

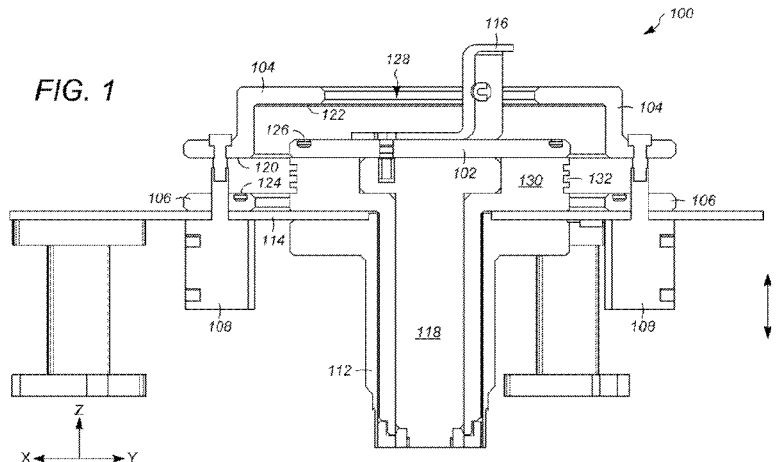


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(54) **Title:** MOVABLE GROUNDING ARRANGEMENTS IN A PLASMA PROCESSING CHAMBER AND METHODS THEREFOR



(57) **Abstract:** A plasma processing systems having at least one plasma processing chamber, comprising a movable grounding component, an RF contact component configured to receive RF energy from an RF source when the RF source provides the RF energy to the RF contact component, and a ground contact component coupled to ground. The plasma processing system further includes an actuator operatively coupled to the movable grounding component for disposing the movable grounding component in a first position and a second position. The first position represents a position whereby the movable grounding component is not in contact with at least one of the RF contact component and the ground contact component. The second position represents a position whereby the movable grounding component is in contact with both the RF contact component and the ground contact component.



MOVABLE GROUNDING ARRANGEMENTS IN A PLASMA PROCESSING CHAMBER AND METHODS THEREFOR

BACKGROUND OF THE INVENTION

[0001] In some plasma processing chambers, the upper electrode can be configured to execute in the grounded mode or the RF-powered mode. Generally speaking, the bottom electrode that supports the substrate may be powered with an appropriate RF power source (which may provide one or more RF signals to the bottom electrode). The upper electrode may be grounded as is conventional in a capacitively coupled plasma processing chamber or may be powered with one or more RF signals. When the upper electrode is configured to execute in the RF-powered mode, RF power is supplied to the upper electrode. When the upper electrode is configured to run in the grounded mode, the upper electrode is grounded.

[0002] While there exist many techniques to alternately couple the upper electrode to ground or to an RF source, engineers are constantly looking for ways to improve the reliability and the maintainability of the chamber. Given the high energy and high RF frequency involved in RF electrode operation, reliability and maintainability of the switching mechanism is paramount. If the switching from the RF-powered mode to the grounded mode (and vice versa) is improperly designed, arcing may result and may detrimentally affect the grounding and/or RF connection and may alter the process result from substrate to substrate. Furthermore, a more robust switching mechanism may extend the service interval, allowing the plasma processing system to operate for a longer period of time before maintenance and/or replacement is required.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

[0004] Fig. 1 shows, in accordance with embodiments of the invention, a portion of the switching mechanism employed for selectively and alternately provide ground and RF energy to the upper electrode.

[0005] Fig. 2 shows, in accordance with embodiments of the invention, the arrangement of Fig. 1 when operated in the grounded mode.

[0006] Fig. 3 shows, **in accordance** with an **embodiment of the invention**, the steps for switching the upper electrode **of the** plasma processing chamber from a RF powered mode to a grounded mode and vice versa.

DETAILED DESCRIPTION OF EMBODIMENTS

[0007] The present invention will now be described **in** detail with **reference to** a few embodiments thereof as **illustrated in the accompanying** drawings. **In** the following description, numerous specific details are set forth in order to provide **a thorough** understanding of the present **invention**. It will be apparent, however, to one skilled in **the** art, that **the** present **invention** may be practiced without some or all of these specific details. **in** other instances, well known process steps and/or structures have not been described in detail in order to **not** unnecessarily obscure the present invention.

[0008] Various **embodiments** are described hereinbelow, **including** methods and techniques. It should be kept in mind that the invention might also cover articles of manufacture that includes a computer readable **medium** on which **computer-readable instructions** for carrying out **embodiments of the** inventive technique are stored. The computer readable medium may include, for example, **semiconductor**, magnetic, opto-magnetic, optical, or other forms of computer readable medium **for** storing computer readable code. The computer readable **medium** may include **non-transitory** (i.e., not a wave **form**) computer readable medium. Further, **the** invention may **also** cover apparatuses **for practicing** embodiments **of the** invention. Such **apparatus** may include circuits, dedicated **and/or** programmable, to **carry out** tasks pertaining to **embodiments of the** invention. Examples **of such** apparatus include **a** general-purpose computer **and/or** a dedicated computing device when appropriately programmed and may include a combination of a computer/computing device and dedicated/programmable circuits adapted for the various tasks **pertaining to** embodiments of the invention.

[0009] Embodiments **of the** invention relate to methods and apparatus for grounding an RF electrode **in** a plasma processing chamber of a plasma processing system. **In** the following example, a capacitively coupled plasma processing chamber in which the upper electrode can be operated in either the RF-powered mode **or** the **grounded** mode is employed to **illustrate** the inventive switching arrangement. It should be understood, however, that the invention is not limited **to** the examples herein and may be practiced in different plasma processing systems

employing different configurations, geometries, and plasma-generating technologies (such as inductively coupled systems, electron-cyclotron resonance systems, microwave systems, etc.).

[00010] In one or more embodiments, there is provided **a movable** grounding component that is made of a **conductive** material and is configured to make or break contact **with** both a RF contact component and **a** ground contact component (which is grounded). The movable grounding component, **in** the first position, is spatially separate from both the RF contact component and the ground contact component. In this first position, RF energy may be provided to the RF contact **component**, which **serves** as a pathway for RF energy to be provided to an upper electrode plate. In the second position, the movable **grounding** component physically couples **with** both the RF contact component and the ground contact **component**, thereby coupling the RF contact component to ground and thus grounding the RF contact component. In this second position, RF **energy** is preferably not provided to the RF contact component, thereby allowing the upper electrode that is coupled to the RF contact **component** to be grounded instead.

[00011] In one or more embodiments, the movable grounding component is a plate-shaped component. In one or more embodiments, the movable grounding component is a ring-shaped component. **In** one or more embodiments, the movable **grounding** component is a ring-shaped component **with** an RF **strap** fed through a hole disposed in **the** movable grounding component. **In** one or more embodiments, the movable grounding component is a hat-shaped **component**. In one or more embodiments, the movable grounding component is a hat-shaped component having therein a hole to allow an RF strap **to** feed through. In one or more embodiments, the movable grounding component is made of a conductive material such as aluminum.

[00012] In one or more embodiments, the RF contact component is coupled to both an RF strap for receiving RF energy from an RF power supply and to a conductor for providing the RF energy to **the** upper electrode plate. In one or more embodiments, the grounded contact component and the RF contact component are co-planar. In one **or** more embodiments, the grounded contact component and **the** RF contact component are separated in the z-direction to minimize **arcing**.

[00013] In one or more embodiments, the **RF** contact component is a plate-shaped component. In one or more embodiments, the RF contact component is a ring-shaped component. In one or more embodiments, the RF contact component is a hat-shaped component. In one or more embodiments, the RF contact component is made of a conductive material such as aluminum.

[00014] In one or more embodiments, the ground contact component is a plate-shaped component. In one or more embodiments, the ground contact component is a ring-shaped component. In one or more embodiments, the ground contact component is a hat-shaped component. In one or more embodiments, the ground contact component is made of a conductive material such as aluminum.

[00015] In one or more embodiments, the movable grounding component is **disposed** above both the RF contact component and the ground contact component in the first position and also in a non-contacting relationship with both the RF contact component and the ground component **when** the upper electrode is run in the RF-powered mode. In one or more embodiments, the **movable** grounding component is moved into the second position whereby the movable grounding component physically contacts both the RF contact component and the ground contact component when the upper electrode is run in the grounded mode.

[00016] In a preferred embodiment, the movable grounding component is ring-shaped or hat-shaped with a hole therein to allow an RF strap to be fed through. The RF strap is coupled to the **RF** contact component, which is disposed below the movable grounding component. The RF contact component is also electrically coupled to the upper electrode plate to provide **RF** power to the upper **electrode** plate when the **RF** contact component receives **RF** energy from an RF energy source via the **RF strap** and the **RF contact** component is not grounded. The movable grounding component is moved upward to **be** disposed in a non-contact relationship with the RF contact component when the upper electrode runs in the RF-powered mode. The movable grounding component is moved downward to physically contact both the ground **contact** component and the RF contact component, thereby grounding the RF contact component when it is desired to operate the upper electrode in the grounded mode.

[00017] If the RF contact component and the ground contact component are co-planar, the **movable-grounding** component may be ring-shaped. **If** the **RF** contact component and the ground contact component are non co-planar in the Z direction, the movable grounding component may be ring-shaped to permit the movable grounding component to **physically** contact both the **RF contact** component and the ground contact component when it is desired to operate the upper electrode in the grounded mode. Physically separating the RF contact component and ground contact component in the Z direction is preferred in many chambers since the greater spatial separation of the RF contact component and RF ground component may

reduce arcing. Some systems may not have enough room to accommodate the desired physical separation in the X-Y plane. A hat-shaped movable grounding component permits robust grounding and is physically robust and easy to manufacture when such Z-direction separation exists between the RF contact component and ground contact component.

[00018] The features and advantages of embodiments of the invention may be better understood with reference to the figures and discussions that follow,

[00019] Fig. 1 shows, in accordance with embodiments of the invention, a portion of the switching mechanism employed for selectively and alternately provide ground and RF energy to the upper electrode. In the example of Fig. 1, the switching mechanism is disposed, at least in part, in an RF match network housing. However, it is possible to implement part or all of the switching mechanism inside or outside of the match network if desired.

[00020] Referring to Fig. 1, there is shown a switching mechanism 100, which includes a RF contact component 102, a movable grounding component 104, and a ground contact component 106. In the example of Fig. 1, the movable grounding component is in the up (+ Z) and non-contacting position, meaning that the RF contact component 102 is removed from ground. Actuators 108 (of which two are shown in Fig. 1) are employed to move movable grounding component 104 up and down in the Z direction as shown. In the example of Fig. 1, the actuators are air actuated although they may also employ mechanical, electromagnetic, hydraulic, electro-mechanical, etc. for actuation of movable grounding component 104 as desired.

[0002.1] Ground contact component 106 is coupled to a ground adaptor 112 via conductive frame 114 as shown. Ground adaptor 112 is coupled to RF ground (not shown) via an appropriate conductor or strap. Conductive frame 114 represents the bottom of the match network housing and serves to couple ground contact component 106 to ground. In the example of Fig. 1, ground contact component 106 is a ring although other shapes may also be employed, as mentioned. Preferably, ground contact component 106 is sufficiently thick and robust (since it does not have to be bendable or springy) for long life and is formed of a conductive metal (such as aluminum).

[00022] RF contact component 102 is in the form of a plate in the example of Fig. 1 and is coupled to RF strap 116 to receive RF energy from a suitable RF power supply. RF contact component 102 is also made relatively thick and robust (since it does not have to be bendable or springy) for long life. When RF contact component 102 is provided with RF energy and is not

coupled to ground (such as the case **in** the example **of Fig. 1**), RF energy is provided to an upper electrode plate disposed at the bottom of the figure (not shown) via conductor 118, which is configured as a conductive rod in this example.

[00023] Movable grounding **component 104** is formed of a **conductive** metal such as aluminum and is the form of a hat-shaped ring as shown in the example of Fig. 1. Movable grounding component 104 is also made relatively thick and robust (since it does not have to be bendable or springy) for long life. In an example embodiment, movable grounding component is formed of aluminum and is about 0.125 to about 0.5 inch thick, more preferably about 0.250 inch thick.

[00024] A hole 128 (which may **be** centered or off-centered) exists **in** movable grounding component 104 to allow RF strap 116 to pass **through in a non-contacting** manner. However, **it is possible that** movable **grounding component 104 may have other shapes as discussed and may be provided with or without an RF strap hole** (the **RF strap** may be routed in other ways, including through the side or from below, for example).

[00025] Movable **grounding** component 104 has a first contact area 120 and a second contact area 122 for coupling with ground contact component 106 and RF contact component 102 respectively when **movable** grounding component 104 is lowered in the **down (-Z)** direction. To improve grounding, RF gaskets 124 and 126 may be provided with ground contact component 106 and RF contact component 102 respectively. As shown in Fig. 1, RF contact component 102 is electrically insulated from ground (such as conductive frame 114 and ground adaptor 112) by **an** insulating component 130, which is in the **form** of a plastic or ceramic or other insulating collar in the example of Fig. 1. Ridges 132 are provided in insulating component 130 to lengthen the RF path from RF hot to ground when the switch arrangement is configured to operate in the RF-powered mode.

[00026] In the **RF-powered** mode (which refers to the mode of operation wherein the RF contact component 102 receives RF energy **from** strap 116 and is ungrounded and **is** configured to provide the received RF energy to an upper electrode via conductor 118), movable grounding component 104 is moved upward (+Z direction) by actuators 108 and is thus spatially separated from one or both of grounding contact component 106 and RF contact component 102. Accordingly, RF contact component 102 is removed from ground since it is disconnected from grounding contact component 106 and insulated from all other grounds otherwise. In this

position, RF energy can be **provided** to the upper **electrode** via **RF strap 116**, **RF contact component 102**, and conductor 118. In this RF-powered mode, the plasma processing **chamber** is operated in the mode where the upper electrode is powered with one or more **RF signals**.

[00027] In the **grounded** mode (which refers to the mode of operation wherein the RF contact component 102 is grounded to ground contact component 106 via movable grounding component 104 and RF contact component 102 receives no **RF** energy from strap 116), movable grounding component 104 is **moved** downward (**-Z** direction) by actuators 108 and is thus coupled with both of grounding contact component 106 and RF contact component 102. Accordingly, RF contact component 102 is electrically coupled to ground (**grounding** contact component. 106) via movable grounding component 104. In this grounded mode, RF contact component 102 is grounded, allowing the plasma processing chamber to operate **with** the upper electrode grounded as is conventional.

[00028] In one or more **embodiments**, the RF contact component and the ground contact component are spatially separated in the Z direction (as **shown** in Fig. 1) to minimize space requirement in the X-Y plane and to minimize arcing **with** the increased distance. Such distance and concomitant reduced arcing make these embodiments highly suitable for use in high energy, high voltage and/or high **RF** frequency systems where arcing is a **concern** when making **and/or breaking contact (whether RF power contact or ground contact)**.

[00029] It is **contemplated** that other geometries and shapes for the various components are also possible. For example, although the preferred configuration is to separate the RF contact component and the ground contact component in the **Z** direction (as shown in Fig. 1), it is also possible to provide such separation in the X-Y plane only. In that case, the RF contact component and the ground contact component may be planar and the movable grounding component may be in the form of a plate or ring if desired.

[00030] As another example, it is possible to use a ring in the example of Fig. 1 with downward protrusions (e.g., pins or **nubs**) to make the grounding **contact** instead of using the **hat-shaped** ring as discussed. As another example, it is possible that the RF contact component be placed below the ground contact component and the movable grounding component be appropriately shaped or **configured to ground them** together when the movable grounding component moves downward in the **-Z** direction.

[00031] As another example, the movable grounding component may be placed below both the RF contact component and the ground contact component (using for example a ring-shaped component) and moved upward to ground the RF contact component and the ground contact component together. As another example, rod-shaped or bar shaped components may be provided instead of ring-shaped or plate-shaped or hat-shaped components for any one or multiple of the RF contact component, ground contact component, and movable grounding component to selectively and alternately provide the RF power and ground to the upper electrode.

[00032] Fig. 2 shows, in accordance with embodiments of the invention, the arrangement of Fig. 1 when operated in the grounded mode. In this grounded mode, movable grounding component 104 is lowered to establish physical contact with both ground contact component 106 and RF contact component 102 (via their respective RF gaskets in the example of Fig. 1). In this position, RF contact component 102 is grounded, allowing the plasma processing chamber to operate with the upper electrode grounded as is conventional.

[00033] Fig. 3 shows, in accordance with an embodiment of the invention, the steps for switching the upper electrode of the plasma processing chamber from a RF powered mode to a grounded mode and vice versa. In step 302, a plasma processing chamber having a dual-mode upper electrode is provided, including step 302A (providing a movable grounding component), step 302B (providing a ground contact component) and step 302C (providing a RF contact component). In step 304, the upper electrode is set up in-situ to operate in the RF powered mode, including step 304A (actuating the actuator to move the movable grounding component away to break contact with at least one of the ground contact component and the RF contact component) and step 304B (providing RF power to the RF contact component to energize the upper electrode with RF power). In step 306, the upper electrode is set up in-situ to operate in the grounded mode, including step 306A (actuating the actuator to move the movable grounding component to create contact with both of the ground contact component and the RF contact component) and step 306B (stop providing RF energy to the RF contact component). If desired, the movable grounding component may be moved between a first position and a second position to switch the chamber operation from a RF powered mode to a grounded mode and vice versa.

[00034] As can be appreciated from the foregoing, embodiments of the invention result in a highly robust and simple-to-manufacture switching arrangement. Bendy or resilient or springy

contact elements or components, with their attendant life or cycle limits, are no longer required. By increasing the distance between the RF contact component and the ground contact component in the Z direction, less space is required in the X-Y plane to accommodate the large distance desired between the hot RF component and the ground component when the upper electrode is operating in the RF-powered mode. The increased spatial separation along with the ridge features in the insulating component contributes to reduce arcing, further improving process control and component life. Actuators permit the movable grounding component to ground and unground the RF contact component in-situ, enabling the chamber to be operated in either mode seamlessly from substrate to substrate or even while processing a single substrate.

[00035] While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and equivalents, which fall within the scope of this invention. Although various examples are provided herein, it is intended that these examples be illustrative and not limiting with respect to the invention. Also, the title and summary are provided herein for convenience and should not be used to construe the scope of the claims herein. Further, the abstract is written in a highly abbreviated form and is provided herein for convenience and thus should not be employed to construe or limit the overall invention, which is expressed in the claims. If the term "set" is employed herein, such term is intended to have its commonly understood mathematical meaning to cover zero, one, or more than one member. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

CLAIMS

What is claimed is:

1. A plasma processing system having at least one plasma processing chamber, comprising;
 - a movable grounding component;
 - an RF contact component configured to receive **RF** energy from an **RF** source when said RF source provides said RF energy to said **RF** contact component;
 - a ground contact component coupled to ground; and
 - an actuator operatively coupled to said **movable** grounding **component** for disposing said movable **grounding component** in a first position and a second position, said first position representing a position whereby said **movable** grounding component is not in **contact with at** least one of said RF contact component and said ground contact component, said second position representing a position whereby said movable **grounding** component is in contact with both said RF contact component and said ground contact component.
2. The plasma **processing** system of claim 1 wherein said movable grounding component is hat-shaped.
3. The plasma processing system of claim 1 wherein said movable grounding component is plate-shaped.
4. The plasma **processing** system of claim 1 wherein said RF **contact component** is coupled to a conductor that is configured to provide said **RF** energy to an upper electrode.
5. The plasma processing system of claim 1 wherein said movable grounding component is configured to be non-bendy.
6. The plasma processing system of claim 1 wherein said movable grounding component is physically apart from both said RF contact component and said ground component in said first position.
7. The plasma processing system of claim 1 wherein said RF contact component represents a plate, said movable grounding component **having** a hat shape having a hole disposed through said hat shape, said ground **contact** component represents a ring disposed in an offset relationship with said RF contact component in a Z direction.
8. The plasma processing system of claim 1 wherein said RF contact component represents a plate, said ground contact component represents a ring disposed co-planar with said **RF** contact component in a Z direction.

9. A method for configuring plasma processing system having at least one plasma processing chamber to have an electrode capable of operating in the alternative a grounded mode and an RF mode, comprising:

providing a movable grounding component;

providing an RF contact component configured to receive RF energy from an RF source when said RF source provides said RF energy to said RF contact component;

providing a ground contact component coupled to ground; and

coupling an actuator to said movable grounding component for disposing said movable grounding component in a first position and a second position, said first position representing a position whereby said movable grounding component is not in contact with at least one of said RF contact component and said ground contact component, said second position representing a position whereby said movable grounding component is in contact with both said RF contact component and said ground contact component.

10. The method of claim 9 wherein said movable grounding component is hat-shaped.

11. The method of claim 9 wherein said movable grounding component is plate-shaped.

12. The method of claim 9 further comprising coupling said RF contact component to a conductor that is configured to provide said RF energy to an upper electrode.

13. The method of claim 9 wherein said movable grounding component is configured to be non-bendy.

14. The method of claim 9 wherein said movable grounding component is physically apart from both said RF contact component and said ground component in said first position.

15. The method of claim 9 wherein said RF contact component represents a plate, said movable grounding component having a hat shape having a hole disposed through said hat shape, said ground contact component represents a ring disposed in an offset relationship with said RF contact component in a Z direction.

16. The method of claim 9 wherein said RF contact component represents a plate, said ground contact component represents a ring disposed co-planar with said RF contact component in a Z direction.

17. A plasma processing system having at least one plasma processing chamber, said chamber having at least one electrode, comprising:

movable grounding means;

RF contact means configured to receive RF energy **from** an RF source when said RF source provides said RF energy to said **RF** contact means;

a ground contact coupled to RF ground; and

actuator means operatively coupled to said movable grounding means for disposing said movable grounding means in a first position and a second position, said first position representing a **position** whereby said **movable grounding** means is not **in** contact with at least one of said RF contact means and said ground contact to remove said RF contact means from said RF ground, said second position **representing** a position whereby said movable **grounding** means is **in** contact with both said RF contact means and said ground **contact**

18. The plasma processing system of claim 17 wherein said **RF** contact means represents a plate, said movable **grounding** means having a hat shape having a hole disposed through said **hat** shape, said ground contact represents a ring disposed **in** an offset relationship with said RF **contact** means in a Z direction.

19. The plasma processing system **of claim** 17 wherein said RF contact means represents a plate, said ground contact represents a ring disposed co-planar with said RF contact means in a Z direction.

20. The plasma processing **system** of claim 17 wherein said electrode represents an upper electrode.

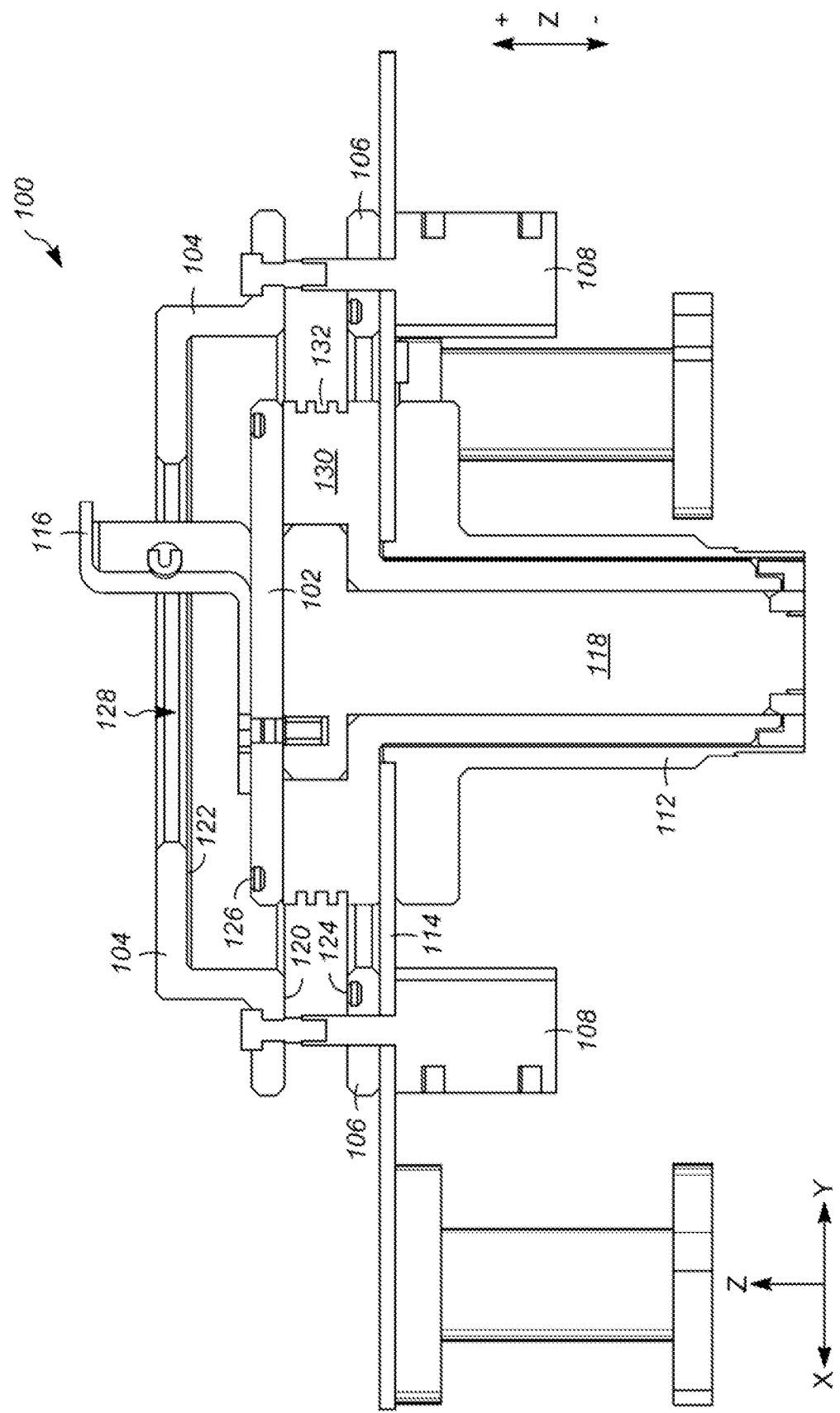


FIG. 1

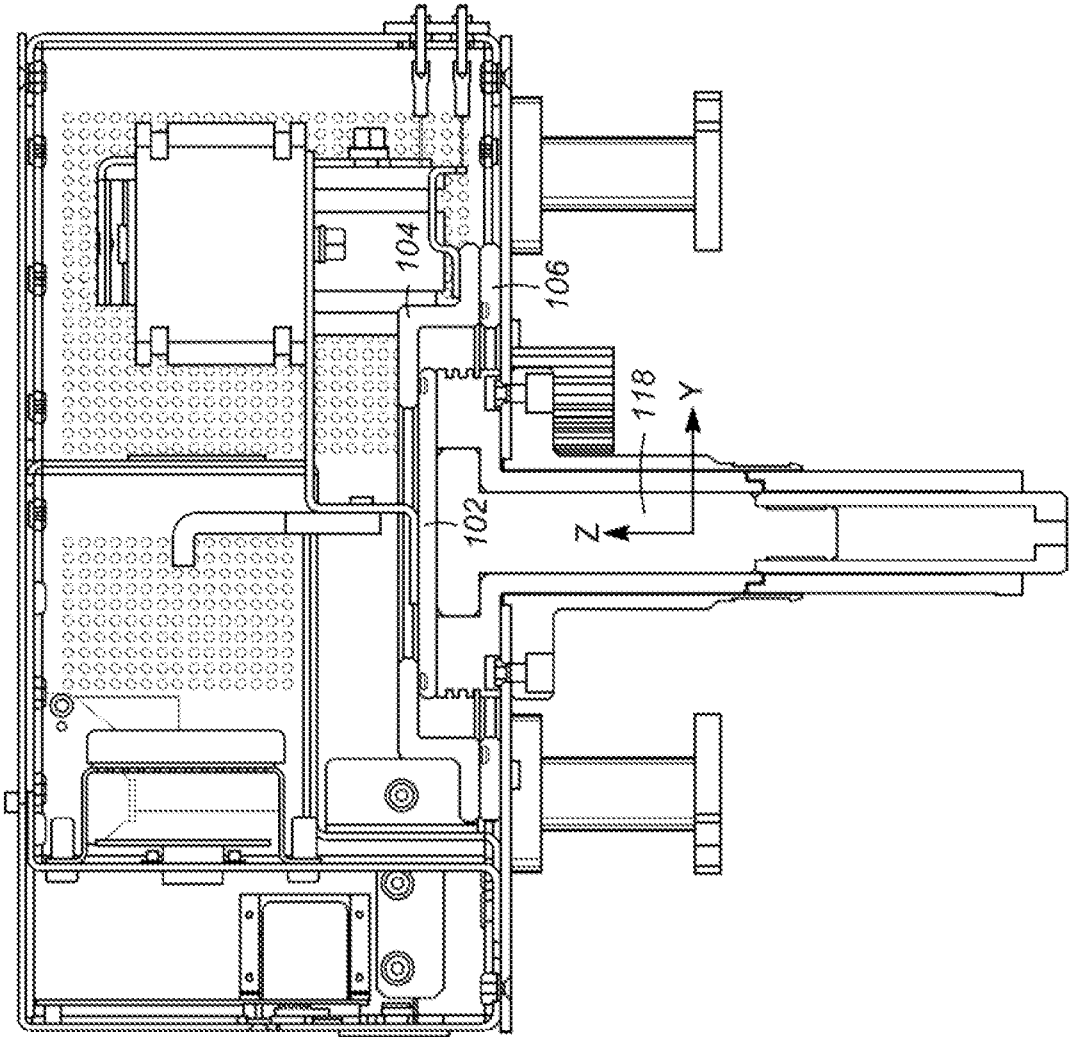
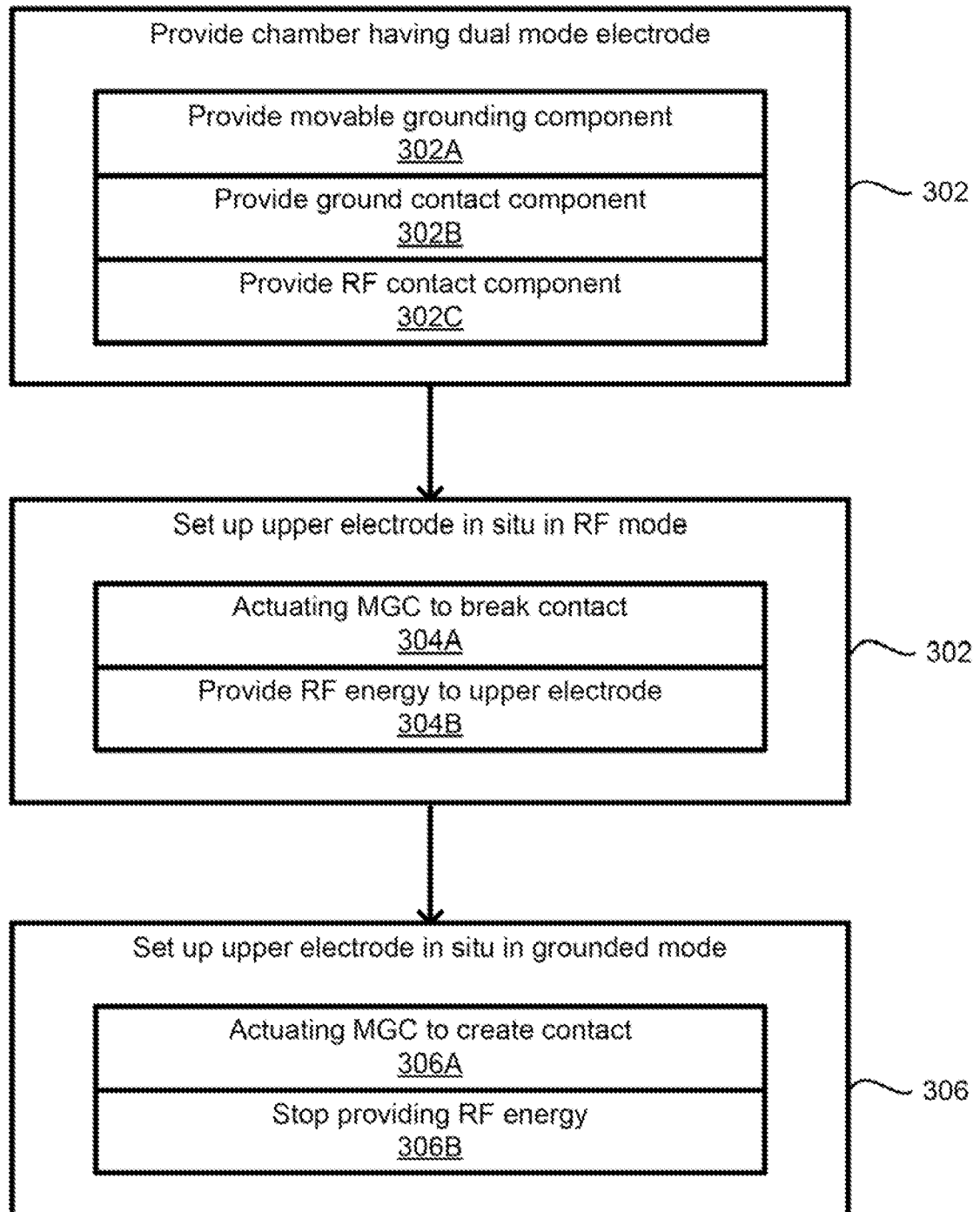


FIG. 2

*FIG. 3*