power applied by the high-frequency RF power supply 111 and/or the low-frequency RF power supply 121 to the at least one electrode segment. Each impedance adjustment circuit 400 includes a high-frequency impedance adjustment circuit 410 or includes the high-frequency impedance adjustment circuit 410 and a low-frequency impedance adjustment circuit 420. The high-frequency impedance adjustment circuit 410 adjusts the high-frequency impedance from the electrode segment to the ground terminal so as to adjust the high-frequency power applied by the high-frequency RF power supply 111 to the electrode segment. The low-frequency impedance adjustment circuit 420 adjusts the low-frequency impedance from the electrode segment to the ground terminal, so as to adjust the low-frequency power applied by the low-frequency RF power supply 121 to the electrode segment. Each of the high-frequency impedance adjustment circuit 410 and the low-frequency impedance adjustment circuit 420 includes at least one of an inductor and a capacitor. Specifically, the high-frequency impedance adjustment circuit 410 includes an inductor 411 and a capacitor 412, and the low-frequency impedance adjustment circuit 420 includes an inductor 421 and a capacitor 422. The ESC voltage application circuit 700 is coupled between the inductor 421 and the capacitor 422 of the low-frequency impedance adjustment circuit 420, and the ESC voltage application circuit 700 applies a voltage to the lower electrode via the inductor 421 to generate an electrostatic adsorption effect on the substrate. In various embodiments, at least one capacitor and/or inductor is adjustable, thereby allowing the impedance from each electrode segment to the ground terminal to be adjustable. Each electrode segment of the lower electrode is coupled to a high-frequency impedance adjustment circuit and a low-frequency impedance adjustment circuit connected in parallel with each other, respectively. The high-frequency impedance adjustment circuit and the low-frequency impedance adjustment circuit are separately grounded. The high-frequency impedance adjustment circuit only allows a high-frequency current to pass through, and the low-frequency impedance adjustment circuit only allows a low-frequency current to pass through, thereby realizing high/low frequency splitting, wherein both the high-frequency RF power and the low-frequency RF power are independently adjustable. The high/low frequency impedance adjustment circuit respectively adjusts the impedance from each electrode segment to the ground terminal by adjusting the inductor and/or the capacitor.

A switch 600 is coupled between each electrode segment and the impedance adjustment circuit 400, respectively. Each switch 600 is used for controlling whether the high-frequency RF power supply 111 and the low-frequency RF power supply 121 apply power to each electrode segment. In one embodiment, each impedance adjustment circuit 400 is coupled to each electrode segment in a one-to-one correspondence via each switch 600, and each switch 600 can control whether the high-frequency RF power supply 111 and the low-frequency RF power supply 121 apply power to the corresponding electrode segment, as shown in FIGS. 1 and 2. In a PECVD process, if the film thickness in the substrate region corresponding to the external electrode is thicker than the film thickness in the substrate region corresponding to the internal electrode, as shown in FIG. 2, the switch 600 corresponding to the external electrode can be turned on, so that an open circuit is formed between the external electrode and the impedance adjustment circuit, and the high-frequency RF power supply 111 and the low-frequency RF power supply 121 do not apply power to the external electrode.

The power measurement module is used for measuring the high-frequency power and the low-frequency power applied by the high-frequency RF power supply and the low-frequency RF power supply to each electrode segment. The power measurement module includes a plurality of sensors 500. Each electrode segment of the lower electrode is coupled to each impedance adjustment circuit 400 via the sensor 500 in a one-to-one correspondence. Each sensor 500 is used for simultaneously measuring currents output by both the high-frequency RF power supply 111 and the low-frequency RF power supply 121 in the same electrode segment, so as to monitor the high-frequency RF power and the low-frequency RF power applied to each electrode segment. The sensors 500 may be voltage sensors or current sensors (e.g., V/I sensors), as shown in FIGS. 1 and 2. In one embodiment, the RF power supply maintains a constant output current to the upper electrode during the entire process, such as during PECVD. In another embodiment, during different processes or different stages of the same process, the electrode impedance adjustment module adjusts the impedance value of the high-frequency impedance and/or the low-frequency impedance from at least one of the plurality of electrode segments to the ground terminal, so that a first current applied by the high-frequency RF power supply and the low-frequency RF power supply to the upper electrode is switched to a second current.

For example, during the same PECVD process, when the stress of a certain electrode segment is relatively high, adjust the low-frequency impedance of the corresponding electrode segment, the low-frequency impedance value is increased, and the high-frequency impedance value is unchanged, so that ion bombardment of this electrode segment is weakened, stress is reduced, and at the same time, the high-frequency impedance is not affected, the film thickness is minimally affected, thereby optimizing uniformity of the film on the substrate surface. In other embodiments, the high-frequency impedance value corresponding to the same electrode segment may also be adjusted while the low-frequency impedance value is unchanged. In yet another embodiment, the high-frequency impedance and the low-frequency impedance values corresponding to the same electrode segment may also be adjusted simultaneously. For example, during different PECVD processes, silicon nitride and silicon oxide deposit films alternately on the substrate surface, and the high-frequency impedance and the low-frequency impedance corresponding to the same electrode segment need to be adjusted simultaneously.

During plasma processing of a substrate, when plasma of a local region of the substrate is adjusted (e.g., adjusting density or movement speed of plasma), the RF voltage/current applied to the electrode segment corresponding to the local region of the substrate can be individually controlled, and high/low frequency power applied to each electrode segment can be separately adjusted by adjusting high/low frequency impedance between each electrode segment and the ground terminal, so that film-forming properties (e.g., film-forming rate, film thickness, etc.) of the local region of the substrate are adjustable, and uniformity of the film on the substrate surface is optimized. For example, when stress at the outer periphery of the substrate is relatively high, the capacitor and/or the inductor in the low-frequency impedance adjustment circuit of the external electrode corresponding to the outer periphery of the substrate is adjusted to increase low-frequency impedance of the external electrode, so that ion bombardment is weakened, thereby reducing stress at the outer periphery of the substrate, and at the same time, power applied by the high-frequency power supply to the external electrode is not affected, and the thickness of the thin film deposited on the substrate surface is not affected.

The above embodiments merely illustrate the principles and efficacies of the

present invention by way of example, and are not intended to limit the present invention. Anyone skilled in the art can modify or change the above embodiments without departing from the spirit and scope of the present invention. Therefore, all equivalent modifications or changes made by those having ordinary skill in the art without departing from the spirit and technical idea disclosed by the present invention shall still be covered by the claims of the present invention.

What is claimed is:

1. A substrate processing apparatus, comprising:

an RF power supply, including a high-frequency RF power supply and a low-frequency RF power supply;

an upper electrode, coupled to the RF power supply;

a lower electrode, including a plurality of electrode segments, the RF power supply applying power to the plurality of electrode segments via the upper electrode, respectively;

a power measurement module, configured to measure the high-frequency power and the low-frequency power applied by the high-frequency RF power supply and the low-frequency RF power supply to each electrode segment;

an electrode impedance adjustment module, configured to adjust the high-frequency impedance and the low-frequency impedance from each electrode segment to a ground terminal according to a measurement signal of the power measurement module.

2. The substrate processing apparatus according to claim 1, wherein, during different processes of substrate processing by the substrate processing apparatus or different stages of the same process, the electrode impedance adjustment module is configured to adjust the impedance value of the high-frequency impedance and/or the low-frequency impedance from the lower electrode to the ground terminal, so that a first current applied by the RF power supply to the upper electrode is switched to a second current.

3. The substrate processing apparatus according to claim 2, wherein the electrode impedance adjustment module is configured to adjust the impedance value of the high-frequency impedance or the low-frequency impedance from at least one electrode segment to the ground terminal.

4. The substrate processing apparatus according to claim 2, wherein the electrode

impedance adjustment module is configured to separately adjust impedance values of the high-frequency impedance and the low-frequency impedance from at least one electrode segment to the ground terminal.

5. The substrate processing apparatus according to claim 1, wherein the electrode impedance adjustment module includes a high-frequency impedance adjustment circuit and a low-frequency impedance adjustment circuit, and each of the high-frequency impedance adjustment circuit and the low-frequency impedance adjustment circuit includes a capacitor and/or an inductor.

6. The substrate processing apparatus according to claim 5, wherein the capacitor and/or the inductor is adjustable.

7. The substrate processing apparatus according to claim 1, wherein each electrode segment is coupled to the electrode impedance adjustment module via a switch, respectively, and the switch is used for controlling the on and off of each electrode segment.

8. The substrate processing apparatus according to claim 1, wherein the lower electrode is equally divided.

9. The substrate processing apparatus according to claim 1, wherein the lower electrode includes an internal electrode and at least one external electrode surrounding the internal electrode, and the internal electrode and the external electrode serve as the electrode segments.

10. The substrate processing apparatus according to claim 9, wherein a plurality of external electrodes are provided, and the plurality of external electrodes are spaced apart and arranged radially outward from the outer edge of the internal electrode in order.

11. The substrate processing apparatus according to claim 9, wherein the internal electrode and/or at least one external electrode is equally divided.

12. The substrate processing apparatus according to claim 1, wherein the electrode impedance adjustment module includes a plurality of impedance adjustment circuits,

each of the impedance adjustment circuits includes a high-frequency impedance circuit and a low-frequency impedance circuit connected in parallel with each other, and is configured to adjust the high-frequency impedance and the low-frequency impedance from each electrode segment to the ground terminal, respectively.

13. The substrate processing apparatus according to claim 1, wherein the power measurement module includes a voltage sensor and a current sensor.