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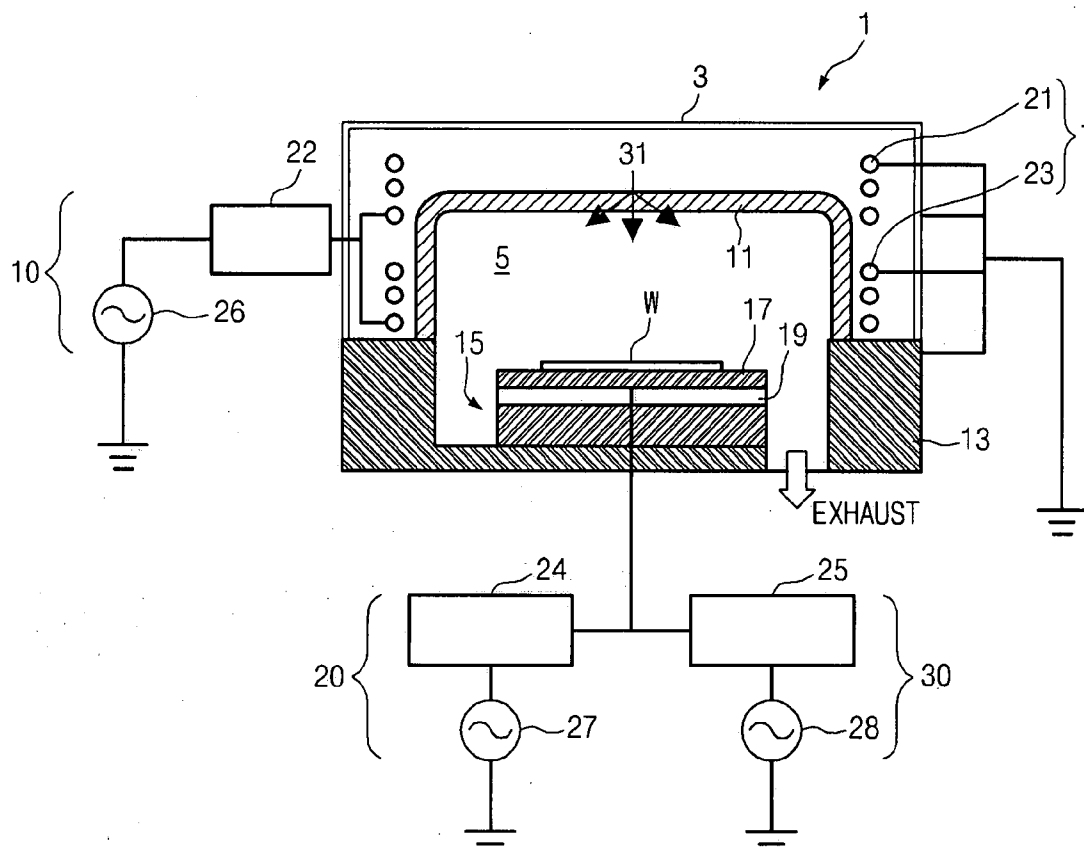
(19) **United States**(12) **Patent Application Publication**
Lee(10) **Pub. No.: US 2007/0221331 A1**(43) **Pub. Date: Sep. 27, 2007**(54) **HYBRID PLASMA REACTOR****Publication Classification**(75) Inventor: **Weon-Mook Lee, Yongin-si (KR)**(51) **Int. Cl.**
C23F 1/00 (2006.01)(52) **U.S. Cl.** **156/345.38; 156/345.47; 156/345.48**(57) **ABSTRACT**

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Ltd., Hwaseong-si (KR)(21) Appl. No.: **11/724,861**(22) Filed: **Mar. 16, 2007**(30) **Foreign Application Priority Data**

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Provided is a hybrid plasma reactor. The hybrid plasma reactor includes an ICP (Inductively Coupled Plasma) source unit and a bias RF (Radio Frequency) power supply unit. The ICP source unit includes a chamber, an antenna coil unit, and a source power supply unit. The chamber includes a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body. The antenna coil unit is disposed outside of the dielectric window. The source power supply unit supplies a source power to the antenna coil unit. The bias RF power supply unit supplies a bias RF power to a cathode. The cathode is installed within the chamber and mounts a target wafer on its top.



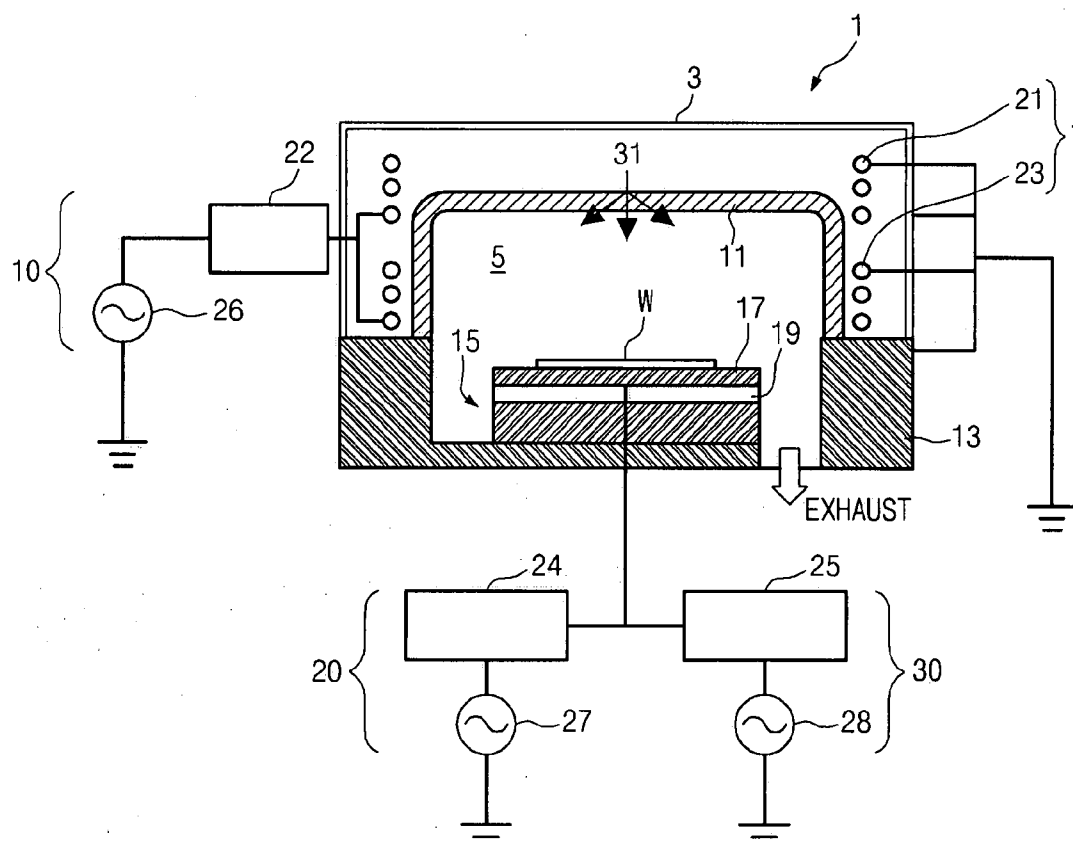


FIG.1

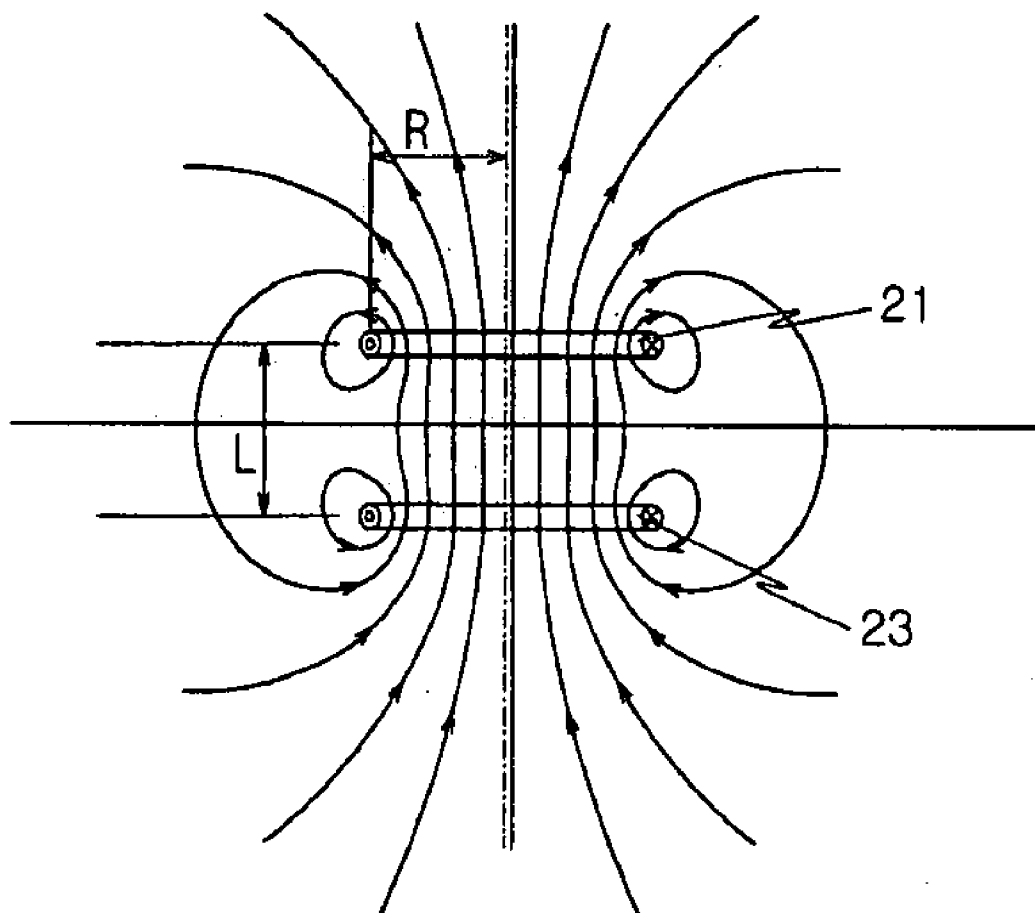


FIG. 2

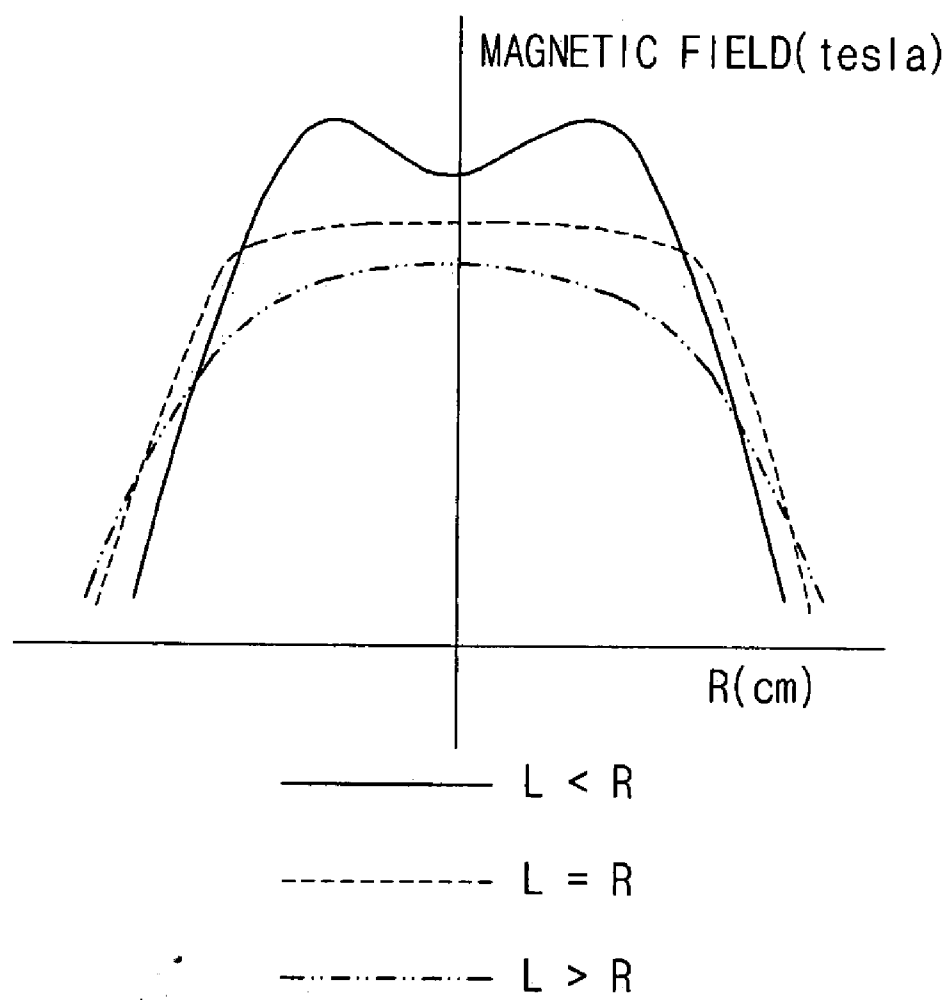


FIG. 3

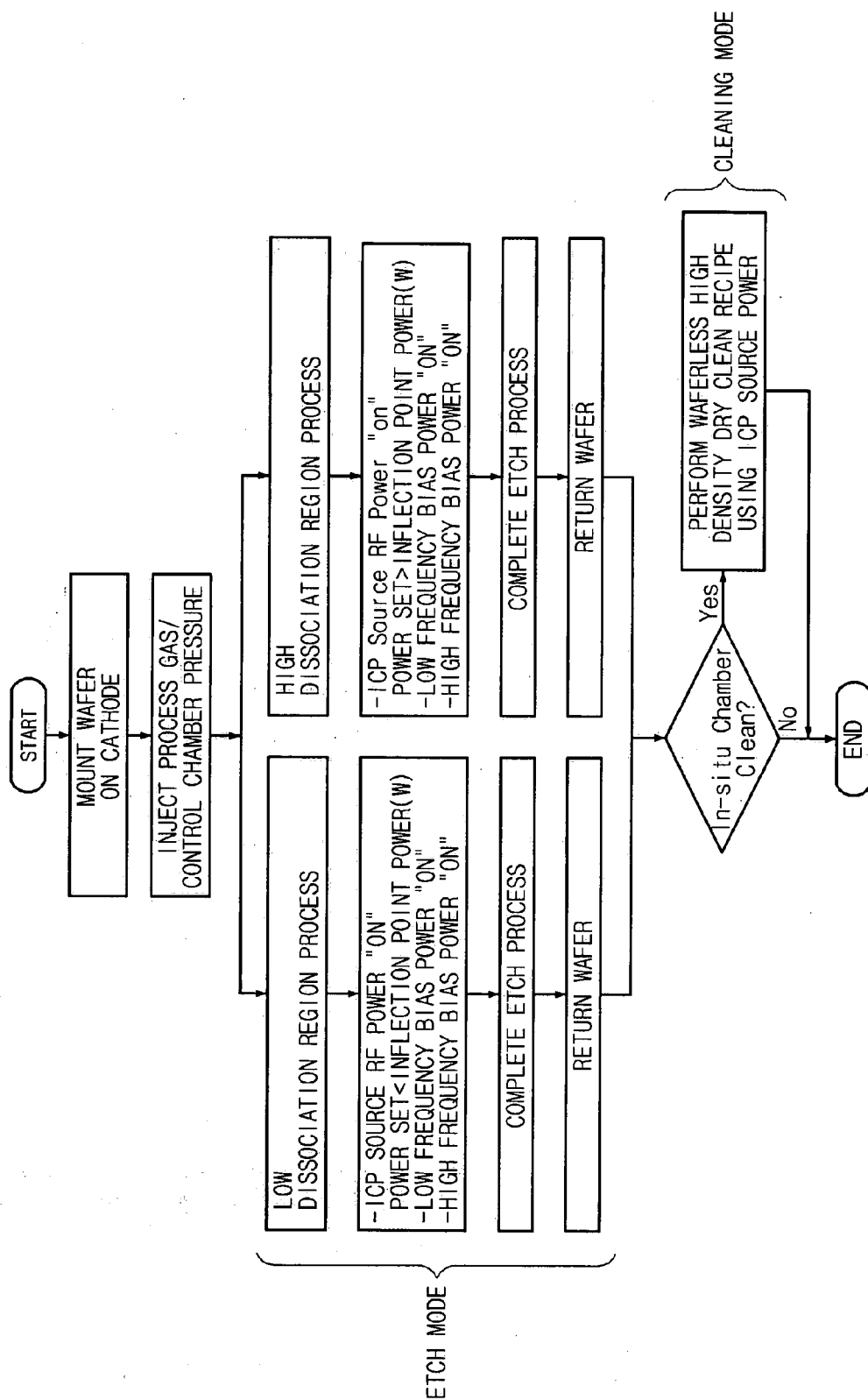


FIG. 4

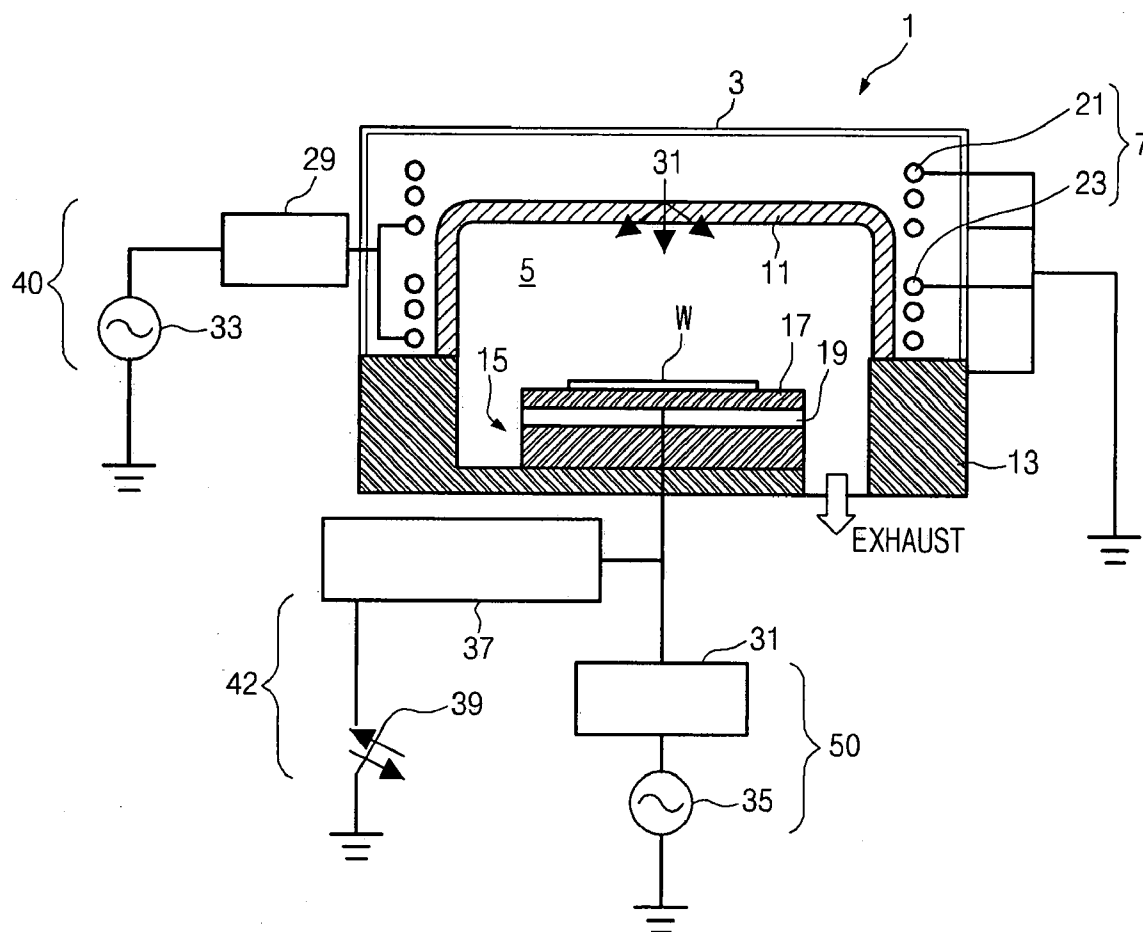


FIG. 5

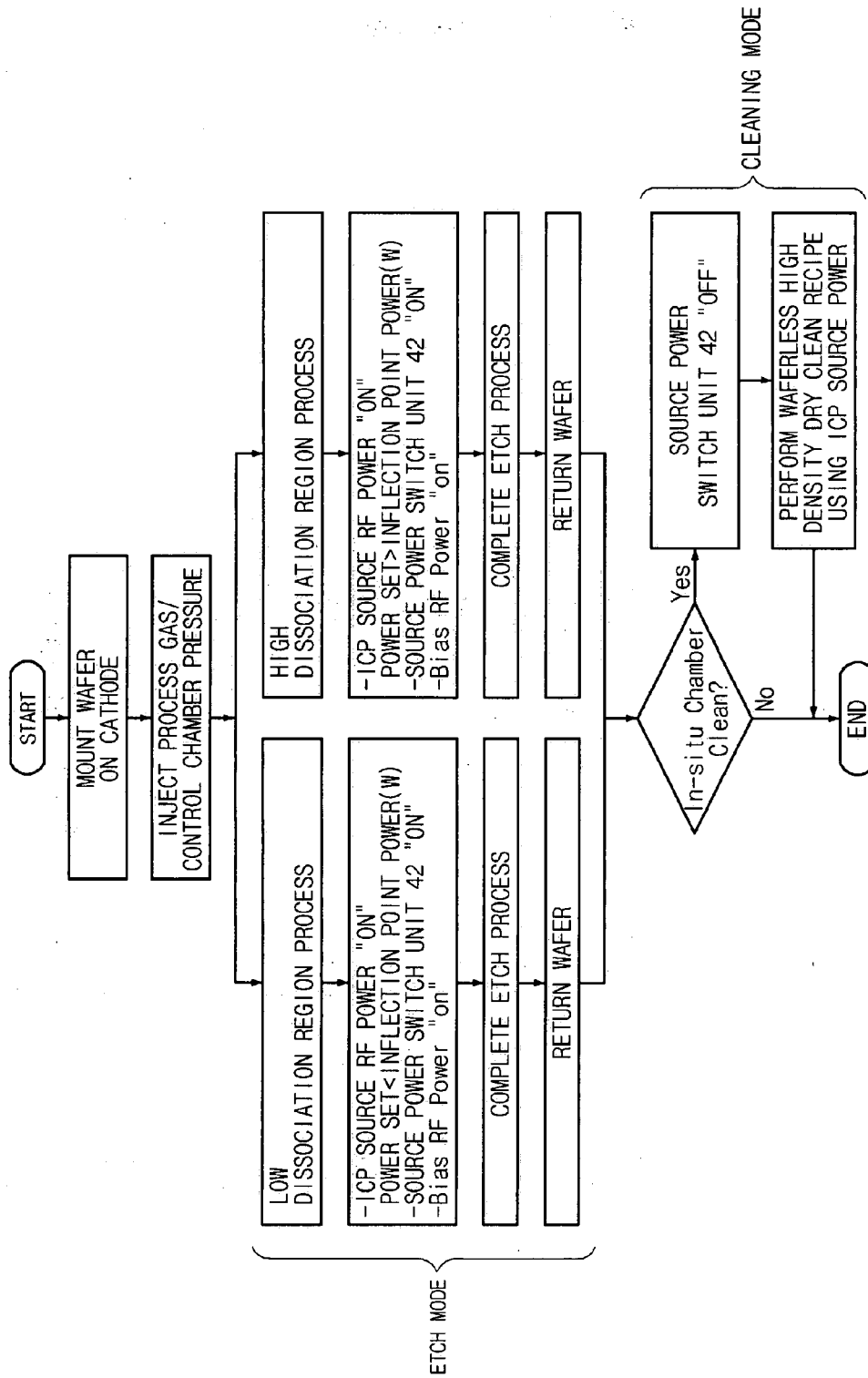


FIG. 6

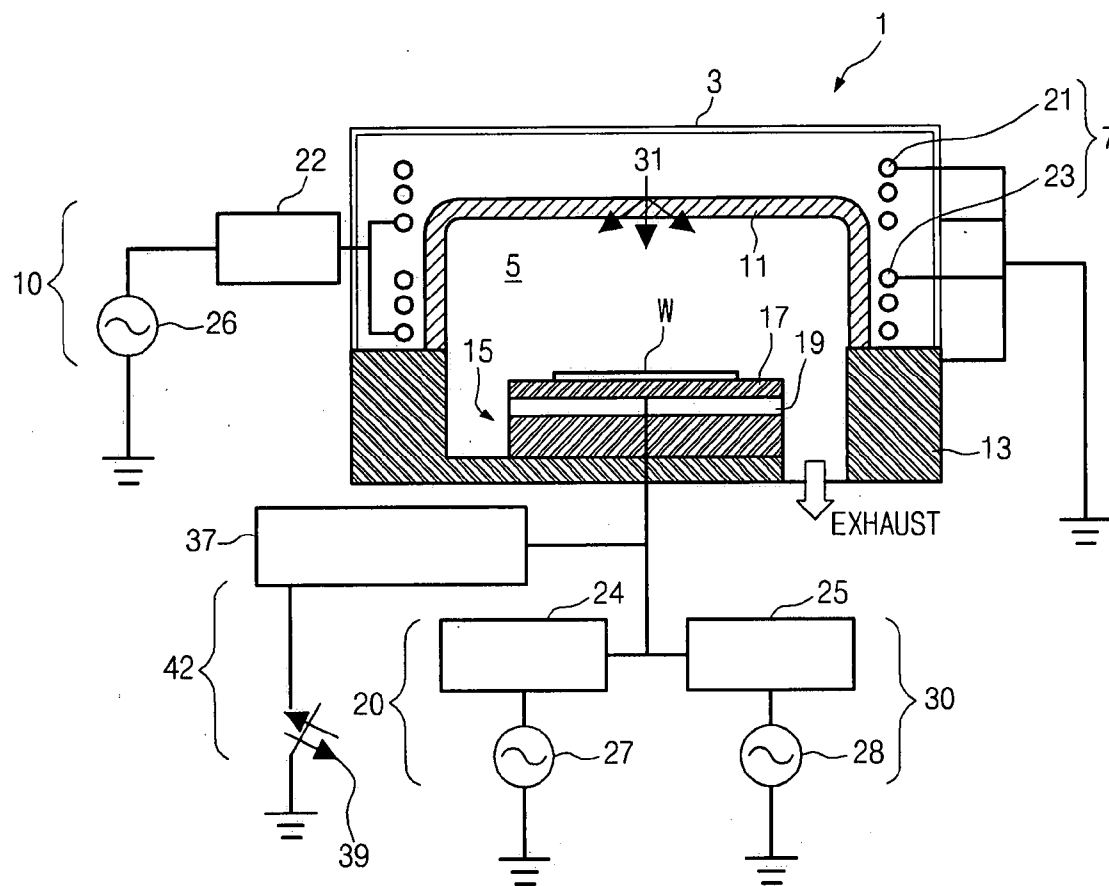


FIG. 7

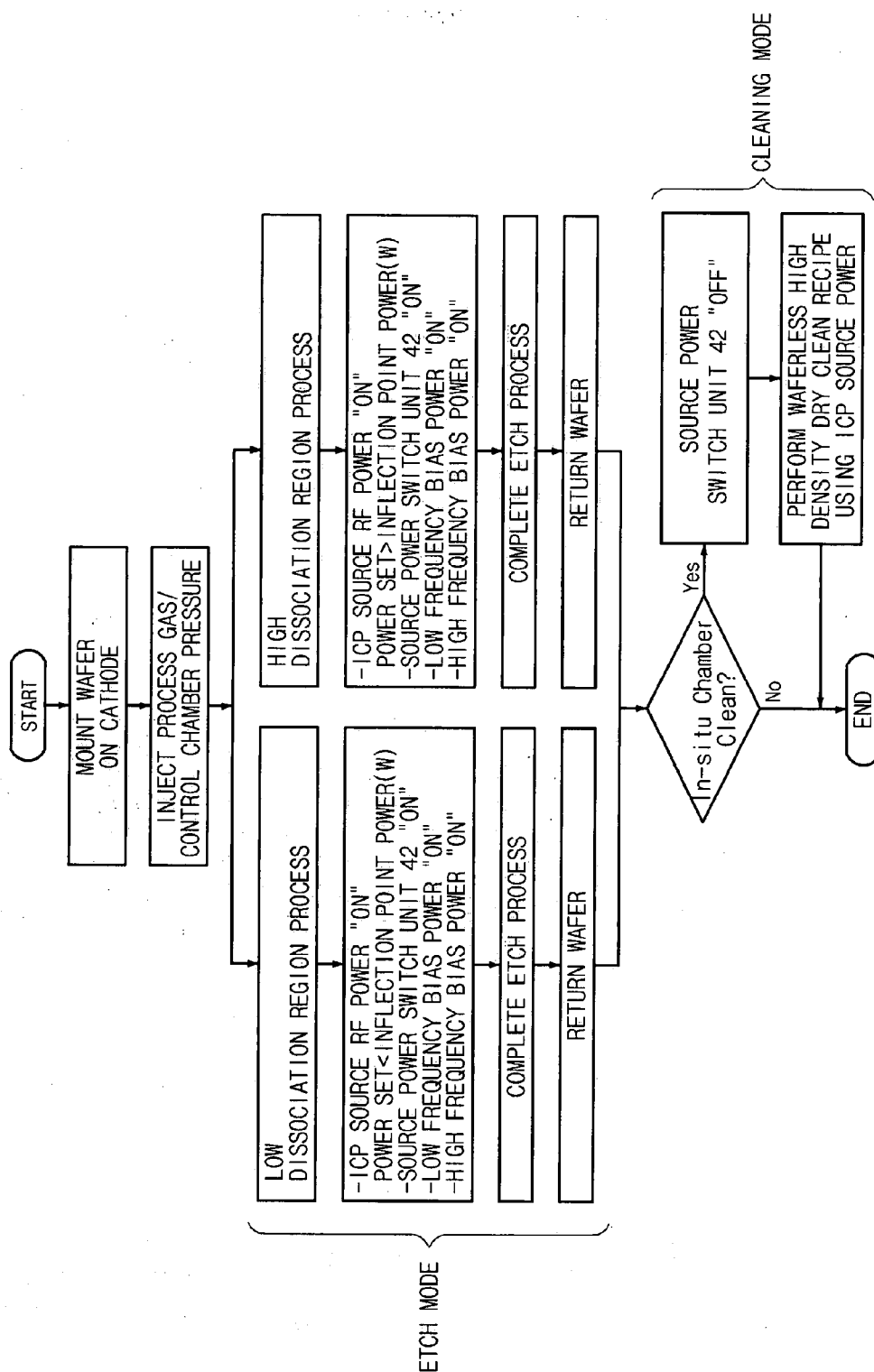


FIG. 8

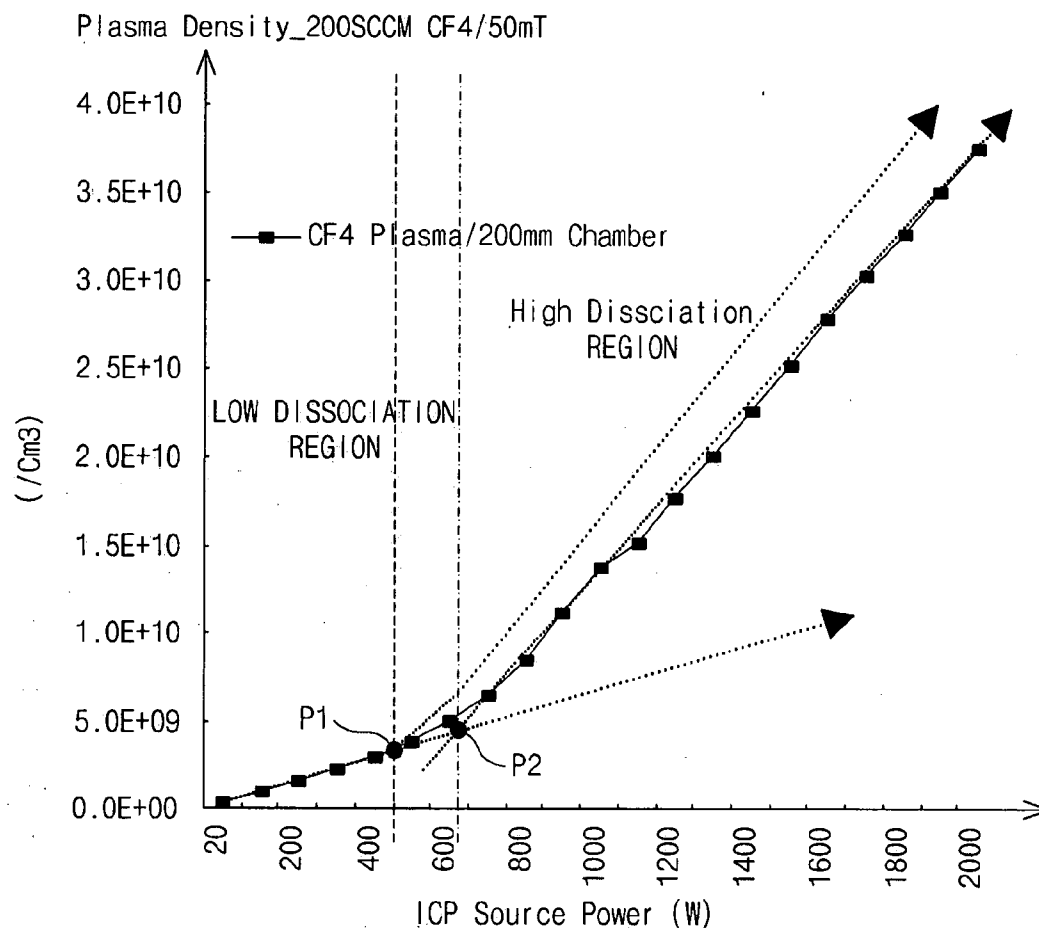


FIG. 9

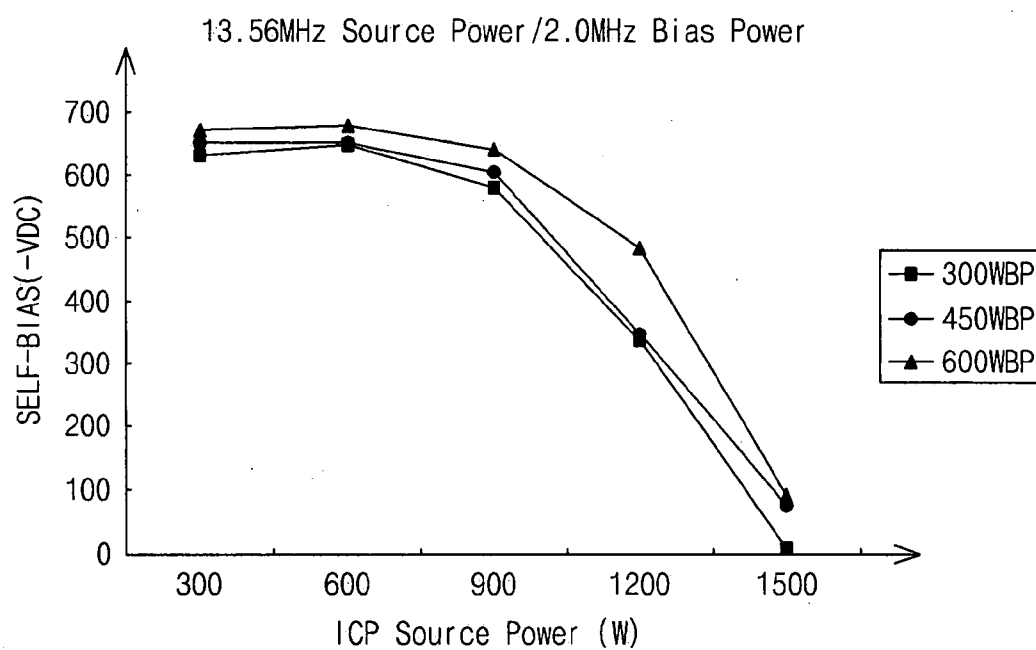


FIG. 1 0

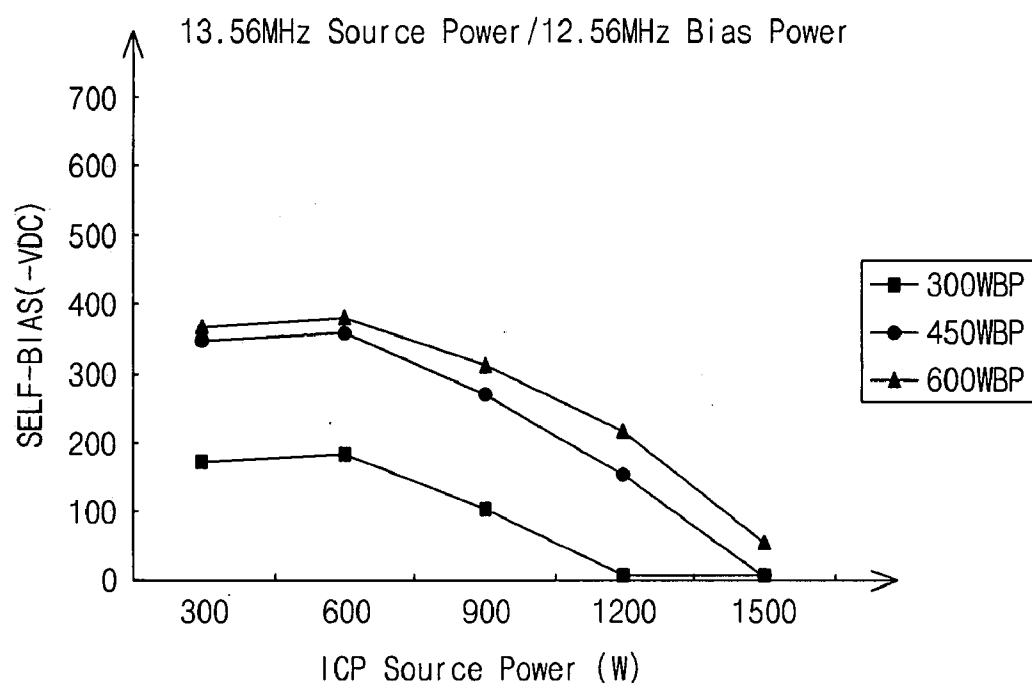


FIG. 1 1

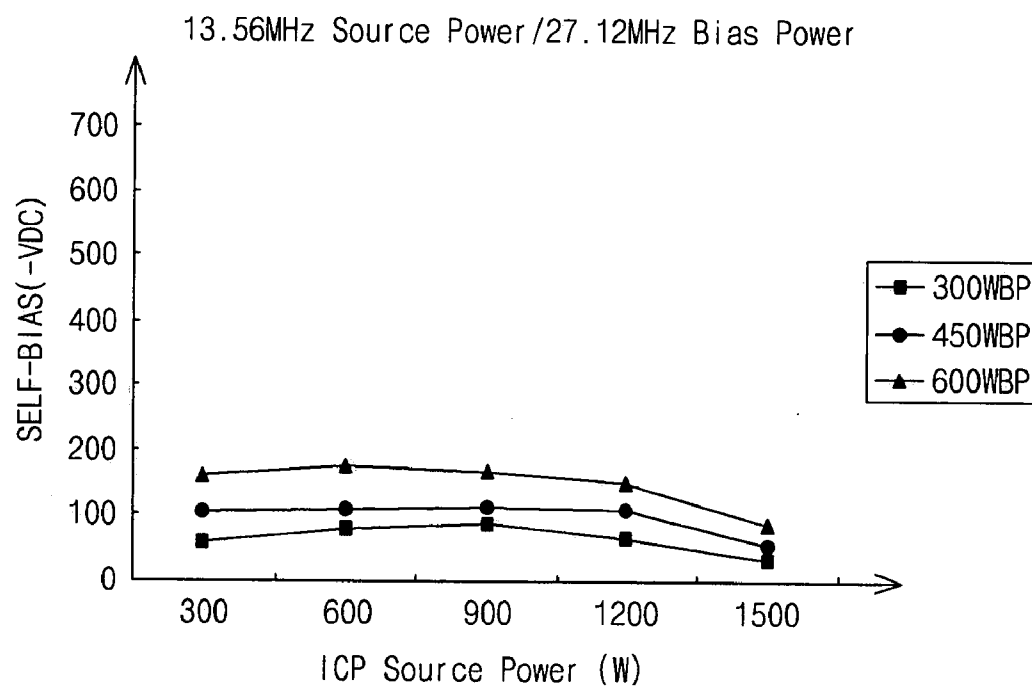


FIG. 1 2

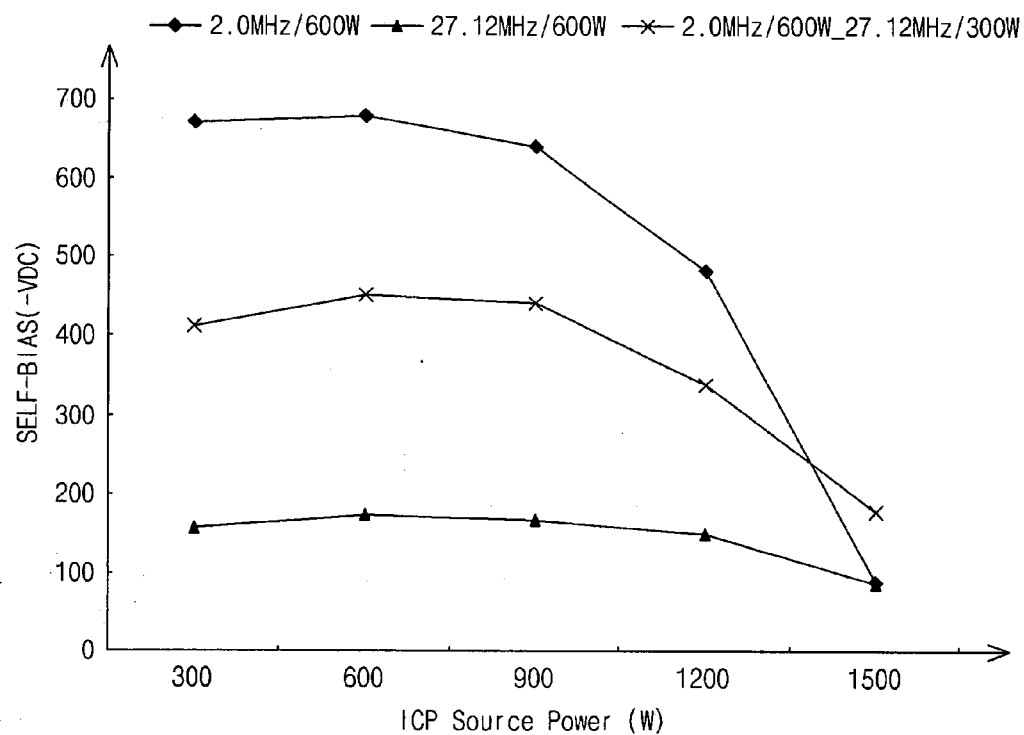


FIG. 1 3

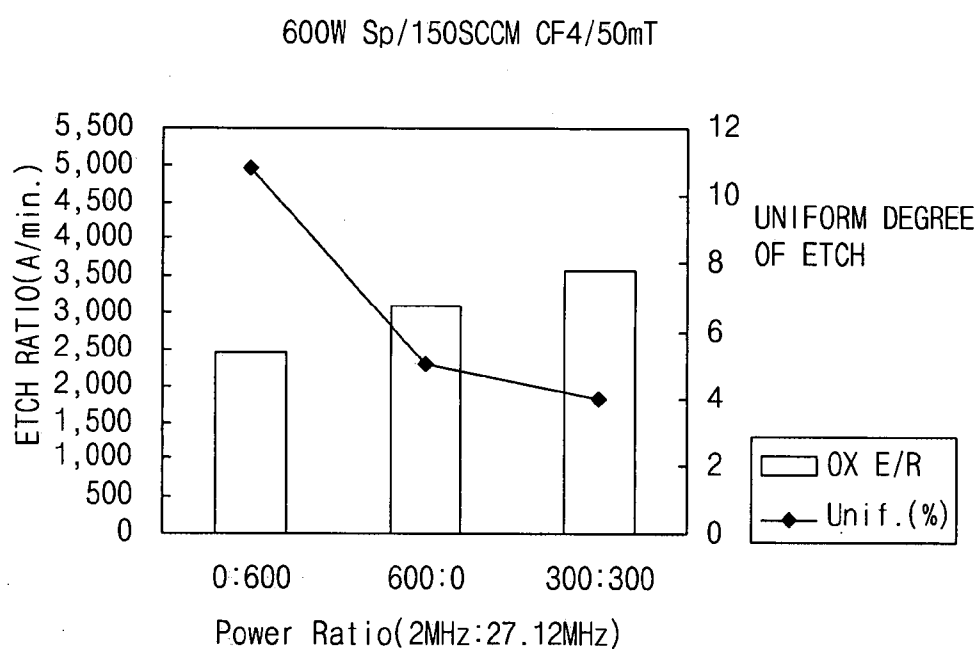


FIG. 1 4

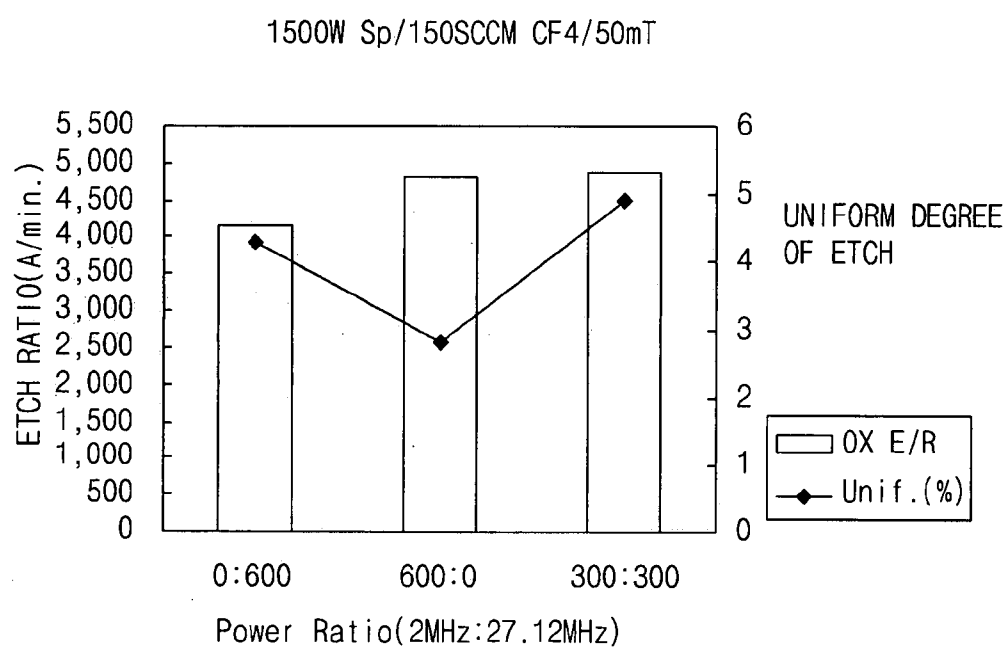


FIG. 1 5

HYBRID PLASMA REACTOR

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a device used in a semiconductor fabrication process, and more particularly, to a plasma reactor.

[0003] 2. Description of the Related Art

[0004] In general, a plasma reactor performing a dry etch process using plasma is classified into a Capacitively Coupled Plasma (CCP) type plasma reactor and an Inductively Coupled Plasma (ICP) type plasma reactor, depending on a method for generating plasma within a chamber. As known in the art, in the CCP type plasma reactor, ion flux energy proportionally increases within a plasma chamber as a frequency of a Radio Frequency (RF) power supplied to an upper electrode or a cathode gets lower. Also, in the CCP type plasma reactor, ion density increases as the frequency of the RF power supplied to the upper electrode or the cathode gets higher. In the ICP type plasma reactor, low dissociation condition and high dissociation condition can be provided within the chamber as an RF power supplied to an antenna coil increases. A degree of dissociation of reaction gas is small under the low dissociation condition, and is great under the high dissociation condition. In case where the ICP type plasma reactor performs an etch process under each of the low and high dissociation conditions, a target wafer shows physical properties different from each other. In detail, when the ICP type plasma reactor performs the etch process under the low dissociation condition, the target wafer shows a similar physical property with when the CCP type plasma reactor performs an etch process. When the ICP type plasma reactor performs the etch process under the high dissociation condition, an increase of the RF power supplied to the antenna coil results in a sudden reduction of plasma ion energy within the chamber as a frequency of a bias RF power supplied to a cathode gets lower.

[0005] As the dry etch process implemented using plasma, there are an insulating film (oxide) etch process and a poly/metal etch process. The insulating film etch process is mainly based on a physical etch process. Thus, an insulating film is etched mainly using a narrow gap CCP type plasma reactor in which a multi frequency RF power is applied to an upper electrode or a cathode. Such the CCP type plasma reactor has an advantage of being capable of generating high energy ions using high electric field. However, the CCP type plasma reactor leads to process kit damage caused by ion impact, and leads to arcing problem caused by high plasma potential because of its characteristic. Low dissociation reduces an efficiency of In-situ Chamber Cleaning (ICC) and thus, a Mean Time Between Chamber clean (MTBC) is implemented shortly. The CCP type plasma reactor is problematic in hardware design and cost required for supplying a high frequency power to the upper electrode or the cathode.

[0006] Unlike the insulating film etch process, the poly/metal etch process generally based on a relatively chemical etch way is mainly using the ICP type plasma reactor. This is because the ICP type plasma reactor can independently control plasma ion density and energy within the chamber, facilitate generation of high-density and large-scale plasma at a low pressure, and sufficiently etch a device by a small plasma ion energy, thereby reducing a device damage.

[0007] Parameters of much importance in realizing the ICP type plasma reactor are a damage of a dielectric window caused by high voltage supplied to the antenna coil, high/low plasma ion density and uniformity over a wide area, a control of a concentration of excessive radicals, tunable ion energy, and a wide ion energy distribution.

[0008] However, an ICP type plasma reactor created up to now can generate high density plasma ions, but cannot control a concentration of excessive radicals, control plasma ion energy, and expand a plasma ion energy distribution. Therefore, the ICP type plasma reactor shows a poorer process performance than the CCP type plasma reactor though it is more effective than the CCP type plasma reactor. As a result, the ICP type plasma reactor is difficult to perform a high aspect ratio process while guaranteeing a high PhotoResist (PR) selectivity.

[0009] In case where the ICP type plasma reactor performs the dry etch process, a high dissociation of reaction gas and an increase of a source power lead to a sudden reduction of plasma ion energy when a low frequency RF power is supplied to the cathode. As a result, there occurs a phenomenon such as etch stop, chamber matching, low PR selectivity, and narrow process window.

SUMMARY OF THE INVENTION

[0010] An aspect of exemplary embodiments of the present invention is to address at least the problems and/or disadvantages and to provide at least the advantages described below. Accordingly, an aspect of exemplary embodiments of the present invention is to provide a hybrid plasma reactor for supplying a bias RF power, which is a mixture of a high frequency RF power and a low frequency RF power, to a cathode and controlling a source power supplied to an antenna coil, thereby compensating a sudden reduction of plasma ion energy caused by an increase of the source power and sustaining plasma ion density and energy within a set range, when the low frequency RF power is supplied to the cathode.

[0011] According to one aspect of exemplary embodiments of the present invention, there is provided a hybrid plasma reactor. The hybrid plasma reactor includes an ICP (Inductively Coupled Plasma) source unit and a bias RF (Radio Frequency) power supply unit. The ICP source unit includes a chamber, an antenna coil unit, and a source power supply unit. The chamber includes a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body. The antenna coil unit is disposed outside of the dielectric window. The source power supply unit supplies a source power to the antenna coil unit. The bias RF power supply unit supplies a bias RF power to a cathode. The cathode is installed within the chamber and mounts a target wafer on its top. A plasma ion density within the chamber is greater when a source power greater than a set power is supplied to the antenna coil unit than when a source power smaller than the set power is supplied to the antenna coil unit. A plasma ion energy within the chamber is greater when the source power smaller than the set power is supplied to the antenna coil unit than when the source power greater than the set power is supplied to the antenna coil unit. In order to increase the set power and expand a tunable range of the source power, the bias RF power supply unit supplies the bias RF power, which is a mixture of a high frequency RF power and a low frequency RF power, to the cathode so that a sudden reduction of the plasma ion energy

within the chamber occurring as the source power supplied to the antenna coil unit increases greater than the set power is compensated or so that the plasma ion density and energy within the chamber is sustained within a set range.

[0012] According to another aspect of exemplary embodiments of the present invention, there is provided a hybrid plasma reactor. The hybrid plasma reactor includes an ICP source unit and a high frequency RF power supply unit. The ICP source unit includes a chamber, an antenna coil unit, and a source power supply unit. The chamber includes a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body. The antenna coil unit is disposed outside of the dielectric window. The source power supply unit supplies a source power to the antenna coil unit. The high frequency RF power supply unit supplies a bias RF power to a cathode. The cathode is installed within the chamber and mounting a target wafer on its top. The low frequency RF power supply unit connects to the cathode in parallel with the high frequency RF power supply unit, and supplies a low frequency RF power to the cathode. A plasma ion density within the chamber is greater when a source power greater than a set power is supplied to the antenna coil unit than when a source power smaller than the set power is supplied to the antenna coil unit. A plasma ion energy within the chamber is greater when the source power smaller than the set power is supplied to the antenna coil unit than when the source power greater than the set power is supplied to the antenna coil unit. In order to increase the set power and expand a tunable range of the source power, the high frequency RF power supply unit and the low frequency RF power supply unit operate together and supply a bias RF power, which is a mixture of the high frequency RF power and the low frequency RF power, to the cathode so that a sudden reduction of the plasma ion energy within the chamber occurring as the source power supplied to the antenna coil unit increases greater than the set power is compensated or so that the plasma ion density and energy within the chamber is sustained within a set range.

[0013] According to a further another aspect of exemplary embodiments of the present invention, there is provided a hybrid plasma reactor. The hybrid plasma reactor includes an ICP source unit, a high frequency RF power supply unit, a low frequency RF power supply unit, and a source power switch unit. The ICP source unit includes a chamber, an antenna coil unit, and a source power supply unit. The chamber includes a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body. The antenna coil unit is disposed outside of the dielectric window. The source power supply unit supplies a source power to the antenna coil unit. The high frequency RF power supply unit supplies a bias RF power to a cathode. The cathode is installed within the chamber and mounting a target wafer on its top. The low frequency RF power supply unit connects to the cathode in parallel with the high frequency RF power supply unit, and supply a low frequency RF power to the cathode. The source power switch unit connects to the cathode in parallel with the high frequency RF power supply unit. The source power switch unit switches on to selectively connect the cathode to the ground via the source power switch unit so that the high frequency RF power generated from the source power supply unit is selectively supplied to the cathode.

[0014] A closed loop is formed including the source power supply unit, the antenna coil unit, the cathode, the source

power switch unit, and the ground when the cathode connects to the ground via the source power switch unit. The source power is any one of an RF power having a frequency higher than that of the high frequency RF power, an RF power having a frequency lower than that of the low frequency RF power, and an RF power having a frequency between frequencies of the low frequency RF power and the high frequency RF power.

[0015] A plasma ion density within the chamber is greater when a source power greater than a set power is supplied to the antenna coil unit than when a source power smaller than the set power is supplied to the antenna coil unit. A plasma ion energy within the chamber is greater when the source power smaller than the set power is supplied to the antenna coil unit than when the source power greater than the set power is supplied to the antenna coil unit.

[0016] In order to increase the set power and expand a tunable range of the source power, the high frequency RF power supply unit, the low frequency RF power supply unit, and the source power switch unit operate together and supply a bias RF power obtained by mixing the high frequency RF power and the low frequency RF power with the source power, to the cathode so that a sudden reduction of the plasma ion energy within the chamber occurring as the source power supplied to the antenna coil unit increases greater than the set power is compensated or so that the plasma ion density and energy within the chamber is sustained within a set range.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The accompanying drawings, which are included to aid in The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings in which:

[0018] FIG. 1 illustrates a construction of a plasma reactor according to a first exemplary embodiment of the present invention;

[0019] FIG. 2 illustrates a cross-sectional diagram of an antenna coil unit shown in FIG. 1, and a distribution of magnetic field generated around the antenna coil unit when a source power is supplied to the antenna coil unit;

[0020] FIG. 3 is a graph illustrating an intensity of magnetic field depending on each radius (R) of a primary antenna coil group and a secondary antenna coil group included in the antenna coil unit shown in FIG. 2 and a length (L) between the primary and secondary antenna coil groups;

[0021] FIG. 4 is a flowchart illustrating an etch procedure implemented by the plasma reactor shown in FIG. 1;

[0022] FIG. 5 illustrates a construction of a plasma reactor according to a second exemplary embodiment of the present invention;

[0023] FIG. 6 is a flowchart illustrating an etch procedure implemented by the plasma reactor shown in FIG. 5;

[0024] FIG. 7 illustrates a construction of a plasma reactor according to a third exemplary embodiment of the present invention;

[0025] FIG. 8 is a flowchart illustrating an etch procedure implemented by the plasma reactor shown in FIG. 7;

[0026] FIG. 9 is a graph illustrating a plasma ion density characteristic depending on an increase of a source power;

[0027] FIG. 10 is a graph illustrating variation of a self-bias (−VDC) formed in a cathode versus variation of a

source power when a bias RF power of 2 MHz is supplied to the cathode of a plasma reactor according to the present invention;

[0028] FIG. 11 is a graph illustrating variation of a self-bias (–VDC) formed in a cathode versus variation of a source power when a bias RF power of 12.56 MHz is supplied to the cathode of a plasma reactor according to the present invention;

[0029] FIG. 12 is a graph illustrating variation of a self-bias (–VDC) formed in a cathode versus variation of a source power when a bias RF power of 27.12 MHz is supplied to the cathode of a plasma reactor according to the present invention;

[0030] FIG. 13 is a graph illustrating variation of a self-bias (–VDC) formed in a cathode versus variation of a source power, in each case where a single frequency bias RF power is supplied and a mixed frequency bias RF power is supplied to the cathode of a plasma reactor according to the present invention;

[0031] FIG. 14 is a graph illustrating variation of an etch rate versus variation of a frequency mixture rate of a bias RF power supplied to a cathode, when a source power of 600 W is supplied to an antenna coil unit of a plasma reactor according to the present invention; and

[0032] FIG. 15 is a graph illustrating variation of an etch rate versus variation of a frequency mixture rate of a bias RF power supplied to a cathode, when a source power of 1500 W is supplied to an antenna coil unit of a plasma reactor according to the present invention.

[0033] Throughout the drawings, the same drawing reference numerals will be understood to refer to the same elements, features and structures.

DETAILED DESCRIPTION OF THE INVENTION

[0034] Exemplary embodiments of the present invention will now be described in detail with reference to the annexed drawings. In the following description, a detailed description of known functions and configurations incorporated herein has been omitted for conciseness.

[0035] The present invention is to provide a hybrid type plasma generating apparatus and method for providing plasma properties (e.g., tunable plasma ion density, tunable ion energy distribution, tunable ion energy, tunable radical, and low ion damage plasma) required for a process of fabricating a semiconductor, a Liquid Crystal Diode (LCD), and other integrated circuits. These plasma properties can be controlled using a multi antenna coil structure, a cylinder type dielectric window, an Inductively Coupled Plasma (ICP) source unit provided above a chamber, and a mixture frequency bias applied to a cathode.

[0036] FIG. 1 illustrates a construction of a plasma reactor according to a first exemplary embodiment of the present invention. Referring to FIG. 1, the plasma reactor includes an Inductively Coupled Plasma (ICP) source unit 1, and bias RF power supply units that are a low frequency Radio Frequency (RF) power supply unit 20 and a high frequency RF power supply unit 30. The ICP source unit 1 includes a chamber 5, an antenna coil unit 7, and a source power supply unit 10. The chamber 5 includes a chamber body 13, and a cylinder type dielectric window 11. The chamber body 13 is opened at its top. The dielectric window 11 covers the opened top of the chamber body 13. The antenna coil unit 7 includes a primary antenna coil group 21 and a secondary

antenna coil group 23. The primary antenna coil group 21 is arranged at an upper side around the dielectric window 11 outside the dielectric window 11. The secondary antenna coil group 23 is arranged at a lower side around the dielectric window 11 outside the dielectric window 11. A shield part 3 is attached to an upper part of an external sidewall of the chamber body 13 as surrounding the dielectric window 11 and the antenna coil unit 7 to shield the dielectric window 11 and the antenna coil unit 7 from the exterior.

[0037] The dielectric window 11 has a gas injection port 31 at its top. A gas injection system (not shown) injects a reaction gas into the chamber 5 through the gas injection port 31. A cathode assembly support 15 is arranged within the chamber 5. The cathode assembly support 15 is physically fixed to the chamber body 13, and is electrically grounded. A cathode 17 is disposed over the cathode assembly support 15. An insulator 19 is disposed between the cathode assembly support 15 and the cathode 17. The insulator 19 electrically insulates between the cathode assembly support 15 and the cathode 17. Wafer (W), a process target, is mounted on the cathode 17. In detail, the wafer (w) is fixed using a Ceramic Electro-Static Chuck (CESC) (not shown) provided on the cathode 17.

[0038] The source power supply unit 10 supplies each source power to the primary and secondary antenna coil groups 21 and 23. The source power supply unit 10 includes a source impedance matching circuit 22 for source impedance matching, and a source high frequency generator 26. The source impedance matching circuit 22 connects the primary and secondary antenna coil groups 21 and 23 with the source high frequency generator 26. The source high frequency generator 26 connects to the ground. When the source power supply unit 10 supplies a source power to the primary and secondary antenna coil groups 21 and 23, a magnetic field is generated around the primary and secondary coil groups 21 and 23. As a result, an RF electric field is induced within the chamber 5.

[0039] The low frequency RF power supply unit 20, which is the bias RF power supply unit, supplies a low frequency RF power to the cathode 17. The low frequency RF power supply unit 20 includes a bias impedance matching circuit/low pass filter (LF match/LPF) 24 and a bias low frequency generator 27. The LF match/LPF 24 matches impedance and selectively passes only the low frequency RF power. The bias low frequency generator 27 generates the low frequency RF power.

[0040] The high frequency RF power supply unit 30 includes a bias impedance matching circuit/high pass filter (HF match/HPF) 25 and a bias high frequency generator 28. The HF match/HPF 25 matches impedance and selectively passes only a high frequency RF power. The bias high frequency generator 28 generates the high frequency RF power. A bias RF power, which is a mixture of the high frequency RF power and the low frequency RF power, is supplied to the cathode 17 when the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 operate together.

[0041] A plasma ion density within the chamber 5 is much greater when a source power smaller than a set power (hereinafter, it is defined as “inflection point power”) is supplied to the antenna coil unit 7 than when a source power greater than the set power is supplied to the antenna coil unit 7. The inflection point power is a criterion for dividing a low dissociation region and a high dissociation region. Referring

to FIG. 9, when the source power greater than the inflection point power is supplied to the antenna coil unit 7, a dissociation degree of reaction gas is much greater than when the source power smaller than the inflection point power is supplied to the antenna coil unit 7. For example, the inflection point power can be set within a range of about 500 W to 700 W in the plasma reactor for processing a wafer having a diameter of 200 mm. The inflection point power can be greater or smaller depending on a size, a type, and a process condition of the plasma reactor.

[0042] Plasma ion energy within the chamber 5 is greater when the source power smaller than the set power is supplied to the antenna coil unit 7 than when the source power greater than the set power is supplied to the antenna coil unit 7. When the bias RF power supply units that are the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 supply the bias RF power that is the mixture of the low frequency RF power and the high frequency RF power to the cathode 17, the set power can more increase. As a result, a tunable range of the source power in the low dissociation region can be more expanded. For example, there occurs a phenomenon in which the plasma ion energy within the chamber 5 suddenly reduces when only the low frequency RF power is supplied to the cathode 17 and the source power is supplied more than the set power to the antenna coil unit 7. Also, the plasma ion energy within the chamber 5 reduces to the extent that an etch process cannot be normally implemented though the source power increases, when only the high frequency RF power is supplied to the cathode 17. However, when the bias RF power, the mixture of the low frequency RF power and the high frequency RF power, is supplied to the cathode 17, a sudden reduction of the plasma ion energy within the chamber 5 can be compensated, and the plasma ion energy can be sustained within a set range enabling normal implementation of the etch process.

[0043] According to the present invention, the ICP plasma source unit 1 includes the antenna coil unit 7, for example. As shown in FIGS. 2 and 3, the antenna coil unit 7 provides a property of uniform magnetic field and a plasma property of FIG. 9. This enables selective use of low and high dissociation regions, and the uniform ion density as described later.

[0044] The cylinder dielectric window 11 guarantees a constant distance between bulk plasma and a Ceramic Electro-Static Chuck (CESC) (not shown) on the cathode 17 for placing the wafer, the process target, thereby enabling an independent control of the plasma ion density and energy. As a result, the cylinder dielectric window 11 minimizes a physical damage while enabling effective etching of the process target.

[0045] The antenna coil unit 7 is positioned outside of the cylinder dielectric window 11. The cylinder dielectric window 11 is of a structure in which its top surface is flat. The gas injection system is positioned at the gas injection port 31 provided in the dielectric window 11. The gas injection system effectively exhausts an etch by-product generated in etching via an exhaust hole. Resultantly, reaction gas can have a constant residence time for a whole surface of the process target, thereby guaranteeing a wide process window. Further, a hardware design is flexible because a monitoring system can be installed in a space above the dielectric window 11.

[0046] As shown in FIG. 2, the antenna coil unit 7 includes the primary antenna coil group 21 and the secondary antenna coil group 23. The primary and secondary antenna coil groups 21 and 23 each have a plurality of antenna coils connecting in parallel. The secondary antenna coil group 23 is positioned keeping a distance from the primary antenna coil group 21 by a coil radius (R) or smaller or greater than the coil radius (R). An intensity of the magnetic field generated in the chamber 5 can be suitably controlled when the length (L) between the two antenna coil groups 21 and 23 is controlled. This provides useful flexibility to a chamber design for acquiring an ion density uniformity/intensity and a uniform etch rate. FIG. 3 is a graph illustrating a distribution of the intensity of the magnetic field generated within the chamber 5, respectively, when the length (L) between the antenna coil groups 21 and 23 is smaller than the coil radius (R), when it is equal to the coil radius (R), and when it is greater than the coil radius (R). As shown in the graph of FIG. 3, magnetic field increases in intensity when the length (L) is equal to or smaller than the radius (R). A magnetic field can be generated with uniformity and intensity greater than those of a conventional solenoid type antenna coil, when the antenna coil unit 7 satisfies the above conditions and the respective antenna coil groups 21 and 23 are equal to each other in current direction. This enables realization of uniform and high plasma ion density within the chamber 5.

[0047] The primary and secondary antenna coil groups 21 and 23 each comprised of the plurality of coils have low reactance values. Accordingly, a relatively small source power voltage can be dispersed and applied to the plurality of coils. This can reduce sputtering occurring within the chamber 5 (that is, a low sputtering effect), and minimize damage and contamination of the dielectric window 11 caused by the sputtering.

[0048] Plasma strike and sustain at a low RF power of about less than 20 W are possible. When the bias RF power that is the mixture of the high frequency and low frequency RF powers is applied to the cathode 17, the set source power (that is, an inflection point), which serves as a criterion for dividing into the low dissociation region and the high dissociation region, shifts from a point (P1) to a point (P2) as shown in FIG. 9. As the shift result, the low and high dissociation regions can be guaranteed relatively widely and the flexibility of an insulating film etch process can be guaranteed. In other words, a radical concentration can be controlled by a control of a high dissociation property of the ICP type plasmas reactor. In-situ Chamber Clean (ICC) with small damage and high efficiency can be realized, thereby maximizing a Mean Time Between Chamber clean (MTBC) because high plasma ion density and high dissociation condition can be acquired at a constant RF power (about 500 W to 700 W) or more. Also, an effective solution to chronic chamber arcing and process kit damage problems of a Capacitively Coupled Plasma (CCP) type plasma reactor can be provided.

[0049] FIG. 4 is a flowchart illustrating an etch procedure implemented by the plasma reactor shown in FIG. 1.

[0050] Referring to FIG. 4, when the plasma reactor performs dry etch, the wafer (W), which is the process target, is fixed by the CESC (not shown) provided on the cathode 17. Reaction gas is supplied into the chamber 5 through the gas injection port 31. A vacuum pump (not shown) and a pressure control unit (not shown) maintain a pressure within the chamber 5 as an operation pressure.

[0051] In a physical/chemical aspect, plasma generated by the ICP plasma source unit 1 can acquire two modes: a CCP mode and an ICP mode. As shown in FIG. 9, as an ICP source power increases, a specific plasma ion density does not greatly increase in the low dissociation region (the CCP mode), and dissociation suddenly occurs in the high dissociation region (the ICP mode).

[0052] In detail, the plasma reactor shows a CCP property where dissociation does not suddenly occur below a constant RF source power (that is, the inflection point power). The plasma reactor shows an inherent property of ICP where dissociation suddenly occurs above the constant RF source power. When a pressure within the chamber 5 reaches a pressure required for a process, the plasma reactor can selectively operate in any one of the CCP mode and the ICP mode depending on a process characteristic of an etch mode.

[0053] The source power is set below the inflection point power when an etch process in the low dissociation region is implemented. The source power is set above the inflection point power when an etch process in the high dissociation region is implemented. Upon completion of the setting of the source power, the source power supply unit 10, the low frequency RF power supply unit 20, and the high frequency RF power supply unit 30 turn on. As a result, the source power supply unit 10 applies a constant RF power (that is, a source power) to the antenna coil unit 7 while forming plasma within the chamber 5. Low frequency/high frequency RF powers are mixed and applied to the cathode 17.

[0054] In other words, the upper ICP plasma source unit 1 generates plasma suitable to the process characteristic and concurrently applies the high frequency/low frequency RF powers to the cathode 17 in a mixed frequency format suitably to the process characteristic, thereby implementing a desired process. Also, suddenly reduced ion energy intensity/ion density/radical concentration can be controlled by suitably controlling the ICP source power and amounts of the low/high frequency RF powers applied to the cathode in the low dissociation region and the high dissociation region. Thus, a high etch rate, a high PhotoResist (PR) selectivity, and a wide process window can be guaranteed.

[0055] During the etch process, the etch by-product is exhausted outside the chamber 5 by an exhaust system, and its part is deposited onto an inner wall of the chamber 5. The etch by-product deposited onto the inner wall of the chamber 5 changes the process characteristic and concurrently serves as dusts, thereby causing a problem of serious contamination on the process target and thus reducing quality and productivity. In order to solve this problem, ICC using plasma is implemented for the plasma reactor.

[0056] When the plasma reactor is in an ICC cleaning mode, it performs a waferless high-density dry clean recipe using only the ICP source power, that is, using the RF power from the source power supply unit 10. In detail, when the plasma reactor operates in the ICC cleaning mode, the source power supply unit 10 supplies the source power to the antenna coil unit 7, and the bias RF power supply unit (that is, the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30) stops supplying the bias RF power to the cathode 17. Resultantly, the plasma reactor performs an ICC process using high-density plasma with the target wafer (W) not mounted on the cathode 17.

[0057] FIG. 5 illustrates a construction of a plasma reactor according to a second exemplary embodiment of the present invention.

[0058] Referring to FIG. 5, a construction and a detailed operation of the plasma reactor will be described on the basis of several differences because they are almost the same as those of the plasma reactor according to the first exemplary embodiment of the present invention. One of the differences is that an RF power supply unit 50 generating only any one of a high frequency RF power and a low frequency RF power connects to a cathode 17. In other words, a high frequency RF power supply unit or a low frequency RF power supply unit connects to the cathode 17. Another one of the differences is that a source power switch unit 42 connects to the cathode 17 in parallel with the RF power supply unit 50. The source power switch unit 42 enables the cathode 17 to selectively connect to the ground via the source power switch unit 42 such that the high frequency or low frequency RF power generated by a source power supply unit 40, is supplied to the cathode 17 selectively. When the cathode 17 connects to the ground via the source power switch unit 42, a closed loop is formed including a source power supply unit 40, an antenna coil unit 7, the cathode 17, the source power switch unit 42, and the ground. The source power switch unit 42 includes a source power filter 37 and a switch 39. The source power filter 37 filters a source power received from the antenna coil unit 7 through the cathode 17, except signals of frequencies other than a frequency of the source power. The switch 39 electrically connects or disconnects the source power filter 37 from the ground. A bias RF power, which is a mixture of the high frequency RF power and the low frequency RF power, is supplied to the cathode 17, when the cathode 17 connects to the ground via the source power switch unit 42 and the bias RF power supply unit 50 and the source power supply unit 40 operate. Resultantly, a bias RF power supply unit including the high frequency or low frequency RF power supply unit 50 and the source power switch unit 42 supplies the bias RF power to the cathode 17.

[0059] In case where the bias RF power supply unit 50 is comprised of the low frequency RF power supply unit and supplies the low frequency RF power to the cathode 17, the source power supply unit 40 is comprised of the high frequency RF power supply unit and selectively supplies the high frequency RF power to the cathode 17 by the source power switch unit 42.

[0060] In case where the bias RF power supply unit 50 is comprised of the high frequency RF power supply unit and supplies the high frequency RF power to the cathode 17, the source power supply unit 40 is comprised of the low frequency RF power supply unit and selectively supplies the low frequency RF power to the cathode 17 by the source power switch unit 42.

[0061] The source power filter 37 is tuned to the frequency of the source power generated from the source power supply unit 40.

[0062] FIG. 6 is a flowchart illustrating an etch procedure implemented by the plasma reactor shown in FIG. 5. Referring to FIG. 6, when a pressure within a chamber 5 reaches a pressure required for a process, the plasma reactor can selectively operate in any one of a CCP mode and an ICP mode, depending on a process characteristic of an etch mode, in a similar way with the plasma reactor according to the first exemplary embodiment of the present invention.

[0063] The source power supplied to the antenna coil unit 7 is set below an inflection point power when an etch process in a low dissociation region is implemented. The source

power supplied to the antenna coil unit 7 is set above the inflection point power when an etch process in a high dissociation region is implemented. Upon completion of the setting of the source power, the source power supply unit 40, the source power switch unit 42, and the bias RF power supply unit 50 turn on. Resultantly, while the RF power supply unit 50 supplies the high frequency or low frequency bias RF power to the cathode 17, the source power supply unit 40 supplies the source power to the cathode 17 through the antenna coil unit 7. At this time, the cathode 17 connects to the ground via the source power switch unit 42.

[0064] When the plasma reactor is in the etch mode, the source power switch unit 42 switches on and the etch process is performed. When the plasma reactor is in an ICC cleaning mode, the source power switch unit 42 switches off and the source power is applied only to the antenna coil unit 7. The plasma reactor according to the second exemplary embodiment of the present invention provides an advantage of reducing a cost and an equipment size because it can acquire a performance corresponding to the plasma reactor according to the first exemplary embodiment of the present invention while replacing the three RF generators and the three impedance matching circuits/filters by two RF power generators 33 and 35 and two impedance matching circuits/filters 29 and 31.

[0065] The inflection point power gets greater than the inflection point power of the first exemplary embodiment because it enables an ICP source power to be doubly applied to the antenna coil unit 7 and the cathode 17 of an ICP source unit 1.

[0066] FIG. 7 illustrates a construction of a plasma reactor according to a third exemplary embodiment of the present invention. Referring to FIG. 7, the plasma reactor has a similar structure with a combination of the plasma reactors according to the first and second exemplary embodiments of the present invention. The plasma reactor is similar with the plasma reactor according to the first exemplary embodiment of the present invention in that a bias RF power supply unit includes a low frequency RF power supply unit 20 and a high frequency RF power supply unit 30. The plasma reactor is similar with the plasma reactor according to the second exemplary embodiment of the present invention in that it further includes a source power switch unit 42 for selectively supplying a source power to a cathode 17.

[0067] In detail, the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 electrically connect to the cathode 17 in parallel such that low frequency/high frequency RF powers are mixed and applied to the cathode 17. The source power switch unit 42 is constructed to selectively supply the source power to the cathode 17.

[0068] In case where the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 included in the bias RF power supply unit each supply the low frequency RF power and the high frequency RF power to the cathode 17, a source power supply unit 10 can selectively supply a low frequency RF power lower than the low frequency RF power applied to the cathode 17 by the source power switch unit 42.

[0069] In case where the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 included in the bias RF power supply unit each supply the low frequency RF power and the high frequency RF power to the cathode 17, the source power supply unit 10 can

selectively supply a low frequency RF power, which is greater than the low frequency RF power and smaller than the high frequency RF power applied to the cathode 17, using the source power switch unit 42.

[0070] In case where the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 included in the bias RF power supply unit each supply the low frequency RF power and the high frequency RF power to the cathode 17, the source power supply unit 10 can selectively supply a high frequency RF power greater than the high frequency RF power applied to the cathode 17, using the source power switch unit 42.

[0071] FIG. 8 is a flowchart illustrating an etch procedure implemented by the plasma reactor shown in FIG. 7.

[0072] Referring to FIG. 8, when a pressure within a chamber 5 reaches a pressure required for a process, the plasma reactor can selectively operate in any one of a CCP mode and an ICP mode depending on a process characteristic of an etch mode in a similar way with the plasma reactor according to the first exemplary embodiment of the present invention.

[0073] The source power supplied to an antenna coil unit 7 is set below an inflection point power when an etch process in a low dissociation region is implemented. The source power supplied to the antenna coil unit 7 is set above the inflection point power when an etch process in a high dissociation region is implemented. Upon completion of the setting of the source power, the source power supply unit 10, the low frequency and high frequency RF power supply units 20 and 30, and the source power switch unit 42 turn on. Resultantly, the low frequency RF power supply unit 20 and the high frequency RF power supply unit 30 apply a mixture of the low frequency/high frequency RF power to the cathode 17, and the source power supply unit 40 supplies the source power to the cathode 17 through the antenna coil unit 7. At this time, the cathode 17 connects to the ground via the source power switch unit 42.

[0074] When the plasma reactor is in the etch mode, the source power switch unit 42 switches on and the etch process is performed. When the plasma reactor is in an ICC cleaning mode, a waterless high density ICC recipe is performed in state where the source power switch unit 42 switches off and the source power is applied only to the antenna coil unit 7. The plasma reactor according to the third exemplary embodiment of the present invention is provided for the purpose of expanding a large scale wafer (300 mm, 450 mm). The plasma reactor can reduce a cost and an equipment size because it can replace the four RF power generators and the four impedance matching circuits/filters by three RF generators 26, 27, and 28 and three impedance matching circuits/filters 22, 24, and 25.

[0075] The inflection point power gets greater than the inflection point power of the first exemplary embodiment because it enables an ICP source power to be doubly applied to the antenna coil unit 7 and the cathode 17 of an ICP source unit 1.

[0076] A graph illustrating an ICP property is shown in FIG. 9 so as to describe an operation of the present invention in detail. Referring to FIG. 9, there are provided a low dissociation region and a high dissociation region. As an RF source power supplied to the antenna coil unit 7 increases, reaction gas is not suddenly dissociated in the low dissociation region, and is suddenly dissociated in the high dissociation region. In detail, the plasma reactor shows a

CCP property where dissociation does not suddenly occur below a constant RF source power. The plasma reactor shows an inherent property of ICP where dissociation suddenly occurs above the constant RF source power.

[0077] In addition to an ICP source power, a bias power should be applied to the cathode 17 to process a wafer placed on the cathode 17. In case where bias powers having frequencies different from each other (low/medium/high frequency) and a bias power having a mixed frequency each are applied to the cathode 17, two properties of ICP plasma, that is, properties of self-biases ($-VDC$) determining amounts of ion energy in the low dissociation region and the high dissociation region are compared, and it is predicted whether any process result is obtained in each case. By doing so, it can be appreciated why an insulating film etching device, one of etching equipments employing a conventional ICP type plasma reactor, does not provide a good result and why many systems are withdrawn from a production line.

[0078] FIG. 10 is a graph illustrating variation of a self-bias ($-VDC$) formed in a cathode versus variation of a source power when a bias RF power of 2 MHz is supplied to the cathode of the plasma reactor according to the present invention. FIG. 11 is a graph illustrating variation of a self-bias ($-VDC$) formed in the cathode versus variation of a source power when a bias RF power of 12.56 MHz is supplied to the cathode of the plasma reactor according to the present invention. FIG. 12 is a graph illustrating variation of a self-bias ($-VDC$) formed in the cathode versus variation of a source power when a bias RF power of 27.12 MHz is supplied to the cathode of the plasma reactor according to the present invention.

[0079] The graphs shown in FIGS. 10 to 12 represent values measured in a process condition where a reaction gas of CF_4 is injected into the chamber 5 at a flow rate of 150 Standard Cubic Centimeter per Minute (SCCM) and the chamber 5 has an internal pressure of about 50 mTorr.

[0080] Low Dissociation Region

[0081] In a region below a constant ICP source RF power (about 500 W to 700 W) of FIG. 9, an ion density does not suddenly increase as an RF power increases. In this region, dissociation does not suddenly occur.

[0082] The properties of the self-bias ($-VDC$) determining the amount of plasma ion energy can vary depending on the low frequency of 2.0 MHz, the medium frequency of 12.56 MHz, and the high frequency of 27.12 MHz of the bias power applied to the cathode in order to process the wafer placed on the cathode. These properties are shown by the graphs of FIGS. 10 to 12. From the graphs, it can be appreciated that the self-bias ($-VDC$) increases as the source power increases in the region below the constant ICP source power (about 500 W to 700 W). Also, the plasma ion energy gets greater as the frequency of the bias power applied to the cathode gets lower. The plasma ion energy gets smaller as the frequency of the bias power applied to the cathode gets higher.

[0083] FIG. 13 is a graph illustrating variation of a self-bias ($-VDC$) formed in the cathode versus variation of a source power, in each case where a single frequency bias RF power is supplied and a mixed frequency bias RF power is supplied to the cathode of the plasma reactor according to the present invention. In FIG. 13, a “♦” marked line represents the variation of the self-bias ($-VDC$) (corresponding to plasma ion energy) when the low frequency bias

RF power is supplied to the cathode. A “▲” marked line represents the variation of the self-bias ($-VDC$) when the high frequency bias RF power is supplied to the cathode. An “X” marked line represents the variation of the self-bias ($-VDC$) when the bias RF power, which is the mixture of the high frequency and low frequency RF powers, is supplied to the cathode. As appreciated from the respective lines, when the mixed frequency bias RF powers are supplied to the cathode, an amount of ion energy is approximately equal to an average value of when the low/high frequency RF powers each are supplied to the cathode.

[0084] In the graph of FIG. 13, a measured value is not shown but plasma ion density may have a greater value depending on a frequency magnitude and an amount of the bias power in the low dissociation region.

[0085] Resultantly, the reaction gas is not suddenly dissociated as the source power increases in the low dissociation region. Excessive radicals can be controlled in concentration because ion energy intensity and ion density are relatively dependent on the frequency and the amount of the bias power. A very wide process window and a stable process are possible.

[0086] As in a graph of FIG. 14 showing an etch rate of an insulating film (SiO_2), the etch rate is the highest at the mixed frequency when the bias power of the same amount is applied. This results from great ion energy due to the low frequency applied to the cathode and a high ion density due to the high frequency. Under this condition, an etch rate and an etch rate non-uniformity are more dependent on the bias power.

[0087] High Dissociation Region

[0088] In a region above a constant ICP source RF power (about 500 W to 700 W) of FIG. 9, the ion density suddenly increases as the RF power increases. In this region, dissociation suddenly occurs.

[0089] FIGS. 10 to 12 are graphs illustrating the properties of the self-bias ($-VDC$) determining the amount of plasma ion energy depending on the low frequency of 2.0 MHz, the medium frequency of 12.56 MHz, and the high frequency of 27.12 MHz of the bias power applied to the cathode in order to process the wafer mounted on the cathode. From the graphs, it can be appreciated that the self-bias ($-VDC$) greatly varies as the source power increases in the region above the constant ICP source power (about 500 W to 700 W). In other words, it can be appreciated that the self-bias ($-VDC$) suddenly gets smaller as the source power increases in this region. Also, the self-bias more suddenly gets smaller as the frequency gets smaller. The self-bias gradually gets smaller as the frequency gets greater.

[0090] FIG. 13 is a graph illustrating a relationship between the self-bias ($-VDC$), that is, the ion energy and the single and mixed frequencies. An intensity of ion energy at the mixed frequency is equal to an approximate mean value of those at the low/high frequencies. A sudden reduction of ion energy at the low frequency of 2.0 MHz can be greatly smooth by adding the high frequency of 27.12 MHz.

[0091] Here, a measured value is not shown but plasma ion density may have a greater value depending on the frequency magnitude and the amount of the bias power in the high dissociation region.

[0092] Resultantly, the reaction gas is suddenly dissociated as the source power increases in the high dissociation region. The high frequency is added and applied to guaran-

tee a stable and wide process window because the intensity of ion energy suddenly varies as the frequency applied to the cathode gets lower.

[0093] As in a graph of FIG. 15 showing an etch rate of an insulating film (SiO_2), the etch rates are almost similar at the low frequency and the mixed frequency when the bias power of the same amount is applied. It can be appreciated that a variation of the etch rate in the high dissociation region is greatly different from that of the low dissociation region. This is because the ion density of the plasma reactor is more dependent on the ICP source power. The suddenly reduced ion energy intensity/ion density/radical concentration can be controlled by suitably controlling the ICP source power and the amounts of the low/high frequency RF powers applied to the cathode in the high dissociation region. Thus, the high etch rate, the high selectivity, and the wide process window can be guaranteed.

[0094] As described above, the present invention provides the hybrid plasma reactor for simultaneously realizing a capacitive and inductive coupling function to double a process performance and productivity. In detail, the present invention can suitably harmonize the ICP source power having a property of high ion density plus low ion energy with the mixed frequency bias RF power, thereby improving the process performance such as the tunable ion density, the tunable ion energy and ion energy distribution, and the radical concentration control as well as enhancing productivity such as the remarkable improvement of MTBC.

[0095] According to the present invention, when the ICP type reactor implements the dry etch process, the high frequency is additionally applied to thereby compensate the sudden reduction of the ion energy intensity occurring as the ICP source power increases in the high dissociation region, when the low frequency is applied to the cathode. By doing so, the present invention can provide solutions to the drawbacks of the ICP type reactor of etch stop, chamber matching, low PR selectivity, and narrow process window. The present invention can add the high frequency to the low frequency in the low dissociation region, thereby guaranteeing the high ion energy and ion density, and increasing the etch rate.

[0096] The present invention can make the most use of advantages of the ICP type reactor such as high efficiency, low ion damage, and decoupled effect, and can effectively perform the waterless ICC compared with the CCP type reactor. The present invention can provide a solution to the chronic arcing problem occurring in the CCP type plasma reactor.

[0097] The inventive plasma reactor can suppress excessive dissociation of reaction gas, sustain the high plasma ion density, and compensate the sudden reduction of ion energy intensity at above the constant ICP source power when the low frequency is applied to the cathode.

[0098] While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A hybrid plasma reactor comprising:
an ICP (Inductively Coupled Plasma) source unit comprising:

- a chamber comprising a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body;
 - an antenna coil unit disposed outside of the dielectric window; and
 - a source power supply unit for supplying a source power to the antenna coil unit; and
 - a bias RF (Radio Frequency) power supply unit for supplying a bias RF power to a cathode, the cathode being installed within the chamber and mounting a target wafer on its top,
- wherein a plasma ion density within the chamber is greater when a source power greater than a set power is supplied to the antenna coil unit than when a source power smaller than the set power is supplied to the antenna coil unit,
- wherein a plasma ion energy within the chamber is greater when the source power smaller than the set power is supplied to the antenna coil unit than when the source power greater than the set power is supplied to the antenna coil unit, and
- wherein in order to increase the set power and expand a tunable range of the source power, the bias RF power supply unit supplies the bias RF power, which is a mixture of a high frequency RF power and a low frequency RF power, to the cathode so that a sudden reduction of the plasma ion energy within the chamber occurring as the source power supplied to the antenna coil unit increases greater than the set power is compensated or so that the plasma ion density and energy within the chamber is sustained within a set range.
2. The reactor of claim 1, wherein there are provided an etch process in a low dissociation region and an etch process in a high dissociation region, depending on a degree of dissociation of a reaction gas injected into the chamber, and wherein the plasma reactor performs the etch process in the low dissociation region when the source power smaller than the set power is supplied to the antenna coil unit, and performs the etch process in the high dissociation region when the source power greater than the set power is supplied to the antenna coil unit.
 3. The reactor of claim 1, wherein the bias RF power supply unit comprises:
 - a high frequency RF power supply unit for supplying the high frequency RF power to the cathode; and
 - a low frequency RF power supply unit connecting to the cathode in parallel with the high frequency RF power supply unit, and supplying the low frequency RF power to the cathode,
 wherein the bias RF power, which is the mixture of the high frequency RF power and the low frequency RF power, is supplied to the cathode when the high frequency RF power supply unit and the low frequency RF power supply unit operate together.
 4. The reactor of claim 1, wherein the set power is within a range of 500 W to 700 W when the plasma reactor performs an etch process for a wafer having a diameter of 200 mm.
 5. The reactor of claim 1, wherein when the plasma reactor performs an in-situ chamber cleaning operation, the source power supply unit supplies the source power to the antenna coil unit, and the bias RF power supply unit stops supplying the bias RF power to the cathode, and the plasma

reactor performs a high density plasma chamber cleaning process with the wafer not mounted on the cathode.

6. The reactor of claim 1, wherein the source power supply unit generates the high frequency RF power as the source power,

wherein the bias RF power supply unit comprises:

a low frequency RF power supply unit for supplying the low frequency RF power to the cathode; and

a source power switch unit connecting to the cathode in parallel with the low frequency RF power supply unit, wherein the source power switch unit switches on to selectively connect the cathode to the ground via the source power switch unit so that the high frequency RF power generated from the source power supply unit is selectively supplied to the cathode,

wherein a closed loop is formed comprising the source power supply unit, the antenna coil unit, the cathode, the source power switch unit, and the ground when the cathode connects to the ground via the source power switch unit, and

wherein the bias RF power that is the mixture of the high frequency RF power and the low frequency RF power is supplied to the cathode when the cathode connects to the ground via the source power switch unit and the low frequency RF power supply unit operates.

7. The reactor of claim 1, wherein the source power supply unit generates the low frequency RF power as the source power,

wherein the bias RF power supply unit comprises:

a high frequency RF power supply unit for supplying the high frequency RF power to the cathode; and

a source power switch unit connecting to the cathode in parallel with the high frequency RF power supply unit, wherein the source power switch unit switches on to selectively connect the cathode to the ground via the source power switch unit so that the low frequency RF power generated from the source power supply unit is selectively supplied to the cathode,

wherein a closed loop is formed comprising the source power supply unit, the antenna coil unit, the cathode, the source power switch unit, and the ground when the cathode connects to the ground via the source power switch unit, and

wherein the bias RF power that is the mixture of the high frequency RF power and the low frequency RF power is supplied to the cathode when the cathode connects to the ground via the source power switch unit and the high frequency RF power supply unit operates.

8. The reactor of claim 1, wherein the bias RF power supply unit comprises:

a high frequency RF power supply unit for supplying the high frequency RF power to the cathode;

a low frequency RF power supply unit connecting to the cathode in parallel with the high frequency RF power supply unit, and supplying the low frequency RF power to the cathode; and

a source power switch unit connecting to the cathode in parallel with the high frequency RF power supply unit, wherein the source power switch unit switches on to connect the cathode to the ground via the source power switch unit so that the source power generated from the source power supply unit is selectively supplied to the cathode, and

wherein a closed loop is formed comprising the source power supply unit, the antenna coil unit, the cathode, the source power switch unit, and the ground when the cathode connects to the ground via the source power switch unit.

9. The reactor of claim 8, wherein the source power supply unit generates as the source power an additional RF power having a frequency lower than that of the low frequency RF power,

wherein the bias RF power supply unit generates the bias RF power obtained by additionally mixing the additional RF power with the high frequency RF power and the low frequency RF power, and

wherein the bias RF power obtained by mixing the additional RF power with the high frequency RF power and the low frequency RF power is supplied to the cathode, when the cathode connects to the ground via the source power switch unit and the high frequency RF power supply unit and the low frequency RF power supply unit operate.

10. The reactor of claim 8, wherein the source power supply unit generates as the source power an additional RF power having a frequency higher than that of the low frequency RF power and lower than that of the high frequency RF power,

wherein the bias RF power supply unit generates the bias RF power obtained by additionally mixing the additional RF power with the high frequency RF power and the low frequency RF power, and

wherein the bias RF power obtained by mixing the additional RF power with the high frequency RF power and the low frequency RF power is supplied to the cathode, when the cathode connects to the ground via the source power switch unit and the high frequency RF power supply unit and the low frequency RF power supply unit operate.

11. The reactor of claim 8, wherein the source power supply unit generates as the source power an additional RF power having a frequency higher than that of the high frequency RF power,

wherein the bias RF power supply unit generates the bias RF power obtained by additionally mixing the additional RF power with the high frequency RF power and the low frequency RF power, and

wherein the bias RF power obtained by mixing the additional RF power with the high frequency RF power and the low frequency RF power is supplied to the cathode, when the cathode connects to the ground via the source power switch unit and the high frequency RF power supply unit and the low frequency RF power supply unit operate.

12. A hybrid plasma reactor comprising:

an ICP source unit comprising:

a chamber comprising a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body;

an antenna coil unit disposed outside of the dielectric window; and

a source power supply unit for supplying a source power to the antenna coil unit;

a high frequency RF power supply unit for supplying a bias RF power to a cathode, the cathode being installed within the chamber and mounting a target wafer on its top; and

- a low frequency RF power supply unit connecting to the cathode in parallel with the high frequency RF power supply-unit, and supplying a low frequency RF power to the cathode,
- wherein a plasma ion density within the chamber is greater when a source power greater than a set power is supplied to the antenna coil unit than when a source power smaller than the set power is supplied to the antenna coil unit,
- wherein a plasma ion energy within the chamber is greater when the source power smaller than the set power is supplied to the antenna coil unit than when the source power greater than the set power is supplied to the antenna coil unit, and
- wherein in order to increase the set power and expand a tunable range of the source power, the high frequency RF power supply unit and the low frequency RF power supply unit operate together and supply a bias RF power, which is a mixture of the high frequency RF power and the low frequency RF power, to the cathode so that a sudden reduction of the plasma ion energy within the chamber occurring as the source power supplied to the antenna coil unit increases greater than the set power is compensated or so that the plasma ion density and energy within the chamber is sustained within a set range.
- 13.** The reactor of claim **12**, wherein there are provided an etch process in a low dissociation region and an etch process in a high dissociation region, depending on a degree of dissociation of a reaction gas injected into the chamber, and wherein the plasma reactor performs the etch process in the low dissociation region when the source power smaller than the set power is supplied to the antenna coil unit, and performs the etch process in the high dissociation region when the source power greater than the set power is supplied to the antenna coil unit.
- 14.** The reactor of claim **12**, wherein the set power is within a range of 500 W to 700 W when the plasma reactor performs an etch process for a wafer having a diameter of 200 mm.
- 15.** The reactor of claim **12**, wherein when the plasma reactor performs an in-situ chamber cleaning operation, the source power supply unit supplies the source power to the antenna coil unit, and the high frequency RF power supply unit and the low frequency RF power supply unit stop supplying the bias RF power to the cathode, and the plasma reactor performs a high density plasma chamber cleaning process with the wafer not mounted on the cathode.
- 16.** A hybrid plasma reactor comprising:
- an ICP source unit comprising:
 - a chamber comprising a chamber body whose top is opened and a dielectric window covering the opened top of the chamber body;
 - an antenna coil unit disposed outside of the dielectric window; and
 - a source power supply unit for supplying a source power to the antenna coil unit;
 - a high frequency RF power supply unit for supplying a bias RF power to a cathode, the cathode being installed within the chamber and mounting a target wafer on its top;
- a low frequency RF power supply unit connecting to the cathode in parallel with the high frequency RF power supply unit, and supplying a low frequency RF power to the cathode; and
- a source power switch unit connecting to the cathode in parallel with the high frequency RF power supply unit, wherein the source power switch unit switches on to selectively connect the cathode to the ground via the source power switch unit so that the high frequency RF power generated from the source power supply unit is selectively supplied to the cathode,
- wherein a closed loop is formed comprising the source power supply unit, the antenna coil unit, the cathode, the source power switch unit, and the ground when the cathode connects to the ground via the source power switch unit,
- wherein the source power is any one of an RF power having a frequency higher than that of the high frequency RF power, an RF power having a frequency lower than that of the low frequency RF power, and an RF power having a frequency between frequencies of the low frequency RF power and the high frequency RF power,
- wherein a plasma ion density within the chamber is greater when a source power greater than a set power is supplied to the antenna coil unit than when a source power smaller than the set power is supplied to the antenna coil unit,
- wherein a plasma ion energy within the chamber is greater when the source power smaller than the set power is supplied to the antenna coil unit than when the source power greater than the set power is supplied to the antenna coil unit, and
- wherein in order to increase the set power and expand a tunable range of the source power, the high frequency RF power supply unit, the low frequency RF power supply unit, and the source power switch unit operate together and supply a bias RF power obtained by mixing the high frequency RF power and the low frequency RF power with the source power, to the cathode so that a sudden reduction of the plasma ion energy within the chamber occurring as the source power supplied to the antenna coil unit increases greater than the set power is compensated or so that the plasma ion density and energy within the chamber is sustained within a set range.
- 17.** The reactor of claim **16**, wherein there are provided an etch process in a low dissociation region and an etch process in a high dissociation region, depending on a degree of dissociation of a reaction gas injected into the chamber, and wherein the plasma reactor performs the etch process in the low dissociation region when the source power smaller than the set power is supplied to the antenna coil unit, and performs the etch process in the high dissociation region when the source power greater than the set power is supplied to the antenna coil unit.
- 18.** The reactor of claim **16**, wherein the set power is within a range of 500 W to 700 W when the plasma reactor performs an etch process for a wafer having a diameter of 200 mm.
- 19.** The reactor of claim **16**, wherein when the plasma reactor performs an in-situ chamber cleaning operation, the source power supply unit supplies the source power to the antenna coil unit, and the high frequency RF power supply

unit and the low frequency RF power supply unit stop supplying the bias RF power to the cathode, and the source power switch unit switches off, and the plasma reactor performs a high density plasma chamber cleaning process with the wafer not mounted on the cathode.

20. The reactor of claim **16**, wherein the source power switch unit comprises:

- a source power filter for filtering the source power received from the antenna coil through the cathode, except signals of frequencies other than a frequency of the source power; and
- a switch for electrically connecting or disconnecting the source power filter from the ground.

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