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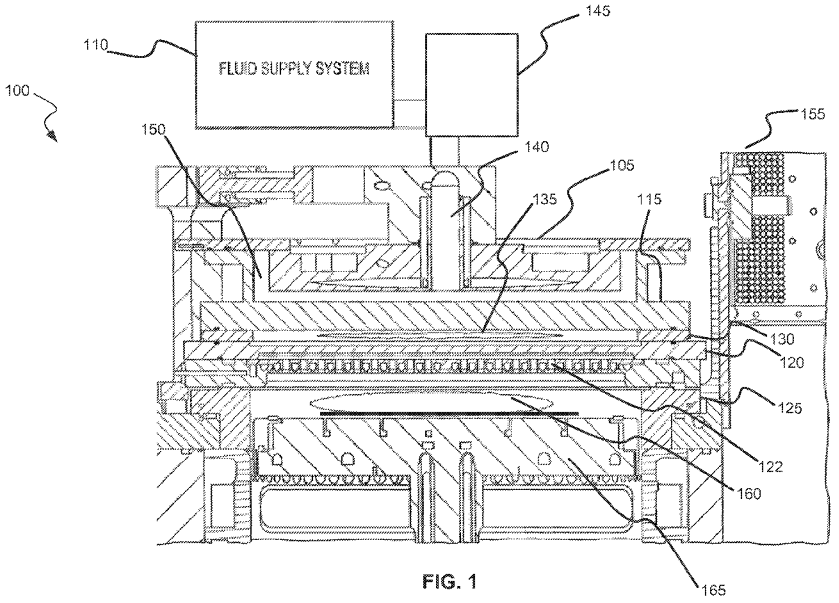

FIG. 1

(57) Abstract: Semiconductor processing systems are described including a process chamber. The process chamber may include a lid assembly, grid electrode, conductive insert, and ground electrode. Each component may be coupled with one or more power supplies operable to produce a plasma within the process chamber. Each component may be electrically isolated through the positioning of a plurality of insulation members. The one or more power supplies may be electrically coupled with the process chamber with the use of switching mechanisms. The switches may be switchable to electrically couple the one or more power supplies to the components of the process chamber.

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SEMICONDUCTOR PROCESSING WITH DC ASSISTED RF POWER FOR IMPROVED CONTROL

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/678,964, filed August 2, 2012, entitled "Semiconductor Processing With DC Assisted RF Power for Improved Control." The entire disclosure of which is incorporated herein by reference for all purposes.

TECHNICAL FIELD

The present technology relates to semiconductor processes and equipment. More specifically, the present technology relates to processing system plasma components.

BACKGROUND

Integrated circuits are made possible by processes which produce intricately patterned material layers on substrate surfaces. Producing patterned material on a substrate requires controlled methods for removal of exposed material. Chemical etching is used for a variety of purposes including transferring a pattern in photoresist into underlying layers, thinning layers, or thinning lateral dimensions of features already present on the surface. Often it is desirable to have an etch process that etches one material faster than another facilitating, for example, a pattern transfer process. Such an etch process is said to be selective to the first material. As a result of the diversity of materials, circuits, and processes, etch processes have been developed with a selectivity towards a variety of materials.

Dry etches produced in local plasmas formed within the substrate processing region can penetrate more constrained trenches and exhibit less deformation of delicate remaining structures. However, as integrated circuit technology continues to scale down in size, the equipment that delivers the precursors can impact the uniformity and quality of the precursors and plasma species used, and the formation and profile of the plasma may also affect the quality of film deposition and etching.

Thus, there is a need for improved system components that can be used in plasma environments effectively to provide improved control over plasma and plasma characteristics. These and other needs are addressed by the present technology.

SUMMARY

Semiconductor processing systems are described including a process chamber. The process chamber may include a lid assembly, grid electrode, conductive insert, and ground electrode. Each component may be coupled with one or more power supplies operable to produce a plasma within the process chamber. Each component may be electrically isolated through the positioning of a plurality of insulation members. The one or more power supplies may be electrically coupled with the process chamber with the use of switching mechanisms. The switches may be switchable to electrically couple the one or more power supplies to the components of the process chamber.

An exemplary processing system may include a processing chamber that includes a lid assembly defining a precursor inlet through which precursor species may be delivered. The chamber may also include a ground electrode and a grid electrode disposed between the lid assembly and the ground electrode, and defining a first plasma region within the chamber between the grid electrode and the lid assembly and a second plasma region within the chamber between the grid electrode and the ground electrode. The chamber may also include a conductive insert disposed between the lid assembly and the grid electrode at a periphery of the first plasma region. The chamber may further include an insulation member positioned to electrically isolate the grid electrode from the conductive insert. The processing system may also include a first power supply electrically coupled with the lid assembly, and a second power supply electrically coupled with at least one of the lid assembly, the grid electrode, or the conductive insert.

A switch such as a first switch may be electrically coupled with the second power supply. The switch may be switchable to electrically couple the second power supply to one of the lid assembly, the grid electrode, or the conductive insert, among other conductive portions of the processing chamber. The processing system may additionally include a second switch that is switchable to electrically couple at least two of the lid assembly, the ground electrode, or the grid electrode such that an electrical potential applied to one of the coupled structures will be applied to both of the coupled structures. The processing system may have the first switch switched to electrically couple the second power supply with the conductive insert. The second switch may also be switched to electrically couple the grid electrode and the ground electrode.

Additionally, the second power supply may be configured to deliver a negative voltage to the conductive insert, and the first power supply may be configured to ignite a plasma in the first plasma region where electron flux is directed to the grid electrode. The second power supply may also be configured to deliver a positive voltage to the conductive insert, and the first power supply may be configured to ignite a plasma in the first plasma region where ion flux is directed to the grid electrode. The first switch may also be switched to electrically couple the second power supply with the lid assembly such that both the first and second power supplies are electrically coupled with the lid assembly. The second switch may also be switched to electrically couple the grid electrode and the ground electrode. The second power supply may also be configured to provide constant voltage to the lid assembly, and the first power supply may be configured to provide pulsed frequency power to the lid assembly.

The processing system may also be configured where the first switch may be switched to electrically couple the second power supply with the lid assembly such that both the first and second power supplies are electrically coupled with the lid assembly, and the second switch may be switched to electrically couple the grid electrode and the lid assembly. The second power supply may also be configured to provide constant voltage to the lid assembly, and the first power supply may be configured to provide pulsed frequency power to the lid assembly. Also, the first switch may be switched to electrically couple the second power supply with the grid electrode. In another arrangement, the second power supply may be configured to provide constant voltage to the grid electrode, and the first power supply may be configured to provide pulsed frequency power to the lid assembly. In disclosed embodiments the first power supply may be an RF power supply, and the second power supply may be a DC power supply.

Methods of producing a plasma in a semiconductor processing chamber are also described, and may include coupling a first power supply with the processing chamber lid assembly to form a plasma within the processing chamber. The methods may also include coupling a second power supply with the processing chamber, and tuning the plasma with the second power supply. The tuning may include a variety of operations including applying a negative voltage with the second power supply to increase the electron flux. Also, the tuning may include applying a positive voltage with the second power supply to increase the ion flux.

The methods may include electrically coupling the second power supply with a switch that may be switchably coupled with multiple conductive sections of the processing chamber. In one example, the second power supply may be switched to be coupled with the lid assembly. The methods may include operating the first power supply so that it provides pulsing power to the lid assembly. The methods may also include utilizing an RF power supply for the first power supply, and a DC power supply for the second power supply.

Such technology may provide numerous benefits over conventional equipment. For example, tunable plasmas may allow increased control over plasma profiles being used in processing operations. Additionally, by adjusting the ion/electron flux profile, etching operations may be tuned in situ as processes are being performed. These and other embodiments, along with many of their advantages and features, are described in more detail in conjunction with the below description and attached figures.

BRIEF DESCRIPTION OF THE DRAWINGS

A further understanding of the nature and advantages of the present technology may be realized by reference to the remaining portions of the specification and the drawings.

FIG. 1 shows a simplified cross-sectional view of a processing system according to embodiments of the present technology.

FIG. 2 shows a simplified cross-sectional view of a processing chamber assembly according to embodiments of the present technology.

FIG. 3 shows a simplified cross-sectional view of a processing system having plasma generation components according to embodiments of the present technology.

FIG. 4 shows a simplified cross-sectional view of another processing system having plasma generation components according to embodiments of the present technology.

FIG. 5 shows a simplified cross-sectional view of another processing system having plasma generation components according to embodiments of the present technology.

FIG. 6 shows a simplified cross-sectional view of another processing system having plasma generation components according to embodiments of the present technology.

FIG. 7 illustrates operations of an exemplary method of tuning a plasma according to embodiments of the present technology.

In the appended figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label with a letter that distinguishes among the similar components and/or features. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the letter suffix.

DETAILED DESCRIPTION

Systems and methods are described for the generation and/or control of a plasma inside a semiconductor processing chamber. The plasma may originate inside the processing chamber, outside the processing chamber in a remote plasma unit, or both. Inside the chamber, the plasma is contained and may be separated from a substrate wafer with the use of power supplies electrically coupled with components of the processing chamber that may serve as electrodes. In some instances, the components may also function as part of a gas/precursor distribution system and may include a suppressor and/or a showerhead, as well as other components of the processing system. In additional instances, the components may function to define a partition between a plasma generation region and a gas reaction region that etches and/or deposits material on exposed surfaces of the substrate wafer.

The present technology includes improved power and control schemes for plasma modulation within a semiconductor process chamber. While conventional plasma generation may simply provide an internal plasma with limited tuning, the presently described technology may allow for improved control and modulation of etching chemistries via plasma manipulation. In so doing, etching depths, profiles, and selectivities may be adjusted as required for a variety of operational conditions.

Exemplary processing system configurations include one or more power supplies that are used as part of a capacitively coupled plasma ("CCP") system. In some embodiments, an RF power supply may be electrically coupled with one portion of the processing chamber, while a DC power supply may be coupled with the same or a different portion of the processing chamber. The DC power supply may allow for a plasma within the processing chamber to be sustained during cycling of the RF power supply, along with manipulation of the generated plasma. The manipulation may include adjusting the specific etch chemistry directed to the substrate wafer or chamber post, the ion flux directed to the substrate wafer or chamber post, as well as the functional capabilities of the ions utilized.

FIG. 1 shows a simplified cross-sectional view of a processing system 100 according to embodiments of the present technology. The processing system may optionally include components located outside the processing chamber 105, such as fluid supply system 110. The processing chamber 105 may hold an internal pressure different than the surrounding pressure. For example, the pressure inside the processing chamber may be about 10 mTorr to about 20 Torr during processing.

The CCP system may be composed of several of the processing chamber components, and may function to generate a plasma inside the processing chamber 105. The components of the CCP system may include a lid assembly or hot electrode 115 that may be composed of several components including a gas box, a blocker, and a faceplate. These components may be directly or indirectly coupled mechanically in order to function as a single electrode. The CCP system also may include a grid electrode 120 that also may be composed of one or more chamber components. For example, the grid electrode 120 may be composed of an ion suppressor or blocker and/or a manifold or showerhead for precursor delivery to the substrate wafer. Again, the components may be electrically coupled with each other in order to function as a single electrode. The CCP system may also include a ground electrode 125 that may include one or more chamber components including a lid spacer.

In some embodiments, the lid 115 and grid electrode 120 are electrically conductive electrodes that can be electrically biased with respect to each other to generate an electric field strong enough to ionize gases between the electrodes into a plasma. An electrical insulator 130 may separate the lid 115 and the grid 120 electrodes to prevent them from short-circuiting when a plasma is generated. The electrical insulator 130 may include multiple layers of material, as will be explained in more detail below with regard to the embodiments discussed with FIG. 2, and may alternatively include additional electrode layers. The plasma exposed surfaces of the lid 115, insulator 130, and grid electrode 120 may define a plasma excitation region 135 in the processing chamber 105.

Plasma generating gases may travel from a gas supply system 110 through a gas inlet 140 into the plasma excitation region 135. The plasma generating gases may be used to strike a plasma in the excitation region 135, or may maintain a plasma that has already been formed. In some embodiments, the plasma generating gases may have already been at least partially converted into plasma excited species in a remote plasma system 145 positioned outside the processing chamber 105 before traveling downstream though the inlet 140 to the plasma excitation region 135. When the plasma excited species reach the plasma excitation region 135, they may be further excited and affected by the characteristics of the plasma generated in the plasma excitation region. In some operations, the degree of added excitation provided by the CCP system may change over time depending on the substrate processing sequence and/or conditions.

The plasma generating gases and/or plasma excited species may pass through a plurality of holes (not shown) in lid 115 for a more uniform delivery into the plasma excitation region 135. Exemplary configurations include having the inlet 140 open into a gas supply region 150 partitioned from the plasma excitation region 135 by lid 115 so that the gases/species flow through the holes in the lid 115 into the plasma excitation region 135. Structural and operational features may be selected to prevent significant backflow of plasma from the plasma excitation region 135 back into the supply region 150, inlet 140, and fluid supply system 110. The structural features may include the selection of dimensions and cross-sectional geometry of the holes in lid 115 that deactivates back-streaming plasma. The operational features may include maintaining a pressure difference between the gas supply region 150 and plasma excitation region 135 that maintains a unidirectional flow of plasma through the grid electrode 120.

As noted above, the lid 115 and the grid electrode 120 may function as a first electrode and second electrode, respectively, so that the lid 115 and/or grid electrode 120 may receive an electric charge. In these configurations, electrical power such as RF power may be applied to the lid 115, grid electrode 120, or both. In one example, electrical power may be applied to the lid 115 while the grid electrode 120 is grounded. The substrate processing system 100 may include an RF generator 155 that provides electrical power to the lid 115 and/or one or more other components of the chamber 105. The electrically charged lid 115 may facilitate a uniform distribution of plasma, i.e., reduce localized plasma, within the plasma excitation region 135. To enable the formation of a plasma in the plasma excitation region 135, insulator 130 may electrically insulate lid 115 and grid electrode 120. Insulator 130 may be made from a ceramic and may have a high breakdown voltage to avoid sparking. In other embodiments discussed in more detail below, the insulator 130 includes several components that may be further utilized to affect the generated plasma, and may include additional electrode materials. The CCP system may also include a DC power system as will be described further below for modulating the RF generated plasma inside the chamber. The CCP system may further include a cooling unit (not shown) that includes one or more cooling fluid channels to cool surfaces exposed to the plasma with a circulating coolant (e.g., water). The cooling unit may include jacketing coupled with the exterior of the chamber 105 walls, as well as channels defined within the interior of the chamber walls that circulate a temperature controlled fluid.

The grid electrode 120 may include a plurality of holes 122 that suppress the migration of ionically-charged species out of the plasma excitation region 135 while allowing uncharged neutral or radical species to pass through the grid electrode 120. These uncharged species may include highly reactive species that are transported with less reactive carrier gas through the holes 122. As noted above, the migration of ionic species through the holes 122 may be reduced, and in some instances completely suppressed. Controlling the amount of ionic species passing through the grid electrode 120 may provide increased control over the gas mixture brought into contact with the underlying wafer substrate, which in turn increases control of the deposition and/or etch characteristics of the gas mixture. For example, adjustments in the ion concentration of the gas mixture can significantly alter its etch selectivity (e.g., SiOx:SiNx etch ratios, Poly-Si:SiOx etch ratios, etc.), as well as shift the balance of conformal-to-flowable of a deposited dielectric material. These features will be explained in more detail below.

The plurality of holes 122 may be configured to control the passage of the activated gas (i.e., the ionic, radical, and/or neutral species) through the grid electrode 120. For example, the aspect ratio of the holes 122 (i.e., the hole diameter to length) and/or the geometry of the holes 122 may be controlled so that the flow of ionically-charged species in the activated gas passing through the grid electrode 120 is reduced. In embodiments where the grid electrode includes an electrically coupled ion suppressor and showerhead, the holes in the ion blocker, which may be disposed above the showerhead, may include a tapered portion that faces the plasma excitation region 135, and a cylindrical portion that faces the showerhead. The cylindrical portion may be shaped and dimensioned to control the flow of ionic species passing to the showerhead. An adjustable electrical bias may also be applied to the grid electrode 120 as an additional means to control the flow of ionic species through the electrode.

Depending on whether a deposition or an etching process is performed, gases and plasma excited species may pass through the grid electrode 120 and be directed to the substrate. The showerhead, which may be a component included in the grid electrode, can further direct the flow of gases or plasma species. The showerhead may be a dual-zone showerhead that may include multiple fluid channels for directing the flow of one or more gases. The dual-zone showerhead may have a first set of channels to permit the passage of plasma excited species into reaction region 160, and a second set of channels that deliver a second gas/precursor mixture into the reaction region 160.

A fluid delivery source may be coupled with the showerhead to deliver a precursor that is able to bypass plasma excitation region 135 and enter reaction region 160 from within the showerhead through the second set of channels. The second set of channels in the showerhead may be fluidly coupled with a source gas/precursor mixture (not shown) that is selected for the process to be performed. For example, when the processing system is configured to perform an etch on the substrate surface, the source gas/precursor mixture may include etchants such as oxidants, halogens, water vapor and/or carrier gases that mix in the reaction region 160 with plasma excited species distributed from the first set of channels in the showerhead. Excessive ions in the plasma excited species may be reduced as the species move through the holes 122 in the grid electrode 120, and reduced further as the species move through channels in the showerhead.

The processing system may still further include a pedestal 165 that is operable to support and move the substrate or wafer. The distance between the pedestal 165 and the bottom of the grid electrode 120 help define the reaction region 160 along with lid spacer 125 defining the periphery of the reaction region 160. The pedestal 165 may be vertically or axially adjustable within the processing chamber 105 to increase or decrease the reaction region 160 and affect the deposition or etching of the wafer substrate by repositioning the wafer substrate with respect to the gases passed through the grid electrode 120. The pedestal 165 may have a heat exchange channel through which a heat exchange fluid flows to control the temperature of the wafer substrate. Circulation of the heat exchange fluid allows the substrate temperature to be maintained at relatively low temperatures (e.g., about -20°C to about 90°C). Exemplary heat exchange fluids include ethylene glycol and water.

The pedestal 165 may also be configured with a heating element such as a resistive heating element to maintain the substrate at heating temperatures (e.g., about 90°C to about 1100°C). Exemplary heating elements may include a single-loop heater element embedded in the substrate support platter that makes two or more full turns in the form of parallel concentric circles. An outer portion of the heater element may run adjacent to a perimeter of the support platten, while an inner portion may run on the path of a concentric circle having a smaller radius. The wiring to the heater element may pass through the stem of the pedestal.

A dual-zone showerhead, as well as the processing system and chamber, are more fully described in Patent Application Ser. No. 13/251,714 filed on Oct. 3, 2011, which is hereby incorporated by reference for all purposes to the extent not inconsistent with the claimed features and description herein.

FIG. 2 shows a simplified cross-sectional schematic of a processing chamber assembly according to embodiments of the present technology. The schematic illustrates a portion of a processing chamber 205 that may be used in semiconductor fabrication processes. Chamber 205 may be similar to processing chamber 105 as shown in FIG. 1. Chamber 205 may include a lid assembly 215 that may in some aspects be comparable to the lid assembly 115 as shown in FIG. 1. For example, lid assembly 215 may define precursor inlet 210, through which a precursor species may be delivered. A remote plasma unit (not shown) may be fluidly coupled with the precursor inlet 210 to provide radical precursor species into processing chamber 205. The radical precursor provided by the plasma unit may be mixed with additional gases inside the processing chamber 205 that are separately flowed into the chamber 205 through alternate channels (not shown).

Processing chamber 205 may include a grid electrode 220 that may include one or more chamber components electrically coupled. The grid electrode 220 may include one or more manifolds, and may include an ion blocker, as well as a showerhead, such as a dual-zone showerhead as previously described. The processing chamber 205 may include a ground electrode 225 that may be composed of additional chamber 205 components. For example, the ground electrode 225 may be a lid spacer or other wall component of the processing chamber 205. The ground electrode may alternatively include a ground connection to a substrate pedestal (not shown), but this may not be required for embodiments of the technology.

Processing chamber 205 may include an insulation section 230 similar to insulator 130 as illustrated in FIG. 1. However, as illustrated in processing chamber 205, insulation section 230 includes multiple components. The processing chamber 205 may include a conductive insert 235 disposed between lid assembly 215 and grid electrode 220. The conductive insert 235 may be a single piece of conductive material of an annular shape disposed as a portion of the chamber 205 wall.

A plurality of insulation members may additionally be incorporated into processing chamber 205 to electrically isolate the chamber components. For example, insulation members 240a-c are positioned between each of the conductive components and electrodes of the chamber housing. The insulation members 240 may be of a single annular shape, or be composed of several sections that when combined provide an electrical barrier between chamber components. For example, the insulation member may resist the flow of electrical charge, and may be of a material having a high dielectric strength. Exemplary insulation members include ceramic plates that may be annular in shape and disposed above and below components including the conductive insert 235. Multiple layers of the insulation members may be positioned in chamber 205 to further isolate components of the chamber. At least one of the plurality of insulation members may be positioned to electrically isolate the conductive insert 235 from the grid electrode 220. The insulation members may additionally isolate both the conductive insert 235 and the grid electrode 220 from the lid assembly 215 and the ground electrode 225. In this way, each conductive section may be electrically isolated from any other conductive section of the processing chamber 205.

The chamber components may define plasma regions within the processing chamber. A first plasma region 245 may be at least partially defined above and below by the lid assembly 215 and the grid electrode 220. The conductive insert may be disposed along the periphery of the first plasma region 245. A second plasma region 250 may be at least partially defined above by the grid electrode 220. The second plasma region 250 may be at least partially defined below by a substrate pedestal (not shown), that may be moveable vertically, axially, or both, to define the area in which the second plasma region 250 exists. The ground electrode 225 may be disposed along the periphery of the second plasma region 250, or may be utilized to produce a boundary at least partially defining the lower bounds of the second plasma region 250.

Power supplies 255, 260 and optionally electrical switches 265, 270 may be coupled with processing chamber 205 to produce a processing system 200 with plasma control. The optional switches may be used to electrically couple components of the system. For example, electrical switch 265 may be electrically coupled with power supply 260, alternatively with power supply 255 and 260, alternatively with power supply 255, or still alternatively with either power supply while an additional switch (not shown) is used to electrically couple the other power supply. In yet another alternative, the switches may be bypassed to directly couple each of the power supplies 255, 260 to portions of the processing chamber. The power supplies 255, 260 may be of any type of power useful in semiconductor manufacturing, and may include RF power supplies, DC power supplies, etc. Optional switch 270 may be used to electrically couple components of the processing chamber 205. For example, switch 270 may be switchable to electrically couple any two or more of the lid assembly 215, the conductive insert 235, the grid electrode 220, and the ground electrode 225. Alternatively, optional switch 270 may be bypassed to directly electrically couple one or more components of the processing chamber 205. The switches 265, 270 may provide additional functionality so that the type of plasma generated, and the location of the plasma may be adjusted at any time during processing operations. The optional switches 265, 270 and power supplies 255, 260 may additionally include remotely located controls to manipulate the settings of the components as will be described further below.

FIG. 3 shows a simplified cross-sectional schematic of a processing system 300 having plasma generation components according to embodiments of the present technology. Chamber 305 of processing system 300 may include similar components as previously described with respect to FIG. 2. Chamber 305 may define a gas inlet 310 through which reactive precursor species may be delivered from, for example, a remote plasma unit (not shown). Chamber 305 may include a lid assembly 315, conductive insert 335, grid electrode 320, and ground electrode 325 along with additional chamber components. One or more of the lid assembly 315, conductive insert 335, grid electrode 320, and ground electrode 325 may be electrically isolated from the other listed components by one or more of a plurality of insulation members 340a-c. System 300 may additionally include power supplies 355, 360 as well as optional switches 365, 370 for electrically coupling the power supplies to the chamber, or components in the chamber to one another.

As illustrated in FIG. 3, power supply 355 may be electrically coupled with lid assembly 315. In some embodiments, power supply 355 is an RF power supply. When in operation, the power supply may provide an electrical charge to lid assembly 315 which may act as a hot electrode for plasma generation. Grid electrode 320 may be coupled with ground electrode 325 thereby defining a plasma region 345 in which plasma may be generated, or plasma conditions may be modulated. The grid electrode 320 may be directly coupled with ground electrode 325, or alternatively may be electrically isolated with insulation member 340c. The insulation may be overcome by electrically coupling the grid electrode 320 and the ground electrode 325. A conductive means may be used to electrically couple the electrodes, and an exemplary system may utilize optional switch 370 that is switchable for electrically coupling the components.

The RF power supply 355 may be configured to deliver an adjustable amount of power to the lid assembly 315 depending on the process performed. Exemplary power supplies may be configured to deliver an adjustable amount of power over a range of from 0 to about 3 kW of power. In deposition processes for example, the power delivered to the lid assembly 315 may be adjusted to set the conformality of the deposited layer. Deposited dielectric films are typically more flowable at lower plasma powers and shift from flowable to conformal when the plasma power is increased. For example, an argon containing plasma maintained in the plasma excitation region 345 may produce a more flowable silicon oxide layer as the plasma power is decreased from about 1000 Watts to about 100 Watts or lower (e.g., about 900, 700, 500, 300, 200, 100, 50, 25 Watts, or less), and a more conformal layer as the plasma power is increased from about 1000 Watts, or more (e.g., about 1200, 1500, 1800, 2000, 2200, 2400, 2600, 2800 Watts, or more). As the plasma power increases from low to high, the transition from a flowable to conformal deposited film may be relatively smooth and continuous or progress through relatively discrete thresholds. The plasma power (either alone or in addition to other deposition parameters) may be adjusted to select a balance between the conformal and flowable properties of the deposited film. For etching processes, reducing the power from 3 kW down below 1 kW or less can affect the removal rate of material being etched, and may reduce the rate at which deposited films are removed. Increasing the power above 1 kW and up to 3 kW can produce higher removal rates of deposited films.

Alternatively, for exemplary etch processes, the frequency and duty cycle of the RF power may be adjusted to modulate the chemistry and flux characteristics of the films. The inventors have also determined that certain frequencies of RF supply may affect the impact on chamber components, such as the grid electrode. A variety of frequencies may be employed, and during continuous operation of the RF power supply 355, frequencies such as up to about 400 kHz, between about 400 kHz and about 13.56 MHz, between about 13.56 MHz and about 60 MHz, and above 60 MHz may be employed. During certain operations, increasing the frequency may produce etchant radicals more efficiently, as well as reduce the damage caused to chamber components.

Power supply 360 may also be utilized during the operation of power supply 355, and may be a DC power supply in some embodiments. Exemplary DC power supplies may be configured for adjustable control between about 500 to about -500 V. Alternatively, power supply 360 may be configured for adjustable control between about 400 to about -400 V, between about 300 to about -300 V, between about 200 to about -200 V, between about 100 to about -100 V, etc., or less. Power supply 360 may be directly coupled with components of chamber 305, or electrically coupled to components with switch 365 that may be switchable to electrically couple power supply 360 to components of the chamber 305. In one embodiment, DC power supply 360 is electrically coupled with conductive insert 335.

RF power supply 355 and DC power supply 360 may be operated together, alternately, or in some other combination. In an exemplary operation, as illustrated in FIG. 3, RF power supply 355 may be operated continuously between about 0 and about 3000 kW to maintain a plasma in plasma reaction region 345. The DC power supply 360 may be unused or off, may be continuously operated, or alternatively may be pulsed during operation. The assistance of DC power may produce effects on the material being etched. For example, if the DC bias is positive, more ion flux from the plasma may move to the grid electrode, and subsequently to the substrate wafer. If the DC bias is negative, more electron flux may be directed to the grid electrode. By adjusting the bias as well as the power of the DC power supply 360, the etch characteristics of the plasma can be modulated. Accordingly, depending on the characteristics of the substrate or on the characteristics of the films being etched, the chemistry of the etchants may be adjusted to produce optimum etching results. For example, the more the etchant chemistry is adjusted to increase the ion or electron flux, the more the etchant fluids may be selective towards one or more deposited films. By combining the DC power supply 360 with the RF power supply 355, more chemistry modulation may be obtained as compared to an RF power supply alone. With the enhanced etchant chemistry modulation, improved etching selectivities may be obtained, which may also provide improved ability for more sensitive removals of deposited films. Sensitivity with removal rates may allow less material to be removed overall, which may allow less material to be deposited initially.

An alternative operational scheme as illustrated by FIG. 3 includes pulsing of the RF power supply 355 along with continuous or pulsed operation of the DC power supply 360. The RF power supply 355 may be configured to provide continuous adjustable modulation of RF pulsing from continuous wave down to about 1000 kHz or more. Alternatively, the RF may be adjusted in discrete increments from continuous wave to about 0.01 kHz, or alternatively about 0.1 kHz, 1 kHz, 10 kHz, 100 kHz, 1000 kHz, etc., or more. In still other embodiments, the RF power supply 355 may be pulsed in any variety or range of values between the listed values.

Alternatively or simultaneously, the duty cycle may be modulated. Adjusting the duty cycle, or the time in the active state, for the RF power supply may affect the flux of ions produced in the plasma. For example, when a reduction in the duty cycle occurs, a relatively or substantially commensurate reduction in ion current may be produced. During etching processes, by reducing the ion current, the etching rate may be reduced proportionately. However, when an RF power supply is cycled, it is switched on and off during the cycling time. When the RF power is cycled off, the generated plasma may dissipate. Accordingly, the amount of duty cycle reduction may conventionally have been limited to the times that may allow the plasma to be maintained at a certain level. However, the inventors have determined that with configurations such as those described here, the DC power supply 360 may be capable of adjusting the chemistry by maintaining ion and electron movement during the periods that the RF power is off. Additionally, by having a certain amount of DC power during the periods when the RF power is off, the plasma may be at least partially sustained by the DC power. In this way, the plasma may not fully dissipate when the RF power is cycled off. This may allow further adjustment of the chemistry because the etchant chemistry may adjust when the RF power is switched from on to off. By utilizing the DC power supply 360 during some or all of the on and/or off times of the RF power supply 355, the etchant chemistries may be further modified. Accordingly, further adjustment of the RF power may be acceptable with reduced duty cycles. As such, the duty cycle of the RF power may be operated from about 100% to about 0% during operation, less than or about 75%, less than or about 50%, or less than or about 25%. Alternatively, the duty cycle maybe operated at about 90%, 80%, 75%, 70%, 60% 50%, 40%, 30%, 25%, 20%, 15%, 10%, 5%, or less. In still alternative configurations, the power supply may be configured to have an adjustable duty cycle at or between any of the listed cycle percentages, as well as ranges of any of the recited cycles. Pulsing of the RF power supply may allow further adjustment of the etching parameters by allowing reduced and more selective removals. For example, when a large amount of material is being removed, a continuous supply of RF power may be utilized. On the other hand, when small amounts of material, or more selective removals are required, RF pulsing may be employed. The RF pulsing may be capable of removing amounts of less than 100 nm of material, or alternatively less than or about 50 nm, 30 nm, 22 nm, 15 nm, or less including down to a monolayer of deposited film.

FIG. 4 shows a simplified cross-sectional schematic of another processing system 400 having plasma generation components according to embodiments of the present technology. Chamber 405 of processing system 400 may include similar components as previously described with respect to FIG. 2. Chamber 405 may define a gas inlet 410 through which reactive precursor species may be delivered from, for example, a remote plasma unit (not shown). Chamber 405 may include a lid assembly 415, conductive insert 435, grid electrode 420, and ground electrode 425 along with additional chamber components. One or more of the lid assembly 415, conductive insert 435, grid electrode 420, and ground electrode 425 may be electrically isolated from the other listed components by one or more of a plurality of insulation members 440a-c. System 400 may additionally include power supplies 455, 460 as well as optional switches 465, 470 for electrically coupling the power supplies to the chamber, or components in the chamber to one another.

As illustrated in FIG. 4, power supply 455 is electrically coupled with lid assembly 415. In some embodiments, power supply 455 is an RF power supply. When in operation, the power supply 455 provides an electrical charge to lid assembly 415 which may act as a hot electrode for plasma generation. Grid electrode 420 may be coupled with ground electrode 425 thereby defining a plasma region 445 in which plasma may be generated, or plasma conditions may be modulated. The grid electrode 420 may be directly coupled with ground electrode 425, or alternatively may be electrically isolated with insulation member 440c. The insulation may be overcome by electrically coupling the grid electrode 420 and the ground electrode 425. A conductive means may be used to electrically couple the electrodes, and an exemplary system may utilize optional switch 470 for electrically coupling the components. RF power supply 455 may be configured to be adjustable with any of the parameters as previously discussed.

Power supply 460 may also be utilized during the operation of power supply 455, and may be a DC power supply in some embodiments. Exemplary DC power supplies may be configured for adjustable control with any of the parameters as previously described. DC power supply 460 may be operated in continuous or pulsing fashion as previously described. As illustrated in FIG. 4, DC power supply 460 is electrically coupled to lid assembly 415 along with RF power supply 455. Power supply 460 may be directly coupled with the lid assembly 415 or the electrical coupling of RF power supply 455, or electrically coupled to the lid assembly 415 or electrical coupling of RF power supply 455 with switch 465 that may be switchable to electrically couple DC power supply 460 to the components of the chamber 405.

In operation, RF power supply 455 and DC power supply 460 may be operated as illustrated in FIG. 4 to provide additional chemistry modulation of precursor species via an additional form of plasma modulation. Radical precursor species may be delivered to processing chamber 405 from a remote plasma system (not shown) fiuidly coupled to gas inlet 410. RF power supply 455 may be operated as a continuous wave or pulsed to deliver modulated power to lid assembly 415. When engaged in the illustrated configuration, power supply 455 may generate a plasma in plasma region 445. Lid assembly 415, as the hot electrode, may be a major plasma generation area. As previously discussed, conventional operation in this way may have limited the duty cycle modulation of the RF power supply 455 due to the plasma characteristics in the plasma region 445. However, in the described exemplary configuration, DC power supply 460 may be operated to assist RF power supply 455 in maintaining plasma function in the plasma region 445. When RF power supply 455 is cycled off, DC power supply 460 may hold some plasma.

In one example, DC power supply 460 may be operated in continuous fashion while RF power supply 455 is pulsed. DC power supply 460, when electrically coupled with lid assembly 415 and operated continuously, may maintain a plasma in plasma region 445 generated by RF power supply 455. Accordingly, RF power supply may be modulated on and off, and continuously operated power supply 460 may maintain the plasma during the off cycle. As such, RF power supply 455 may be modulated with reduced duty cycles. For example, the duty cycle of the RF power may be operated from about 100% to about 0% during operation, less than or about 75%, less than or about 50%, or less than or about 25%. Alternatively, the duty cycle may be operated at about 90%, 80%, 75%, 70%, 60%, 50%, 40%, 30%, 25%, 20%, 15%, 10%, 5%, or less. In still alternative configurations, the power supply may be configured to have an adjustable duty cycle at or between any of the listed cycle percentages, as well as ranges of any of the recited cycles.

The pulsing capability of RF power supply 455 may be modulated continuously as previously discussed from continuous wave to about 1000 kHz or more. Alternatively, the RF may be adjusted in discrete increments from continuous wave to about 0.01 kHz, or alternatively about 0.1 kHz, 1 kHz, 10 kHz, 100 kHz, 1000 kHz, etc., or more. In still other embodiments, the RF power supply 455 may be pulsed in any variety or range of values between the listed values. When pulsed, the ion current may be reduced as compared to continuous wave operation. Because the DC power supply may assist in holding a plasma during the ‘off cycle of RF power supply 455, further pulsing modulation may be effected. Consequently, reduced etching may be performed to the level of less than 100 nm during an etching process. As the ion current is reduced during an etching process, the same time period for etching may result in a reduced etching amount. Accordingly, further reduction of the ion current via power supply modulation as discussed may allow etching amounts of less than or about 50 nm, 40 nm, 30 nm, 20 nm, 10 nm, 5 nm, etc., or less. Additionally, reducing the duty cycle may further modify the etching amounts by additionally reducing the ion current as the duty cycle is reduced. In combination, pulsing and reduced duty cycle may be combined to provide further chemistry modulation and ion current to allow improved flexibility of operation.

In comparison to the modulation discussed with respect to FIG. 3, the DC power supply may be utilized in several ways. When directed towards the conductive insert 435, the DC power supply may have a greater impact on ion and electron flux, and a positive and negative bias may be applied over a range of power levels to affect the chemistry of the precursors directed to the substrate. Alternatively, when the DC power supply 460 is coupled with the lid assembly in conjunction with the RF power supply 455, the DC power supply 460 may be used for plasma holding, and as such ion current may be further modulated via the RF power supply 455. Further, by utilizing switch 465 that may be electrically coupled with power supply 460, DC power supply 465 may be electrically coupled with different components of processing chamber 405 during different operations. As such, based on the type of etching being performed, types of precursors being used, etc., DC power supply 460 may be appropriately coupled with the chamber 405 to produce the plasma assistance most beneficial for the particular operation. Additionally, these parameters may be adjusted during operation such as if multiple deposited films are being removed, the coupling of power supply 460, and the modulation of both power supplies 455, 460 may be adjusted during processing when operational parameters may benefit from a change in etch performance.

FIG. 5 shows a simplified cross-sectional schematic of another processing system 500 having plasma generation components according to embodiments of the present technology. Chamber 505 of processing system 500 may include similar components as previously described with respect to FIG. 2. Chamber 505 may define a gas inlet 510 through which reactive precursor species may be delivered from, for example, a remote plasma unit (not shown). Chamber 505 may include a lid assembly 515, conductive insert 535, grid electrode 520, and ground electrode 525 along with additional chamber components. One or more of the lid assembly 515, conductive insert 535, grid electrode 520, and ground electrode 525 may be electrically isolated from the other listed components by one or more of a plurality of insulation members 540a-c.

System 500 may additionally include power supplies 555, 560 as well as optional switches 565, 570 for electrically coupling the power supplies to the chamber, or components in the chamber to one another.

As illustrated in FIG. 5, power supply 555 is electrically coupled with lid assembly 515. In some embodiments, power supply 555 is an RF power supply. When in operation, the power supply 555 provides an electrical charge to lid assembly 515 which may act as a hot electrode for plasma generation. Grid electrode 520 may be coupled with lid assembly 515 which allows the hot electrode function to move to the grid electrode 520 level. As such, plasma generation may be shifted below the grid electrode 520 to the wafer level in plasma region 550. The grid electrode 520 may be electrically coupled with lid assembly, and an exemplary system may utilize optional switch 570 for electrically coupling the components. RF power supply 555 may be configured to be adjustable with any of the parameters as previously discussed.

Power supply 560 may also be utilized during the operation of power supply 555, and may be a DC power supply in some embodiments. Exemplary DC power supplies may be configured for adjustable control with any of the parameters as previously described. DC power supply 560 may be operated in continuous or pulsing fashion as previously described. As illustrated in FIG. 5, DC power supply 560 may be electrically coupled with lid assembly 515 along with RF power supply 555. Power supply 560 may be directly coupled with the lid assembly 515 or the electrical coupling of RF power supply 555, or electrically coupled to the lid assembly 515 or electrical coupling of RF power supply 555 with switch 565 that may be switchable to electrically couple DC power supply 560 to the components of the chamber 505.

The exemplary system configuration illustrated in FIG. 5 may be utilized for treatment operations. For example, after an etch process has been performed, such as with one of the prior etch configurations, byproducts may be formed or remain on the substrate surface. Remote plasma systems may be less effective in some circumstances than plasma generated at the wafer level. Accordingly, by utilizing the system configuration illustrated in FIG. 5, a more effective plasma treatment may be formed at the substrate level. However, depending on the type of byproduct and the amount remaining on the surface, plasma modulation may still be utilized with any of the operational manipulations previously discussed. Accordingly, by utilizing one or more of the power supply configurations as previously discussed, modulation of the treatment chemistry may be modulated as previously described. By utilizing switch 570 that may be switchable to couple multiple components of the processing chamber 505, multiple steps of semiconductor processing may be performed in the same chamber 505. For example, after the etching operation as described with regard to the embodiment shown in FIG. 4 is performed, switch 570 may be operated to switch the electrical coupling of the grid electrode 520 from the ground electrode 525 to the lid assembly 515. A subsequent treatment process may be performed with wafer level plasma as illustrated in FIG. 5. Alternatively, an etching operation may be performed as described with regard to the embodiment shown in FIG. 3. After the etching has been completed, switch 565 may be operated to switch the coupling of DC power supply 560 from the conductive insert 535 to the lid assembly 515 or RF power supply 555 electrical coupling, and switch 570 may be operated to switch the electrical coupling of the grid electrode 520 from the ground electrode 525 to the lid assembly 515. Many such options are available with the configurations and switching capabilities as described herein.

FIG. 6 shows a simplified cross-sectional schematic of another processing system 600 having plasma generation components according to embodiments of the present technology. Chamber 605 of processing system 600 may include similar components as previously described with respect to FIG. 2. Chamber 605 may define a gas inlet 610 through which reactive precursor species may be delivered from, for example, a remote plasma unit (not shown). Chamber 605 may include a lid assembly 615, conductive insert 635, grid electrode 620, and ground electrode 625 along with additional chamber components. One or more of the lid assembly 615, conductive insert 635, grid electrode 620, and ground electrode 625 may be electrically isolated from the other listed components by one or more of a plurality of insulation members 640a-c. System 600 may additionally include power supplies 655, 660 as well as optional switches 665, 670 for electrically coupling the power supplies to the chamber, or components in the chamber to one another.

As illustrated in FIG. 6, power supply 655 is electrically coupled with lid assembly 615. In some embodiments, power supply 655 is an RF power supply. When in operation, the power supply 655 provides an electrical charge to lid assembly 615 which may act as a hot electrode for plasma generation. As compared to the embodiment discussed in FIG. 3, grid electrode 620 may not be electrically coupled with ground electrode 625. Accordingly, the ground electrode of the power system may be shifted from the grid electrode 620 to the ground electrode 625. In so doing, the plasma may develop over a slightly larger region of processing chamber 605 including into and through the grid electrode 620. RF power supply 455 may be configured to be adjustable with any of the parameters as previously discussed.

Power supply 660 may also be utilized during the operation of power supply 655, and may be a DC power supply in some embodiments. Exemplary DC power supplies may be configured for adjustable control with any of the parameters as previously described. DC power supply 660 may be operated in continuous or pulsing fashion as previously described, and also may be electrically coupled with any of the components of processing chamber 605 as previously described. In the exemplary system illustrated in FIG. 6, DC power supply 660 is electrically coupled with grid electrode 620. Power supply 660 may be directly coupled with grid electrode 620, or alternatively with switch 665 that may be switchable to electrically couple DC power supply 660 to the components of the chamber 605.

In operation, RF power supply 655 and DC power supply 660 may be operated as illustrated in FIG. 6 to provide additional chemistry modulation of precursor species via an additional form of plasma modulation. Radical precursor species may be delivered to processing chamber 605 from a remote plasma system (not shown) fluidly coupled with gas inlet 610. RF power supply 655 may be operated as a continuous wave or pulsed to deliver modulated power to lid assembly 615. When engaged in the illustrated configuration, power supply 655 may generate a plasma in plasma region 645. During certain etching or treatment operations, byproducts may remain in trench features previously etched. By allowing the plasma region 645 to expand to the level of the grid electrode 620 or below, additional removal of byproducts within etched features may be accomplished. The expanded plasma region may allow certain plasma species to interact at the substrate level and may provide directionality to species that may be utilized in byproduct removal. RF power supply 655 may be modulated via pulsing, or duty cycle modulation may be performed as previously described.

DC power supply 660 may be operated to assist RF power supply 655 in any of the ways previously described. When DC power supply 660 is electrically coupled with grid electrode 620, the DC power supply 660 may be used to provide additional ion and electron flux control with the plasma generated. When electrically coupled with the grid electrode, ion and electron flux can be adjusted through the grid electrode 620 components depending on the bias and power level of the DC power supply as explained above. Alternative embodiments may also electrically couple the DC power supply 660 with the conductive insert 635 or the lid assembly 615 as previously described.

Turning to **FIG.** 7 is shown a method of producing a plasma in a processing chamber according to the present technology. The chamber may be similar to chamber 100 as previously described. The chamber may include one or more power supplies such as supply 155. In operation 710, a first power supply may be coupled with the processing chamber lid assembly. The power supply may also be coupled electrically with additional or alternative structures of the processing chamber. In operation 720 a second power supply may be coupled with the processing chamber, and may be coupled with a similar or different portion of the processing chamber as the first power supply. For example, the second and/or first power supply may be coupled with a switch that may be switchably coupled with one or more conductive sections of the processing chamber. For example, the second power supply may be switchably coupled with the lid assembly or an additional conductive portion of the chamber as previously described.

A plasma may be ignited or otherwise formed in the processing chamber by engaging the first power supply. The action of coupling the power supply if engaged may ignite the plasma between the structure to which the first power supply is electrically coupled and a ground source located within the chamber. In operation 730, the second power supply may be used to tune the plasma profile in one or more ways. For example, a negative voltage may be applied with the second power supply, which may cause a greater electron flux to flow through the chamber such as towards a grid electrode or processing region. Also, a positive voltage may be applied with the second power supply to increase the ion flux through the chamber towards an electrode structure or the processing region. The first power supply may also be operated in a variety of modes, and for example, the first power supply may provide pulsing power to the lid assembly. In disclosed embodiments, the first power supply may include an RF power supply, and the second power supply may include a DC power supply.

In the preceding description, for the purposes of explanation, numerous details have been set forth in order to provide an understanding of various embodiments of the present technology. It will be apparent to one skilled in the art, however, that certain embodiments may be practiced without some of these details, or with additional details.

Having disclosed several embodiments, it will be recognized by those of skill in the art that various modifications, alternative constructions, and equivalents may be used without departing from the spirit of the disclosed embodiments. Additionally, a number of well-known processes and elements have not been described in order to avoid unnecessarily obscuring the present technology. Accordingly, the above description should not be taken as limiting the scope of the technology.

It is noted that individual embodiments may be described as a process which is depicted as a flowchart, a flow diagram, or a block diagram. Although a flowchart may describe the method as a sequential process, many of the operations may be performed in parallel or concurrently. In addition, the order of the operations may be rearranged. A process may be terminated when its operations are completed, but could have additional steps not discussed or included in a figure.

Furthermore, not all operations in any particularly described process may occur in all embodiments. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc.

Where a range of values is provided, it is understood that each intervening value, to the smallest fraction of the unit of the lower limit, unless the context clearly dictates otherwise, between the upper and lower limits of that range is also specifically disclosed. Each smaller range between any stated value or intervening value in a stated range and any other stated or intervening value in that stated range is encompassed. The upper and lower limits of those smaller ranges may independently be included or excluded in the range, and each range where either, neither, or both limits are included in the smaller ranges is also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included.

As used herein and in the appended claims, the singular forms "a", "an", and "the" include plural references unless the context clearly dictates otherwise. Thus, for example, reference to "a dielectric material" includes a plurality of such materials, and reference to "the application" includes reference to one or more applications and equivalents thereof known to those skilled in the art, and so forth.

Also, the words "comprise", "comprising", "contains", "containing", "include", "including", and "includes", when used in this specification and in the following claims, are intended to specify the presence of stated features, integers, components, or steps, but they do not preclude the presence or addition of one or more other features, integers, components, steps, acts, or groups.

WHAT IS CLAIMED IS:

1. A semiconductor processing system comprising:

a processing chamber that includes:

a lid assembly defining a precursor inlet through which precursor species may be delivered;

a ground electrode;

a grid electrode disposed between the lid assembly and the ground electrode, and defining a first plasma region within the chamber between the grid electrode and the lid assembly and a second plasma region within the chamber between the grid electrode and the ground electrode;

a conductive insert disposed between the lid assembly and the grid electrode at a periphery of the first plasma region;

an insulation member positioned to electrically isolate the grid electrode from the conductive insert;

a first power supply electrically coupled with the lid assembly; and

a second power supply electrically coupled with at least one of the lid assembly, the grid electrode, or the conductive insert.

2. The semiconductor processing system of claim 1, further comprising a first switch that is electrically coupled with the second power supply, and that is switchable to electrically couple the second power supply to one of the lid assembly, the grid electrode, or the conductive insert.

3. The semiconductor processing system of claim 1, further comprising a second switch that is switchable to electrically couple at least two of the lid assembly, the ground electrode, or the grid electrode.

4. The semiconductor processing system of claim 3, wherein the first switch is switched to electrically couple the second power supply with the conductive insert, and wherein the second switch is switched to electrically couple the grid electrode and the ground electrode.

5. The semiconductor processing system of claim 4, wherein the second power supply is configured to deliver a negative voltage to the conductive insert, and wherein the first power supply is configured to ignite a plasma in the first plasma region where electron flux is directed to the grid electrode.

6. The semiconductor processing system of claim 4, wherein the second power supply is configured to deliver a positive voltage to the conductive insert, and wherein the first power supply is configured to ignite a plasma in the first plasma region where ion flux is directed to the grid electrode.

7. The semiconductor processing system of claim 3, wherein the first switch is switched to electrically couple the second power supply with the lid assembly such that both the first and second power supplies are electrically coupled with the lid assembly, and wherein the second switch is switched to electrically couple the grid electrode and the ground electrode.

8. The semiconductor processing system of claim 7, wherein the second power supply is configured to provide constant voltage to the lid assembly, and the first power supply is configured to provide pulsed frequency power to the lid assembly.

9. The semiconductor processing system of claim 3, wherein the first switch is switched to electrically couple the second power supply with the lid assembly such that both the first and second power supplies are electrically coupled with the lid assembly, and wherein the second switch is switched to electrically couple the grid electrode and the lid assembly.

10. The semiconductor processing system of claim 9, wherein the second power supply is configured to provide constant voltage to the lid assembly, and the first power supply is configured to provide pulsed frequency power to the lid assembly.

11. The semiconductor processing system of claim 3, wherein the first switch is switched to electrically couple the second power supply with the grid electrode.

12. The semiconductor processing system of claim 11, wherein the second power supply is configured to provide constant voltage to the grid electrode, and the first power supply is configured to provide pulsed frequency power to the lid assembly.

13. The semiconductor processing system of claim 1, wherein the first power supply is an RF power supply, and the second power supply is a DC power supply.

14. A method of producing a plasma in a semiconductor processing chamber, the method comprising:

coupling a first power supply with the processing chamber lid assembly to form a plasma within the processing chamber;

coupling a second power supply with the processing chamber;

tuning the plasma with the second power supply.

15. The method of claim 14, wherein the tuning comprises applying a negative voltage with the second power supply to increase the electron flux.

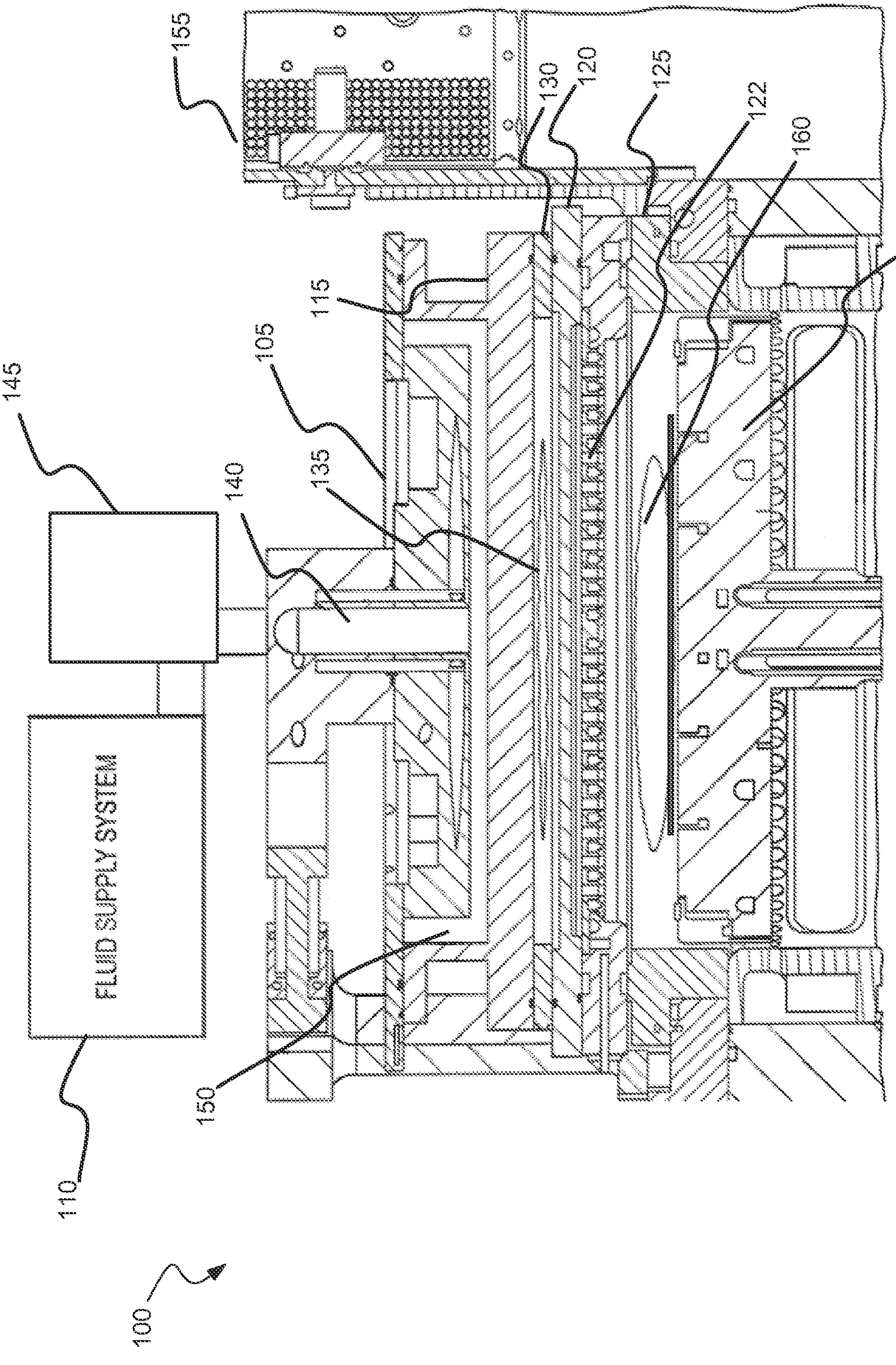
16. The method of claim 14, wherein the tuning comprises applying a positive voltage with the second power supply to increase the ion flux.

17. The method of claim 14, wherein the second power supply is electrically coupled with a switch that is switchably coupled with multiple conductive sections of the processing chamber.

18. The method of claim 17, wherein the second power supply is coupled with the lid assembly.

19. The method of claim 14, wherein the first power supply provides pulsing power to the lid assembly.

20. The method of claim 14, wherein the first power supply comprises an RF power supply, and the second power supply comprises a DC power supply.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FLUID SUPPLY SYSTEM
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FIG. 1

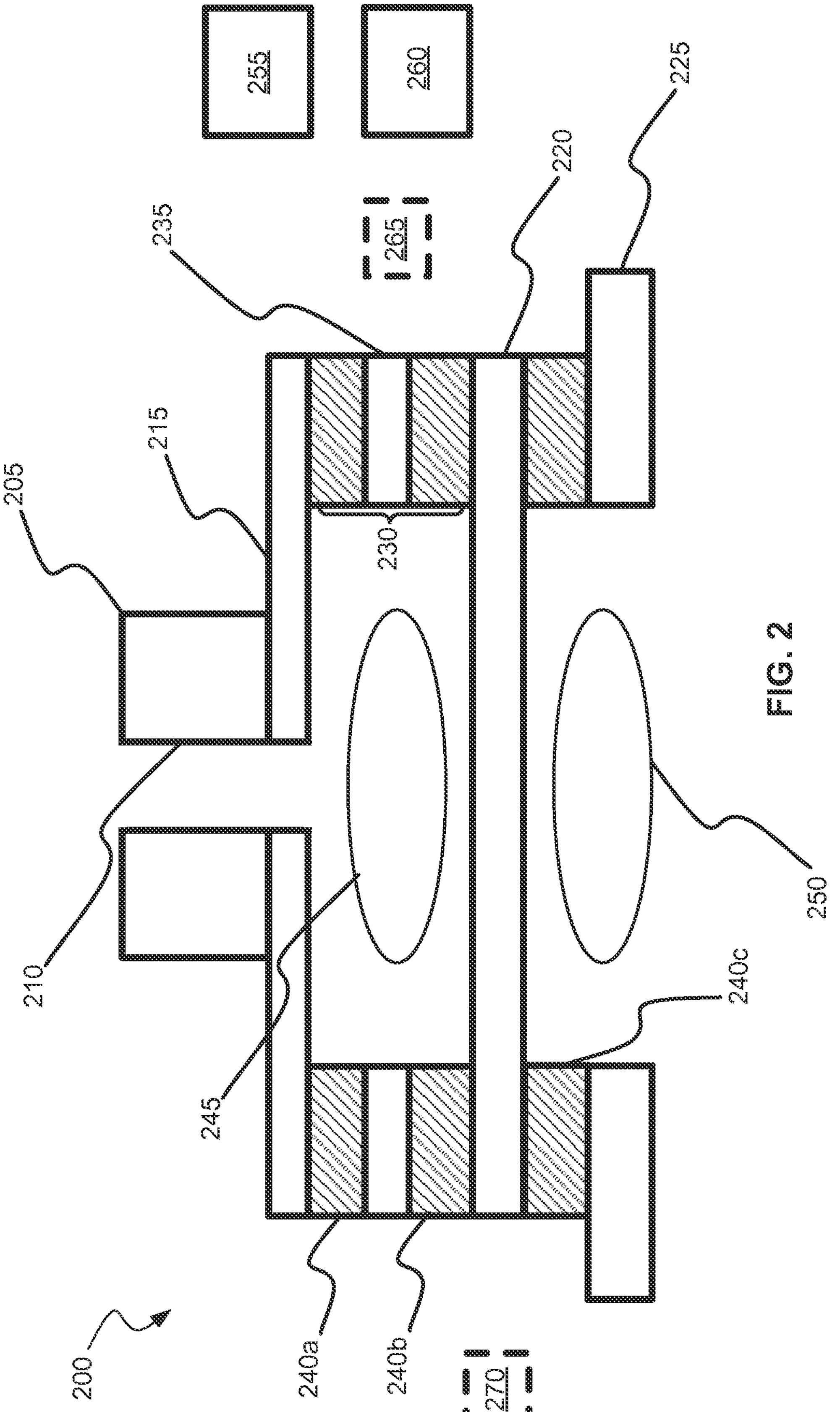
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FIG. 2

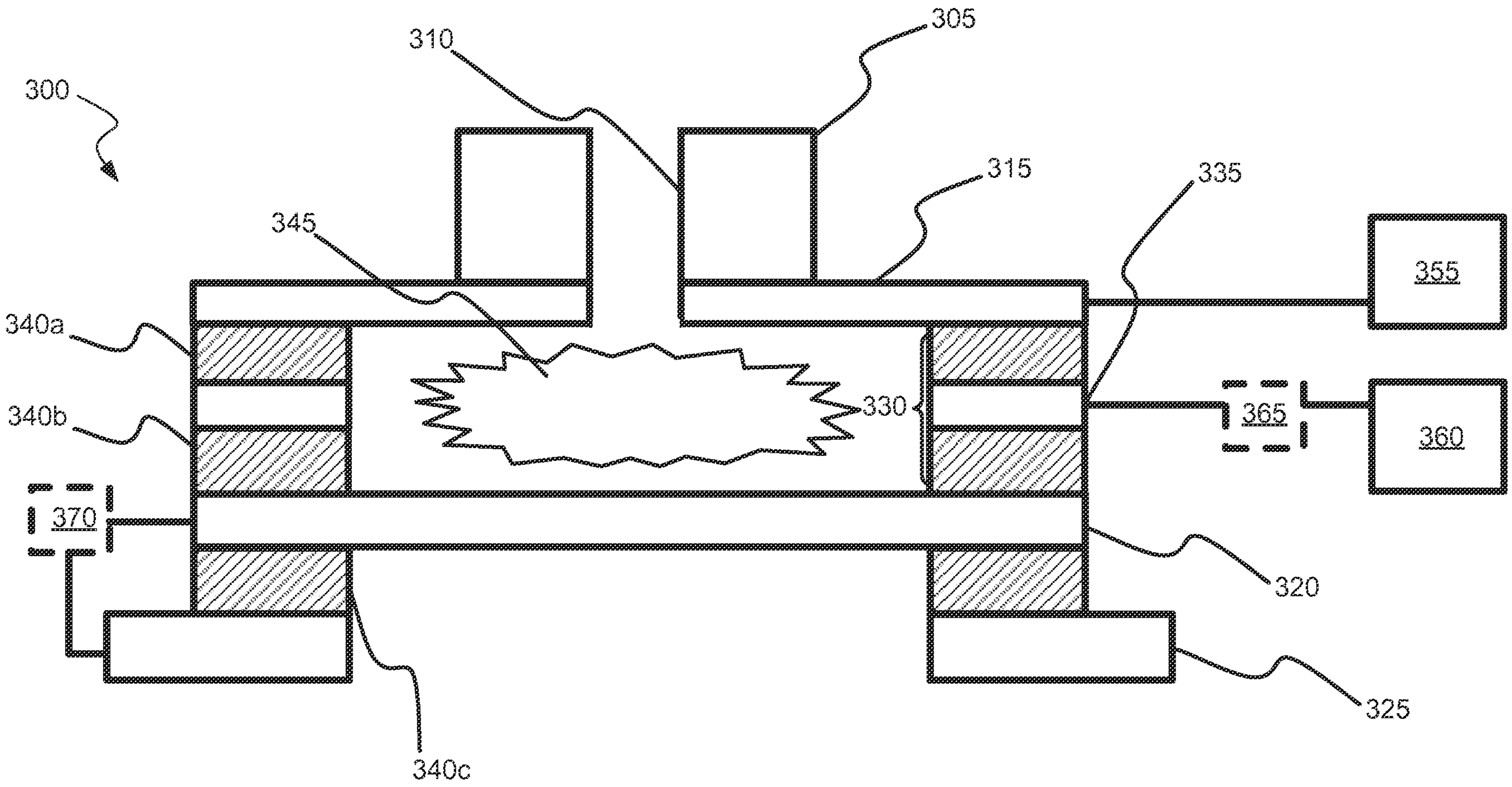
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FIG. 3

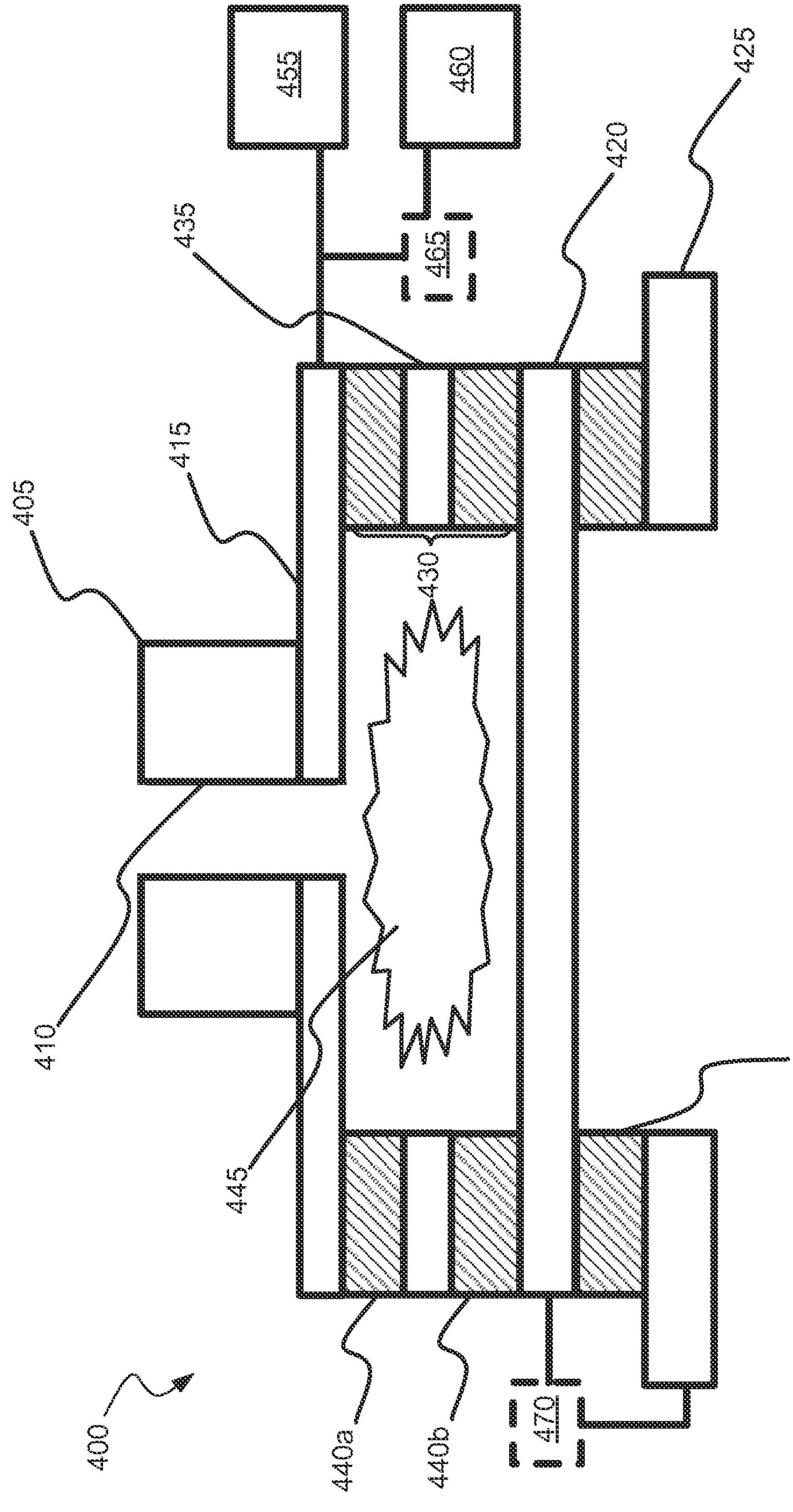
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FIG. 4

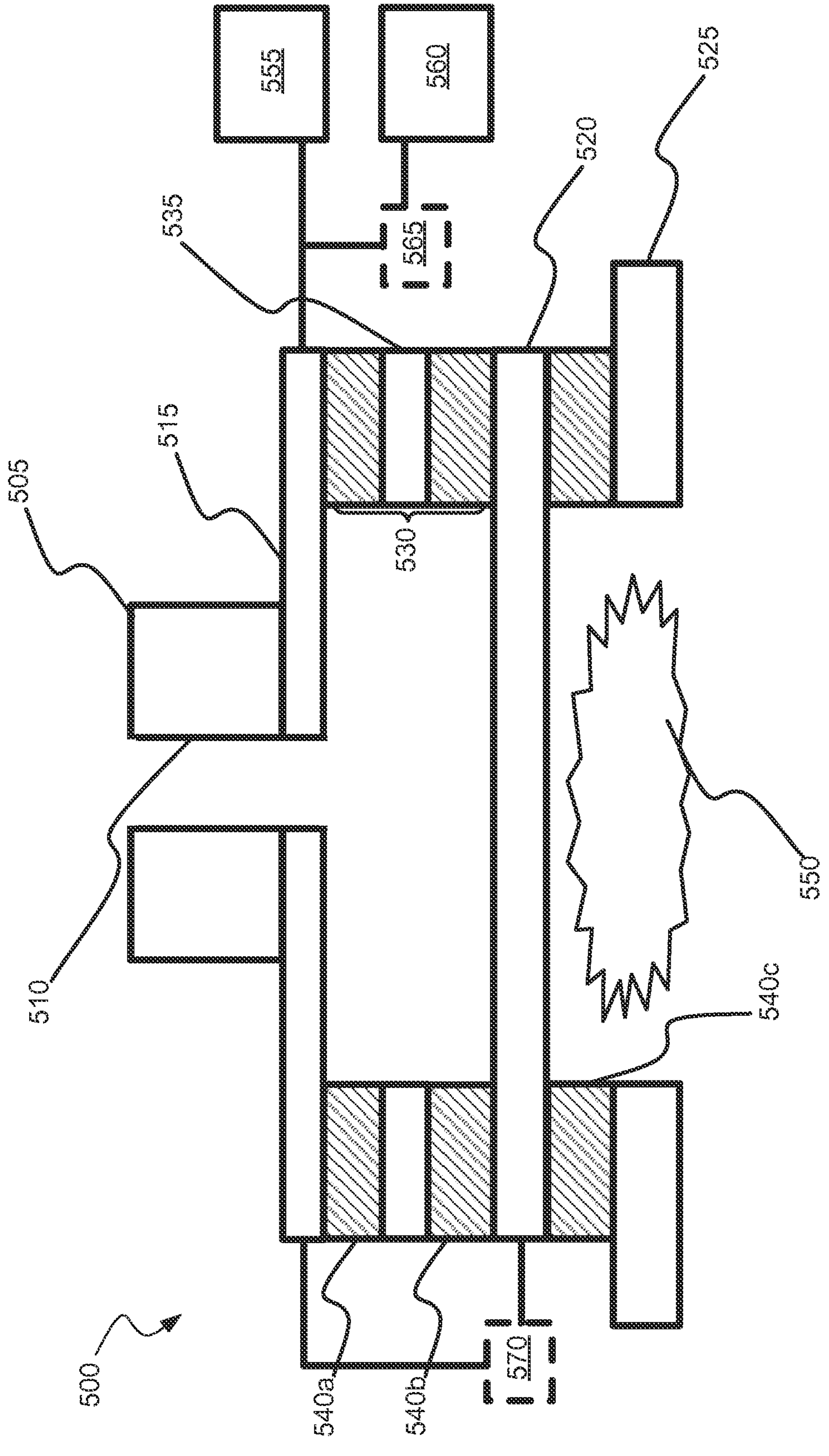
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FIG. 5

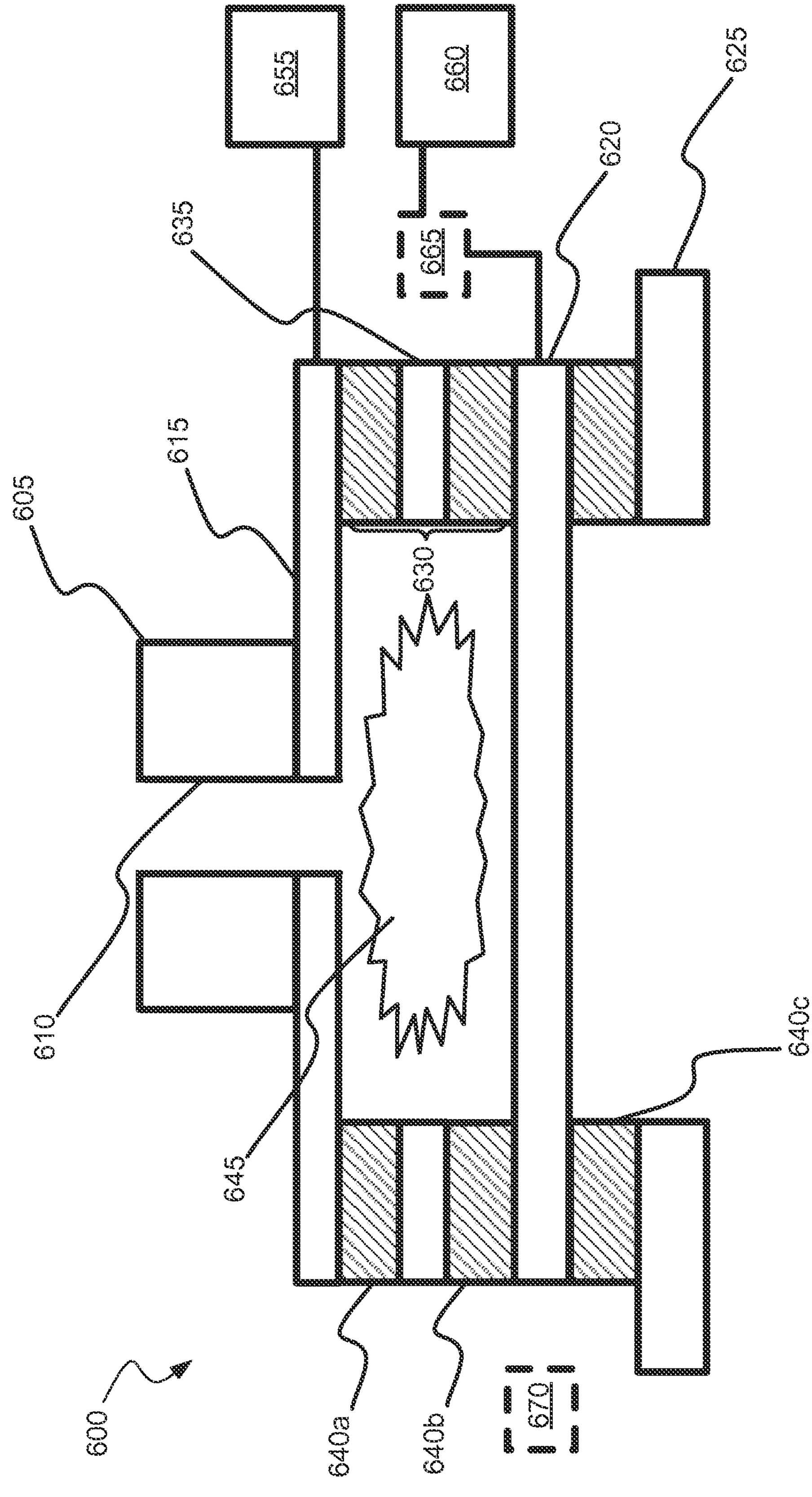
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FIG. 6

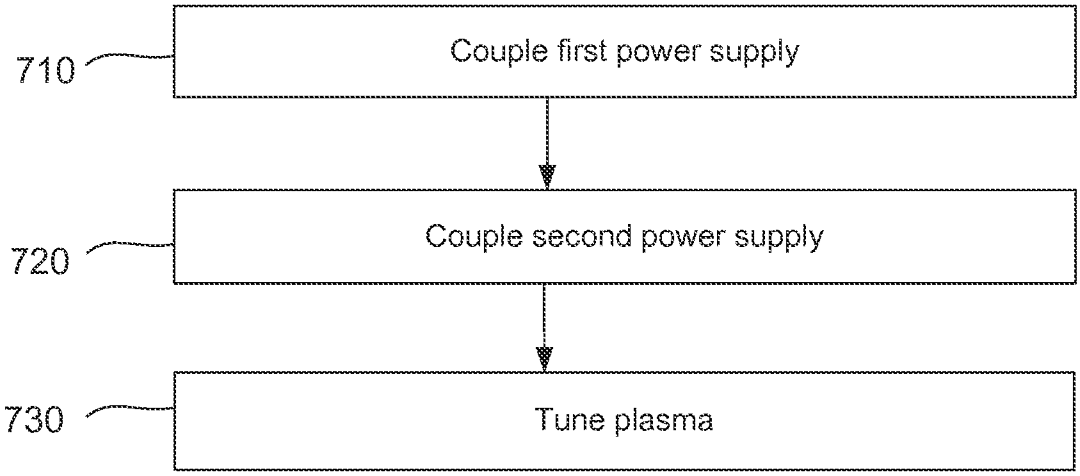
710
Couple first power supply
720
Couple second power supply
730
Tune plasma

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/052039

A. CLASSIFICATION OF SUBJECT MATTER

HOIL 21/3065(2006.01)i, H05H l/30(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
HOIL 21/3065; H05H 1/46; H01L 21/205; H01L 21/18; H05H 1/34; H05H 1/36; H01L 21/00; H05H 1/30

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords:plasma, power, grid, insulation member, tuning, switch.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-2012-0082640 A (RESEARCH & BUSINESS FOUNDATION SUNGKYUNKIAN UNIVERSITY) 24 July 2012 See claims 1, 4-6, paragraphs [0015]-[0025] and figure 1.	1-20
A	KR 10-2008-0063988 A (SAMSUNG ELECTRONICS CO., LTD.) 08 July 2008 See claims 1-3, paragraphs [0026]- [0029] and figures 1-2.	1-20
A	KR 10-2011-0126675 A (APPLIED MATERIALS INC.) 23 November 2011 See claims 1-2, paragraphs [0023]- [0027] and figures 1-3.	1-20
A	KR 10-2000-0008278 A (CHEOL JU HWANG) 07 February 2000 See claims 1, 7-8, and figures 1-4.	1-20
A	KR 10-2005-0042701 A (SAMSUNG ELECTRONICS CO., LTD.) 10 May 2005 See claims 1-2 and figure 3.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 08 November 2013 (08.11.2013)	Date of mailing of the international search report **08 November 2013 (08.11.2013)**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 10-2012-0082640 A	24/07/2012	None	
KR 10-2008-0063988 A	08/07/2008	JP 2008-166822 A	17/07/2008
		US 2008-0156771 A1	03/07/2008
KR 10-2011-0126675 A	23/11/2011	CN 102365906 A	29/02/2012
		JP 2012-518253 A	09/08/2012
		US 2010-0206483 A1	19/08/2010
		WO 2010-094002 A2	19/08/2010
		WO 2010-094002 A3	09/12/2010
KR 10-2000-0008278 A	07/02/2000	None	
KR 10-2005-0042701 A	10/05/2005	CN 1614746 A	11/05/2005
		CN 1614746 C0	01/10/2008
		EP 1530230 A2	11/05/2005
		EP 1530230 A3	07/06/2006
		JP 2005-142568 A	02/06/2005
		JP 4216243 B2	28/01/2009
		US 2005-0093460 A1	05/05/2005