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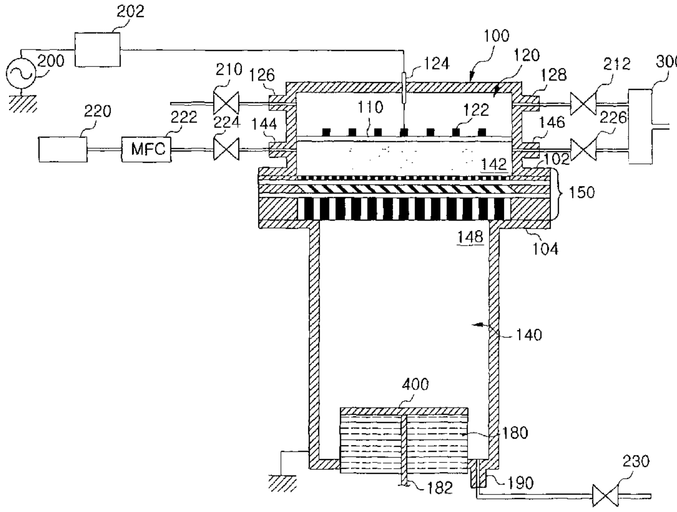
(54) Title: NEUTRAL PARTICLE BEAM PROCESSING APPARATUS WITH ENHANCED CONVERSION PERFORMANCE FROM PLASMA IONS TO NEUTRAL PARTICLES



(57) Abstract: There is provided a neutral particle beam processing apparatus with enhanced conversion performance from plasma ions to neutral particles. More specifically, there is provided a neutral particle beam processing apparatus comprising a high frequency electric power introducing part through which high frequency electric power is supplied, a plasma generating part which transforms gases from a gas injector into plasmas with the high frequency electric power, a neutral particle generating part that converts the obtained plasmas to neutral particles via collisions thereof with a heavy metal plate, and a treating part that treats the surface of a target with the neutral particle beams generated from the neutral particle generating part, wherein inclined slits or inclined holes are formed as beam penetration pathways on the heavy metal plate colliding with the plasmas.

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NEUTRAL PARTICLE BEAM PROCESSING APPARATUS WITH ENHANCED CONVERSION PERFORMANCE FROM PLASMA IONS TO NEUTRAL PARTICLES

Technical Field of the Invention

The present invention relates to a semiconductor manufacturing equipment, more specifically, to an equipment used in the semiconductor manufacturing process to treat surfaces of targets with neutral particle beams.

Background of the Invention

Plasma, which is generated inside a vacuum chamber, is being widely used in unit processes such as dry etching, physical or chemical vapor deposition, sensitizer cleaning, or other surface treatments. In order to generate plasma, there are installed antennas on the upper inside or outside of the plasma chamber and a target holder on the lower portion of the chamber. By supplying high frequency electric power into upper inside space of the chamber through the antennas, a processing gas inside the chamber is dissociated and plasma is generated by glow discharge. When bias voltage applies to the target holder, the generated plasma hits and treats the surface of a target such as wafer.

As semiconductor chips are highly integrated and semiconductor wafers or liquid crystal displays are becoming larger area, required conditions on the apparatus for processing the surface of a target are getting stricter and plasma processing apparatus is under the same situation. Many suggestions have been made to improve the efficiency of the plasma processing apparatus. Such suggestions are focused on increasing the density of plasma in order to reduce the time required for treating a target, and on generating uniformly distributed plasma to treat a target with a larger area. Especially, in terms of increasing the plasma density, an inductively coupled plasma source is widely used. Changing the shape or location of the antenna and changing the location through which a processing gas is supplied are attempted to generate more uniform plasma.

In spite of such efforts, plasma processing methods naturally suffered from that plasma is a charged particle, as thus, super-finely treated target can not be obtained. For instance, use of charged particles for etching often tends to charge the target being etched, which may alter the etch profile, or lead to voltage gradients which may damage the performance of the device formed on the target. Further, the etching reaction by accelerated ions may result in the formation of damaged layers as a result of the dislocation on the surface of a substrate or the formation of deformed surface layers. Therefore, additional treatments such as heat treatment are required to heal such damage.

To overcome such a problem with the plasma processing method, a system using neutral particles instead of the plasma is suggested in US 4,662,977 (Title of the invention: neutral particle surface alteration) issued on May 5, 1987. This system produces neutral particle beams by creating plasmas with plasma gun and directing the plasmas towards an inclined metal plate. Nevertheless, this system is not suitable for treating the surface of a target having 8 inches or more, because of the small cross section of the incident neutral particle beams onto wafers. For the application to the larger target, it is difficult for this system to guarantee the uniformity of the etch profile. Moreover, this system is designed to directly convert atoms or molecules of the active species for etching to plasma, and flux of hyperthermal neutral particle beams from this system is much less than the one from the conventional plasma processing apparatus. Thus, the processing time is very long, thus, not economical.

WO 01/84611 submitted by the present inventors discloses an apparatus for treating surfaces with neutral particle beams comprising a high frequency electric power introducing part, a plasma generating part, a neutral particle generating part and a treating part. In the apparatus, high frequency electric power is introduced through the high frequency electric power introducing part, gases introduced into the plasma generating part are converted to plasmas with the high frequency electric power, the plasmas generated inside the plasma generating part are transformed into neutral particles by collisions of the plasmas with a heavy metal plate, and the neutral particles thus generated are used to treat surfaces of a target. An advantage of the neutral particle beam processing apparatus is a generation of uniform plasma which enables to treat targets with comparatively larger areas. However, there is neither disclosed nor suggested that collisions of the plasmas to the heavy metal plate can be increased by changing the shape of beam penetration pathways to inclined slits or inclined holes. In other words, it was not attempted to introduce a system that improves the conversion performance from plasmas to neutral particle beams by increasing the number of plasma collisions to the heavy metal plate, and thereby improving the efficiency of surface treatment of targets. Moreover, the neutral particle beam processing apparatus has a disadvantage of necessarily requiring one or more deflecting means to change the path of plasmas.

Summary of the Invention

An object of the present invention is to provide a neutral particle beam processing apparatus that makes it possible to increase the number of collisions of plasmas with a heavy metal plate to improve the conversion performance from plasmas to neutral particle beams, thereby improving the efficiency of surface treatment, compared to the apparatus suggested in WO 01/84611.

A secondary object of the present invention is to provide a neutral particle beam processing apparatus that allows optional installation of a deflecting means to change the path of plasma ions.

Another object of the present invention is to provide a neutral particle beam processing apparatus that makes it possible to produce high flux hyperthermal neutral particle beams in a uniformly manner, with larger effective cross section areas, and with high efficiency in order to efficiently treat the surface of a target with the neutral particle beams.

The above objects and others which will be described in the specification could be achieved by providing a neutral particle beam processing apparatus, comprising a high frequency electric power introducing part, a plasma generating part, a neutral particle generating part and a treating part, wherein inclined slits or inclined holes are formed on a heavy metal plate which collides with plasmas.

Brief Description of the Drawings

Figs. 1 to 6 show preferred embodiments of etching apparatus, in accordance with the present invention.

Fig. 7 is an enlarged view of the reflection panel assembly described in Figs. 1 to 3.

Fig. 8 is a schematic view that illustrates the process of producing neutral particle beams on the reflection panel assembly shown on fig. 7.

Fig. 9 is an enlarged view of reflection panel assembly described in Figs. 4 to 6.

Fig. 10 is a schematic view that illustrates the process of producing neutral particle beams on the reflection panel assembly shown on fig. 9.

Detailed Description of the Invention

The present invention relates an apparatus comprising a high frequency electric power introducing part, a plasma generating part, a neutral particle generating part and a treating part, wherein inclined slits or inclined holes as beam penetration pathways are formed on a heavy metal plate that collides with plasmas. More specifically, the present invention relates to an apparatus comprising a high frequency electric power introducing part through which high frequency electric power is supplied, a plasma generating part which transforms gases from a gas injector into plasmas with the high frequency electric power, a neutral particle generating part that converts the obtained plasmas to neutral particles via collisions thereof with a heavy metal plate, and a treating part that treats the surface of a target with the neutral particle beams generated from the neutral particle generating part, wherein inclined slits or inclined holes are formed as beam penetration pathways on the heavy metal plate colliding with the plasmas.

The high frequency electric power introducing part of the neutral particle generating apparatus according to the present invention is comprised of an antenna supporting panel onto which looped or spiral high frequency antennas are installed. These high frequency antennas are connected to a high frequency power supply through a feeding bar so that high frequency power is supplied into the high frequency power introducing part. Further, an impedance matching circuit, which is located between the feeding bar and the high frequency power supply, allows maximum energy to be supplied to the antennas by matching the impedance of the supply with that of the antennas.

The plasma generating part, which plays a role in producing plasmas from gases (or a gas) with the high frequency electric power introduced through the high frequency electric power introducing part, comprises a gas inlet port and a gas outlet port connected to an gas inlet valve and an gas outlet valve which regulate the inner pressure thereof, respectively, The plasma generating part generates plasmas from gases introduced through the gas inlet port with the high frequency power introduced through the high frequency electric power introducing part. The plasma generating part may have several sides of which at least one is defined by the neutral particle generating part. In addition, a bias voltage is applied to at least one side of the plasma generating part to accelerate and direct the generated plasma ions toward the neutral particle generating part. The shape of the plasma generating part is, but not limited thereto, preferably cylindrical. In addition, it is preferable that the ratio of the diameter to the height (diameter/height) is no less than 4.

The neutral particle generating part located below the plasma generating part is equipped with one or more reflecting panels having multiple penetrating holes therein. At least one of these reflecting panels is a heavy metal plate having inclined slits or inclined holes as beam penetrating pathways. As used herein, the term "a heavy metal plate" should be understand as a plate composed of or coated on another plate (including metal or high molecular plate) with a heavy metal whose molecular weight is substantially heavier than that of the gases. Upon colliding with the heavy metal plate, at least some portion of plasma ions are transformed into neutral particles and hyperthermal neutral particles are produced. The number of the reflecting plate used in the neutral particle generating part is, but not limited thereto, preferably 1~5, more preferably 2~5 and most preferably 2~4. At least one of the reflecting panels is the heavy metal plate on which inclined slits or inclined holes are formed. The whole reflecting panel is not necessarily made of the heavy metal. Only the inner wall of the slit or holes is needed to be formed of or coated with a heavy metal. Under the assumption that at least one reflecting panel is a heavy metal plate having inclined slits or holes as beam penetration pathways, the penetrating holes formed on each reflecting panel may be formed in an equal size. But, it is desirable to be formed unequally regarding the function of each of the reflecting plates in the generation of the neutral particles. For instance, in a case that 3 reflecting panels are used, the reflecting panel near the plasma generating part may have vertically shaped holes or slit as beam penetration pathways, the reflecting panel located at a lower part may be a heavy metal plate with inclined slits or holes as beam penetration pathways and the third reflecting panel may have penetration holes with long cylindrical shape having comparatively longer depth than the hole diameter to improve the directionality of the neutral particles. If required, more than 2 reflecting panels may be overlapped. The first reflecting panel plays a role in preventing electrons or lights like ultraviolet ray from passing through the second reflecting panel. Because inclined slits or inclined holes are formed on the panel as beam penetration pathways, The second reflecting panel plays a role in increasing the number of collisions of the plasma ions to the heavy metal plate, which increases the conversion efficiency from plasma ions to neutral particles. Therefore, the efficiency of surface treating of targets can be improved. If required, a first deflecting means may be installed across the neutral particle generating part in order to additionally increase the collision number of the plasma ions to the heavy metal plates. However, since the number of collisions has been sufficiently increased by changing the shape of the holes as beam penetration pathways to the inclined slits or inclined holes, the deflecting means is not needed to be installed.

The neutral particles produced in the neutral particle generating part move down to the treating part through the holes or slits that act as penetration pathways. A target holder to load a target to be treated is installed inside the treating part. This treating part may additionally comprise a gas injection chamber depending to the type of the gas used for surface treatment or the kinds of an additive that needs to be added to the processing gas. A second deflecting means may be required across the treating part in order to deflect the plasma ions that were not transformed into neutral particles to prevent them from reaching the target in the treating part. However, since the efficiency of conversion from plasmas into neutral particles has been sufficiently improved and the probability of the damage of the target by plasma ions is highly decreased, the second deflecting device is needed to be installed.

In the following, the present invention will be more fully described referring to accompanying drawings.

Fig. 1 is a cross sectional view that shows a preferred embodiment of an etching apparatus in accordance with the present invention. The etching apparatus illustrated in Fig.1 is comprised of a cylindrical plasma chamber **100** made of an anodized conductive material such as anodized aluminum or coated internally with a material that is corrosion resistant against oxygen, fluorine or chlorine. According to this embodiment, the chamber **100** is divided into an antenna container **120** and a main container **140** by an antenna-supporting panel **110**. In this example, although the antenna container **120** and the main container **140** are separated by the antenna-supporting panel **110**, they are interconnected to each other by outer vacuum induction units **128**, **212**, **146** and **226**. The antenna-supporting panel **110** is made of a dielectric material such as quartz and alumina. Meanwhile, the main container **140** is divided into a plasma generating part **142** and a treating part **148** by a neutral particle generating part that is comprised of a reflecting panel assembly **150**.

In the antenna container **120**, high frequency antennas **122** having a looped or spiral shape is installed at the upper surface of the antenna-supporting panel **110**. The high frequency antennas **122** are connected to a high frequency power supply **200** through a feed-through **124** positioned across the upper portion of the chamber **100**. The high frequency power supply **200** produces several hundreds kHz to several hundreds MHz of high frequency power and supplies it to the antennas **122** through an impedance matching circuit **202**. The matching circuit **202** makes it possible to supply maximum energy to the antennas **122** by matching the impedance of the power supply **200** with that of the antennas **122**.

Meanwhile, the antenna container **120** comprises a first outlet port **128** at a side wall, and to the first gas outlet port **128**, a first outlet valve **212**, such as needle valve or leak valve, is connected. When the etching apparatus operates, the first outlet valve **212** sucks out an air inside the antenna container **120** and keeps the antenna container **120** to a reduced pressure, for instance, tens or hundreds of mTorr of pressure. As the atmosphere of the antenna container **120** is kept at the reduced pressure, the possibility of plasma production is lower in the antenna container **120** and the deterioration of the antennas by plasma is prevented. In the antenna container **120**, a first gas inlet port **126** to which a first inlet valve **210** is connected is also equipped. The inner pressure of the antenna container **120** is controlled by air supply through the first inlet valve **210** and air exhaust through the first outlet valve **212**. The antenna container **120** can be filled with gases such as oxygen, argon or halogen atoms instead of an air.

The reflecting panel assembly **150** converts plasma ions generated from processing gases with the aid of the electric power supplied into the antennas **122** into neutral particles and supplies neutral particles to the treating part **148**. The reflecting panel assembly **150** is composed of one or more reflecting panels with a number of holes, which will be described below. The reflecting panel assembly **150** is assembled by inserting each of the reflecting panels into flanges **102** and **104** arranged on the upper chamber which defines the antenna container **120** and the plasma generating part **142**, and arranged on the lower chamber housing which defines the lateral side and bottom of the treating part **148**, and by firmly fastened with bolts and nuts.

Preferably, the ratio of the inner diameter to the height of the plasma generating part **142** is to be no less than 4. A second gas inlet port **144** is located at the side wall of the plasma generating part **142**, and a gas supply **220** which supplies the processing gases is connected to the second gas inlet port **144** through a mass flow controller (MFC) **222**. And a second outlet port **146** is located at the side wall of the plasma generating part **142**. A second outlet valve **226** composed of the needle valve or leak valve is connected to the second outlet port **146**. The second outlet valve **226** as well as the first outlet valve **212** is connected through a connection member **300** to a pump and plays a role in regulating the pressure difference between the antenna container **120** and the plasma generating part **142**. Although it is preferable to connect the first outlet valve **212** and the second outlet valve, **226** to a single pump, they can be connected to vacuum pumps each independently.

At the lower portion of the treating part **148**, a target holder **180** is housed having roughly cylindrical or disk shape to load a target **400** such as a wafer. The target holder **180** is supported at the bottom of the chamber **100** by an elevating axis **182** which extends to an elevating device (not shown). Since the target holder **180** can move up and down along the elevating axis **182** by the operation of the elevating device, it can carry in a target **400** such as a wafer to be newly processed and carry out the processed target **400**. A motor (not shown) to rotate the target holder **180** is installed at the lower part of the target holder **180**. As a result, the rotation of the target holder can prevent forming a blind spot caused by local introduction of the neutral particles onto the surface of the wafer, and ensure the neutral particles to be evenly introduced into the whole surface of the target **400**.

A third outlet port **190** is arranged at the bottom or at the side wall of the treating part **148**, which is connected to a third outlet valve **230**. At the beginning of the etching process, the third outlet valve **230** outgases the air of the main container **140** so that it maintains the main container **140** to a vacuum at a pressure of about 1×10^{-6} Torr. In addition, the third outlet valve **230** exhausts effluent gases produced inside main container **140**.

Figs. 7 and 8 show the reflecting panel assembly **150** depicted in Fig. 1 in detail. According to a preferred embodiment of the present invention, the reflecting panel assembly **150** is comprised of three reflecting panels **310**, **320** and **330**. Multiple penetrating holes **312**, **322** and **332** are formed on each reflecting panel. Also, the cooling pipes **314**, **324** and **334** with an O-ring shape are installed on the circumference of each reflecting panel **310**, **320** and **330**. These cooling pipes **314**, **324** and **334** are connected to a temperature controller, which is not shown for clarity. It is possible to remove a heat produced during the generation of neutral particles, and to keep the reflecting panels **310**, **320** and **330** at low temperature by circulating a refrigerant such as water or ethylene glycol through the cooling pipes **314**, **324** and **334**.

Under the assumption that at least one of the reflecting panels **310**, **320** and **330** is a heavy metal plate having inclined holes or slits as beam penetration pathways, these reflecting panels **310**, **320** and **330** may have various forms of penetrating holes, depending on the role of the panels **310**, **320** and **330**. Since the first reflecting panel **310** plays a role mainly in preventing electrons or lights like ultraviolet rays from passing through the second reflecting panel **320**, the plate **310** preferably has vertical holes or slits as beam penetration pathways of which the depth and the size are defined according to the hole or slit sizes of the penetration pathways on the second reflecting panel **320**. Since the second reflecting panel **320** has a function to neutralize the ions produced in the plasma generating part, the panel **320** has inclined holes or inclined slits as beam penetration pathways. The third reflecting panel **330** plays a role in improving the directionality of the neutral particles, it is preferable to have penetrating holes with long cylindrical shape with a longer depth compared to the hole diameter. Meanwhile, at least one of the panels **310, 320** and **330** is connected to the terminal **316** biased to minus in order to attract and direct the plasma ions. As a heavy metal, tantalum (Ta), molybdenum (Mo), tungsten (W), gold (Au), platinum (Pt) or stainless steel may be mentioned, but are not limited thereto. Meanwhile, the reflecting panels that do not directly participate in a neutral particle generation, for example the reflecting plates **310** and **330**, needed not to be made of the heavy metal.

The etching apparatus depicted in Figure 1 operates as follows:

First, the first outlet valve **212** is operated to maintain the antenna container **120** to the reduced pressure, at or around tens or hundreds of millitorr (mTorr). Preferably, the second outlet valve **226** is concurrently operated to prevent the damage of the antenna-supporting panel **110** due to increased pressure difference between the antenna container **120** and the plasma generating part **142**. As a next step, the third outlet valve **230** is operated in order to keep the main container **140** to a vacuum of about 10^{-6} Torr. The processing gases are then supplied into a plasma generating space **142** by manipulating the mass flow controller **222** and the second inlet valve **224**. As a processing gas, fluorine-containing molecules such as argon, oxygen, CFC or PFC, hydrogen peroxide (H_2O_2) or a combination of two or more gases such as argon+oxygen or argon+CFC may be used. When the processing gases are introduced into a plasma generating space **142**, high frequency power is supplied to the antennas **122**, thereby transforming the processing gases into plasmas by glow discharge. In addition, the induced current by the produced plasmas maintains the generation of the plasmas as long as the electric power is supplied into the antennas **122** and the processing gases are supplied from the gas supply **220**. During the plasmas are produced, a bias voltage of from minus tens to minus hundreds of volts are applied to the first reflecting panel **310** and the second reflecting panel **320** of the reflecting plate assembly **150**. The plasma ions, which are positively charged, are directed by the minus bias to the reflecting plate assembly **150** and collide with the second reflecting panel **320**. Since the second reflecting panel **320** is the heavy metal plate, at least some portions of the plasma ions lose a certain amount of energy and pick up electrons from the heavy metal of the second reflecting panel **320** and transform into neutral particles during a collision with the second reflecting panel **320**. In general, it is known that the conversion probability amounts to about 70% and a plasma ion loses about 50% of its energy when an ion collides with a side wall of the penetrating hole of the second reflecting panel **320** (Refer to "Reflection of Plasma Ions from Metals" by John William Cuthbertson issued from The Princeton University in 1991).

As shown in Fig. 8, a plasma ion passed through the first reflecting panel **310** collides with a wall **322a** of an inclined slit or an inclined hole **322** formed in the second reflecting panel **320** and then with the other side wall **322b** again. The positively charged plasma ion is then converted into a neutral particle. The neutral particle reflected from the other side wall **322b** is being a directional neutral particle on the third reflecting panel **330** and enter the treating part **148**. As beam penetration pathways, the first reflecting panel **310** has vertical holes or vertical slits, preferably impressed with minus bias. The plasma ions positively charged are directed to the reflection plate in a perpendicular or almost perpendicular manner by the minus bias impressed to the first reflecting panel **310**, and experience collisions at least once or more in the second reflecting panel **320**. Contrary to the positively charged plasma ions which are always accelerated perpendicularly or near perpendicularly, electrons have their own large kinetic energy so that they are not affected by the minus bias, and therefore, they move down in an isotropic manner. Regardless of the direction of the electrons, the geometrical structure of the first reflecting panel **310** and the second reflecting panel **320** is cooperatively designed so that electrons collide with the first reflecting panel **310** or the second reflecting panel **320** more than once. Therefore, all the electrons that move down are absorbed and extinguished after the collision with the first reflecting panel **310** or the second reflecting panel **320** so that they can not penetrate the second reflecting panel **320** and consequently can not enter the treating part **148**. As a result, only neutral particles enter the third reflecting panel **330**, which is located at the lower end of the second reflecting panel **320**, and there, the neural particles are filtered out so that only the neutral particles with the desired directionality are sent to the treating part **148**.

Regarding that about 70% of the total plasma ions are transformed into neutral particles by a first collision with the side wall **322a** of the second reflecting panel **320** and lose 50% of their energy, and that the plasma ions lose about 60~70% of their energy by a second collision with the other side of wall **322b**, the particle number and energy of neutral particles entered into the treating part **148** can be suitably controlled by adjusting the number of collisions, the biased voltage applied, the angle of inclined slits or holes, and the gap between the slits or holes. Please refer to Figs. 8(b) and 8(c), in which the gap between the inclined slits or holes and the angle of the slits or holes are respectively changed, relatively to Fig. 8(a). The neutral particle beams introduced to a wafer according to the apparatus of the present invention is a hyperthermal neutral particle beam having, on average, a high energy of ~ 10 eV.

As the conversion into the neutral particles takes place, there may be installed in order to increase collisions outside the reflecting assembly **150** a first deflecting means comprised of two magnet units **170** and **172** which imparts a magnetic force to the plasma ions that are not transformed into the neutral particles and deflects the positively charged plasma ions. However, since the positively charged plasma ions enter perpendicularly or almost perpendicularly as a result of the minus bias applied to the reflecting panel and one or more collisions are insured, additional installation of a deflecting means is not required. In addition, since reversed voltage are applied between the minus biased second reflecting panel and the grounded third reflecting panel, the ions which are not transformed into neutral particles can not pass through the second reflecting panel and not reached to the third reflecting panel. Therefore, interference by plasma ions, which are not transformed into neutral particles, can be eliminated, and thus, damage on the target by plasma ions can be prevented without installing a second deflecting means. Furthermore, for the case of operation without impressing minus bias to the second reflecting panel, the amount of ions passing through the second reflecting panel can be reduced by suitable adjusting the gap and the angle between inclined slits or holes formed on the second reflecting panel so that damages on the target by plasma ions can be prevented. For instance, more than about 91% of plasma ions are transformed to neutral particles in a case that two times of collisions are insured, and more than 98% of plasma ions are transformed in a case that 3 or more times of collisions are insured. Such an example is shown in Fig. 2. As shown in Fig 2, by avoiding installing any deflecting means, a neutral particle beam processing apparatus can be simplified and therefore, a more economical neutral particle beam processing apparatus can be offered.

The neutral particles thus generated remove contaminants absorbed or reside as a side product on the target upon collision. Since the neutral particles are not electrically charged ones, they hardly damage the target **400** such as a wafer. During etching progresses, the evaporated effluent gas is exhausted outside through the third outlet port **190** and the third outlet valve **230**.

In a meanwhile, it is well known that the efficiency of the surface treatment is increased by elevating the surface temperature of the target. Therefore, it is preferable to connect a heater to the target holder, which allows raising the temperature of the target surface. As shown in Fig. 3, a gas-supplying chamber **195** may be additionally installed on the side of the main container **140** to maximize etching. The gas-supplying chamber **195** is installed around the main container **140** and is designed to supply active gases or additives to the main container **140** diffusively. A third inlet port **197** is installed on the outside wall of the gas-supplying chamber **195** and A second gas supply **240**, which supplies active gases or additives through a third inlet valve **242**, is connected to the third inlet port **197**. If inactive gases like argon were supplied from the first gas supply **220,** the second gas supply **240** could supply active gases for etching. On the other hand, if the first gas supply **220** supplied active gases, then the second gas supply **240** could supply additives alone or in combination with the active gases. The active gases or active gases and/or additives supplied from the second gas supply **240** chemically react to the material to be etched on the wafer and spontaneously evaporate or are absorbed by the material to be etched.

The above examples are provided for illustrating the present invention, and they should not be construed to limit the scope of the present invention and can be modified as needed. For instance, in the above embodiment, the first reflecting panel **310** was exemplified to be biased negatively to accelerate the plasma ions. However, an ordinary person may apply a plus bias to the whole chamber relative to the first reflecting panel **310**. In this case, since the plasma ions are positively charged ones, they are also accelerated to the first reflecting panel assembly **150**, and there, they are converted into the neutral particles. Once the plasma ions are transformed into neutral particles, they pass through the reflecting panel assembly **150**, and reaches to the target **400** to be treated such as a.wafer.

In addition to the examples referred to above, the reflecting panel assembly **150** can also be modified in various ways. One of such modifications is shown in Fig. 9. As shown in Fig. 9, the first reflecting panel **310** may be a heavy metal plate having inclined slits or inclined holes as beam penetration pathways, by changing the order of the first reflecting panel **310** and the second reflecting panel **320**, compared to the embodiment shown in Fig. 7. Fig. 10 illustrates the generation of neutral particles by the reflecting panel assembly **150** shown in Fig. 9. Plasma ions collide with the first reflecting panel **310** and are converted into neutral particles, electrons or ultraviolet rays, which have passed through the first reflecting panel **310** and extinguished in the second reflecting panel **320**. And directionality of the generated neutral particles is improved while penetrating the third reflecting panel **330** after passing through the second reflecting panel **320**. Figs. 4 to 6 show the etching apparatus comprising of the reflecting panel assembly **150** referred above.

Further, although the above description is focused on the etching apparatus, the apparatus according to the present invention can be also applicable to other semiconductor processing apparatus such as ashing, formation of oxidized film, and cleaning. As used herein, the term "a semiconductor processing" is meant to include various types of processes for forming a semiconductor layer, insulating layer and/or conductive layer on an target, such as the semiconductor wafer or a liquid crystal display, according to a predetermined pattern, enabling the structural bodies to be formed as semiconductor devices or as wiring or electrodes that connect to such devices on subsequent layers of the target. In addition, the neutral particle generating apparatus used for etching with the fluorine-containing gas such as CF_4 or C_2F_2 may also be applicable to ashing of photo-resist (PR etching), in order to perform lithography in semiconductor manufacturing processes with oxygen. More specifically, by anisotropic ashing of the photoresist, the exposure and development processes required for the common photo-lithography processes can be performed simultaneously and therefore simplify the semiconductor manufacturing process.

The processing gas can be also suitably chosen regarding the type of semiconductor manufacturing processes. For etching process, for instance, a fluorine-containing compound such as CF_4 may be a choice as a processing gas, and oxygen can be used as a processing gas for ashing, cleaning and formation of oxidized films. Furthermore, it is also possible to perform surface treatment in combination with the processing gas and the additive gas by additionally installing a gas supplying chamber **195**.

Meanwhile, although antennas **122** having looped or spiral shapes are mentioned for those using high frequencies, antennas wounded around the chamber or other shape of antennas could be also employed. Further, with regard to the type for supplying current to the plasma generating space **142** through the high frequency antenna **122**, a capacitatively coupled type can be applied rather than an inductively coupled type, or mixed type can be also applied. Alternatively, the current can be supplied through waveguide.

Moreover, the antennas could be located inside the chamber at a position facing the target such as semiconductor wafer to be treated. Of course since the antennas according to the preferred embodiment are positioned inside the chamber, the system described can be regarded as one that adopts an internal antenna. In the preferred embodiment, three reflecting panels **310, 320** and **330** are exemplified as a member of the reflecting panel assembly **150**, but are not limited thereto. Preferably, two or more reflecting panels, more preferably, 2~4 reflecting panels are used. In a case that two reflecting panels are used, it is preferable to remove the third reflecting panel such that neutral particles with higher flux is achieved at the cost of lowering the directionality of neutral particles. Conversely, if high directionality is desired, four or more reflecting panels may be used. In other words, as the ratio of the diameter to the depth of the holes formed on the third or more consecutive reflecting panels decreases, the incident angle of the hyperthermal neutral particles to the wafer is closer to perpendicular. However, manufacturing process of the reflecting panel gets more difficult as the diameter-depth ratio gets smaller. Therefore, by taking these issues into account, it is also possible to utilize more than 2 equal reflecting panels in contact with each other, as long as they can be overlapped with their corresponding penetration pathways perfectly aligned. In conclusion, the number of the reflecting panels can be selected regarding the desired incident angel of neutral particles, anisotropic etching requirements and the particle energy.

As mentioned above, the present invention provides a neutral particle beam surface treatment apparatus with enhanced conversion performance of plasma ions to neutral particle beams by increasing the number of collisions of plasma ions with the heavy metal plate, thereby improving the efficiency of surface treatment of targets. Furthermore, the deflecting means that changes the path of the plasma ions could be removed such that the apparatus can be manufactured in a simplified and economic manner. Moreover, because the apparatus according to the present invention treats the surface of targets with neutral particles rather than plasma ions, the possible damages on the target will be reduced to a remarkably low level. Moreover, the apparatus according to the present invention makes it possible to achieve a uniform treatment by uniformly distributed neutral particle beams with the aid of the reflecting panel assembly that forces the plasma ions to be progressed downwards, and the multiple penetrating holes formed on the reflecting panels. Further, it can improve the productivity such that even large wafer can be processed with high speed. In addition, since the plasma ions are accelerated in a step of forming neutral particles, an additional negative bias need not to be applied to the target holder or susceptor, compared to the conventional plasma apparatus.

As described, it should be evident that the present invention can be implemented through a variety of configurations in the aforementioned technical field without affecting, influencing or changing its spirit and scope of the invention. Therefore, it is to be understood that the examples and applications illustrated herein is intended to be in the nature of description rather than of limitation. It should be clear that the scope of the present invention extends far beyond the specific descriptions mentioned above to encompass a far more comprehensive range that will be continually defined by implementation and patent applications that will follow the present invention. Furthermore, the meaning, scope and higher conceptual understandings of the present patent application as well as modifications and variations that arise from thereof should be understood to be extensions to this current application.

Claims

1. A neutral particle beam processing apparatus comprising:

(a) a high frequency power supply introducing part, comprised of an antenna supporting panel by which antennas connected to a high frequency power supply through a RF feed-through are supported;

(b) a plasma generating part which is located below the high frequency power supply introducing part, comprised of an inlet valve and an outlet valve that allow regulation of the inner pressure thereof, a gas inlet port, and a gas outlet port, and which transforms gases introduced through the gas inlet port into plasma ions with high frequency power supplied from the high frequency power supply;

(c) a neutral particle generating part which is located below the plasma generating part, comprised of at least one heavy metal plate, and which transforms the plasma ions generated in the plasma generating part into neutral particles by collisions of the plasma ions with the heavy metal plate; and

(d) a treating part which is located below the neutral particle generator, comprised of a target holder to load a target to be treated with the neutral particles generated in the neutral particle generating part;

wherein, the heavy metal plate has inclined slits or inclined holes as beam penetration pathways.

2. The apparatus as set for in claim 1, further comprising a means for maintaining interior of the high frequency power supply introducing part at a predetermined reduced pressure.

3. The apparatus as set forth in claim 1, wherein the neutral particle generating part comprises two or more reflecting panels including a first reflecting panel located near the plasma generating part and a second reflecting panel located below the first reflecting panel, provided that at least one of the reflecting plates is the heavy metal plates having inclined slits or inclined holes as beam penetration pathways.

4. The apparatus as set forth in claim 1, wherein the neutral particle generating part comprises three reflecting panels in which a first reflecting panel located near the plasma generating part has vertical slits or vertical holes, a second reflecting panel is the heavy metal plates having inclined slits or inclined holes as beam penetration pathways, and a third reflecting panel has long cylindrical holes with a longer hole depth compared to a hole diameter to improve the directionality of the neutral particles.

5. The apparatus as set forth in claim 1, wherein the neutral particle generating part comprises three reflecting panels in which a first reflecting panel located near the plasma generating part is the heavy metal plates having inclined slits or inclined holes as beam

penetration pathways, a second reflecting panel has vertical slits or vertical holes, and a third reflecting has a long cylindrical hole with a longer hole depth compared to a hole diameter to improve the directionality of the neutral particles.

6. The apparatus as set forth in claim 1, wherein a negatively biased voltage is applied to the neutral particle generating part to accelerate the plasma ions generated in the plasma generating part.

7. The apparatus as set forth in claim 1, wherein the heavy metal plate is made of or coated with tantalum, molybdenum, tungsten, gold, platinum and alloy thereof.

8. The apparatus as set forth in claim 1, wherein the heavy metal plate has inclined slits as beam penetration pathways.

9. The apparatus as set forth in claim 1, wherein the heavy metal plate has inclined holes as beam penetration pathways.

10. The apparatus as set forth in claim 1, wherein the interior wall of the apparatus is made of a material that is corrosion resistant against oxygen, fluorine and chlorine gases.

11. The apparatus as set forth in claim 1, wherein the target holder located in the treating part is rotating and vibrates horizontally.

12. The apparatus as set forth in claim 1, wherein a means for heating the target is connected to the target holder to raise the temperature of the target.

13. The apparatus as set forth in claim 1, wherein the neutral particles are entered through a stencil mask in order to perform proximity lithography.

14. The apparatus as set forth in claim 1, further comprising a gas-supplying chamber installed around the target holder in order to supply an addictive gas.

FIG. 1

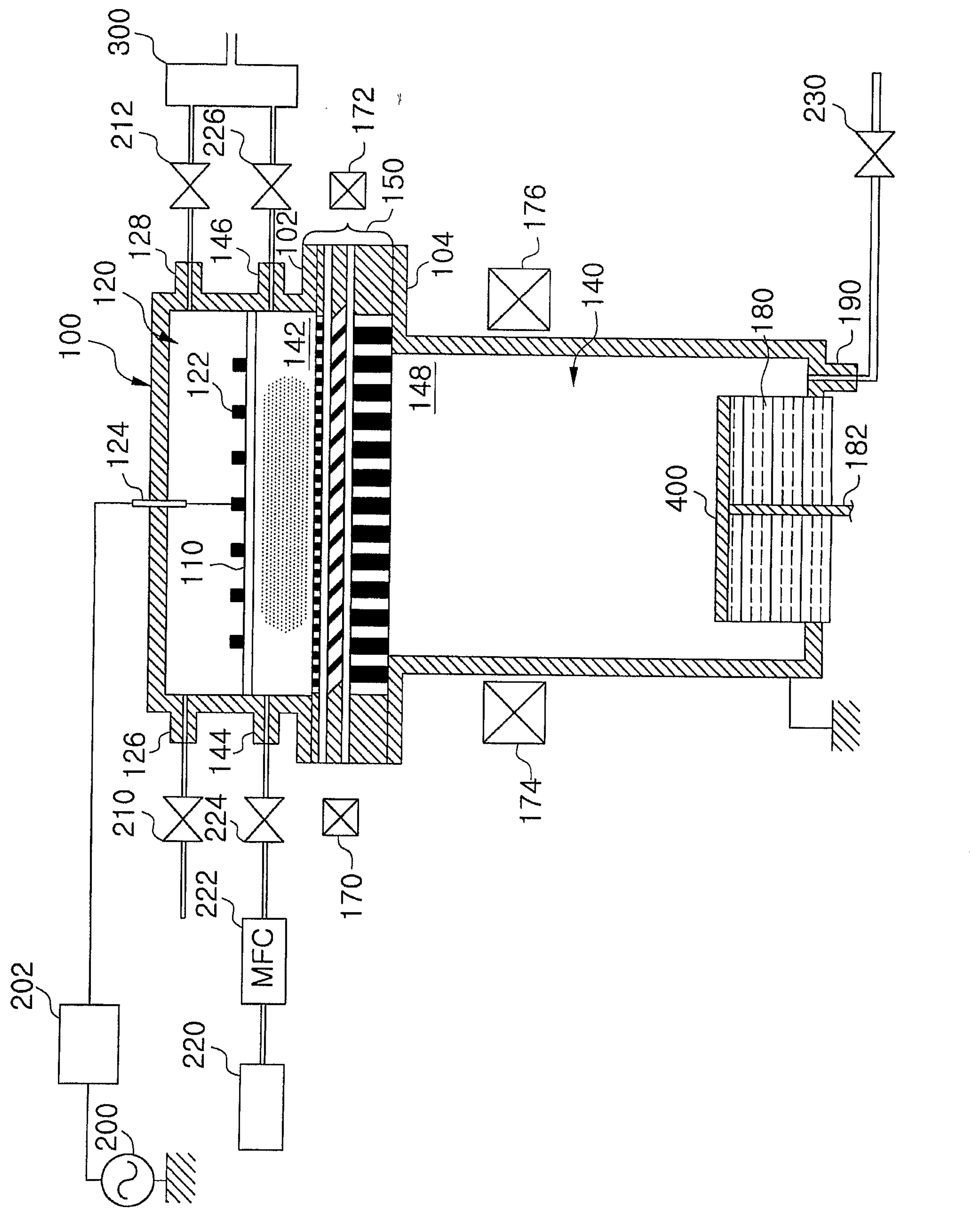
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FIG. 2

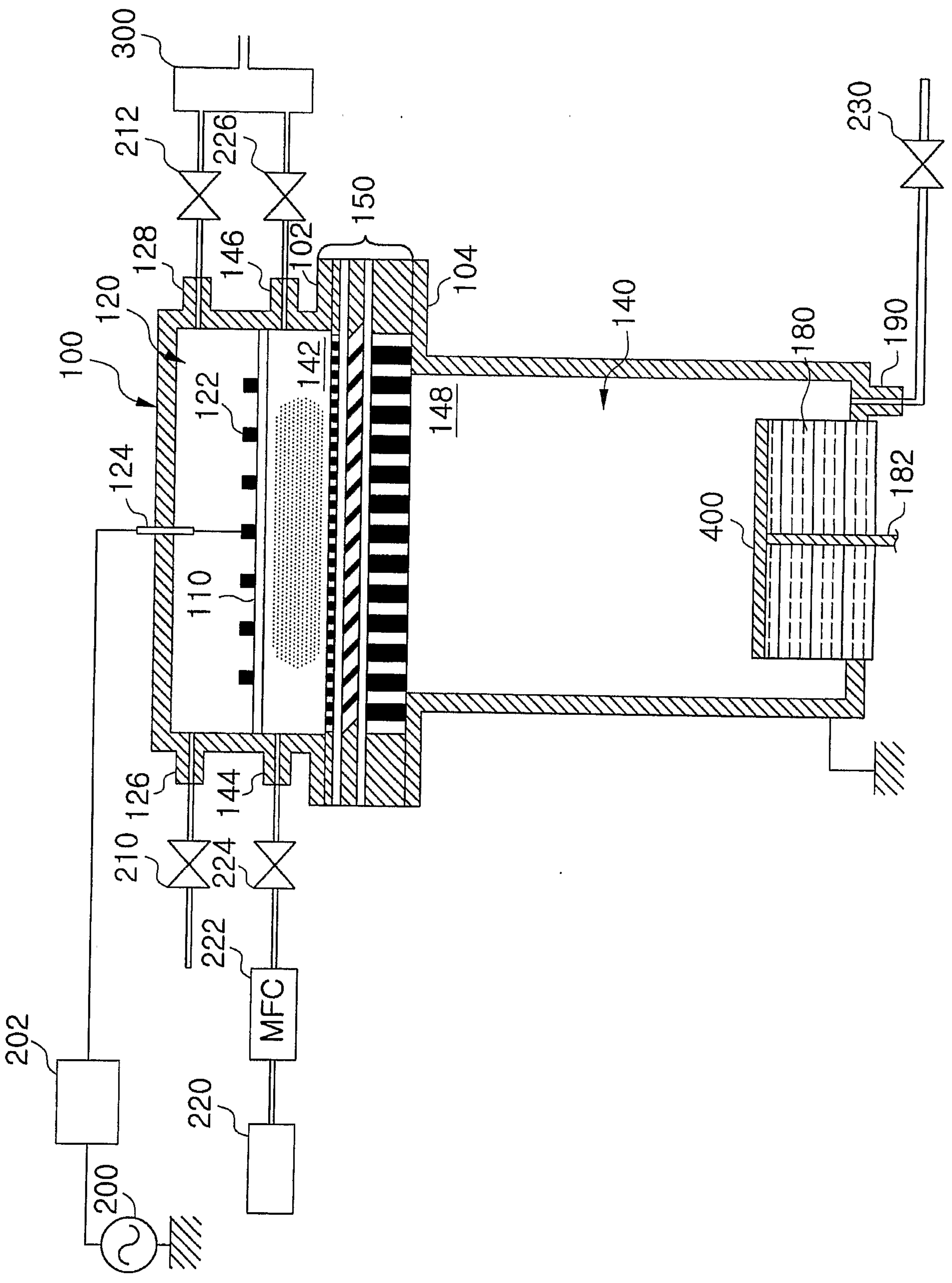
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FIG. 3

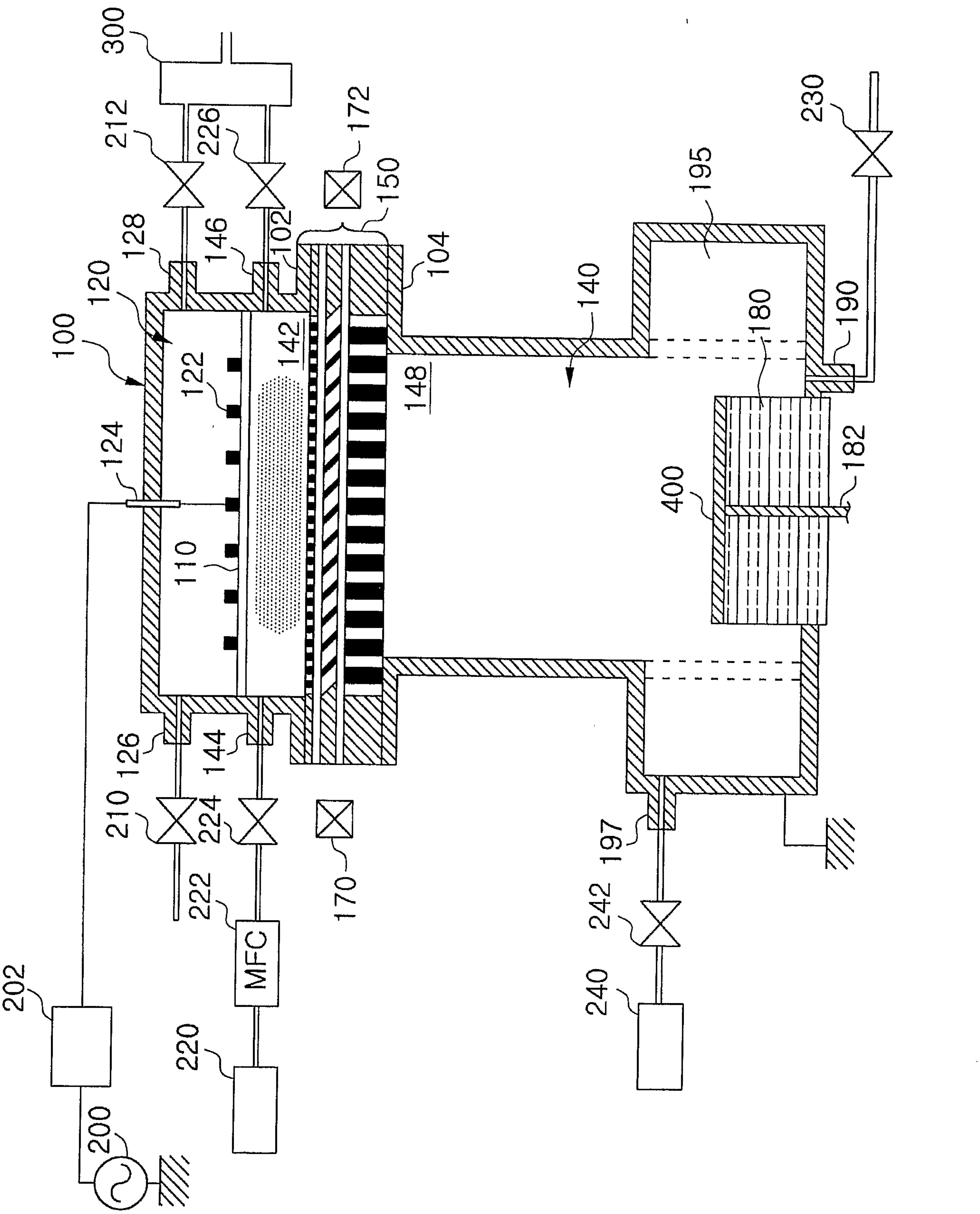
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FIG. 4

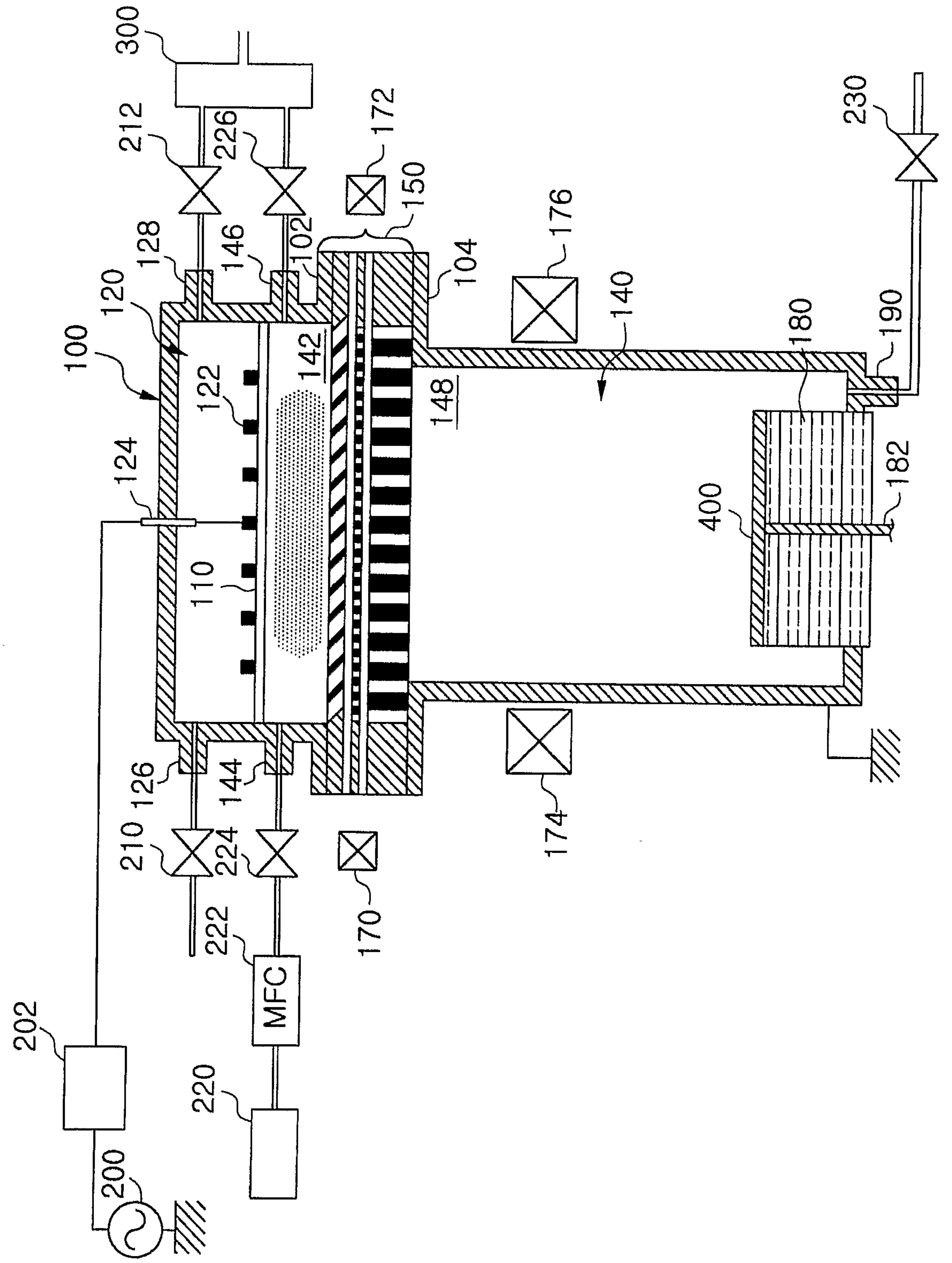
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FIG. 5

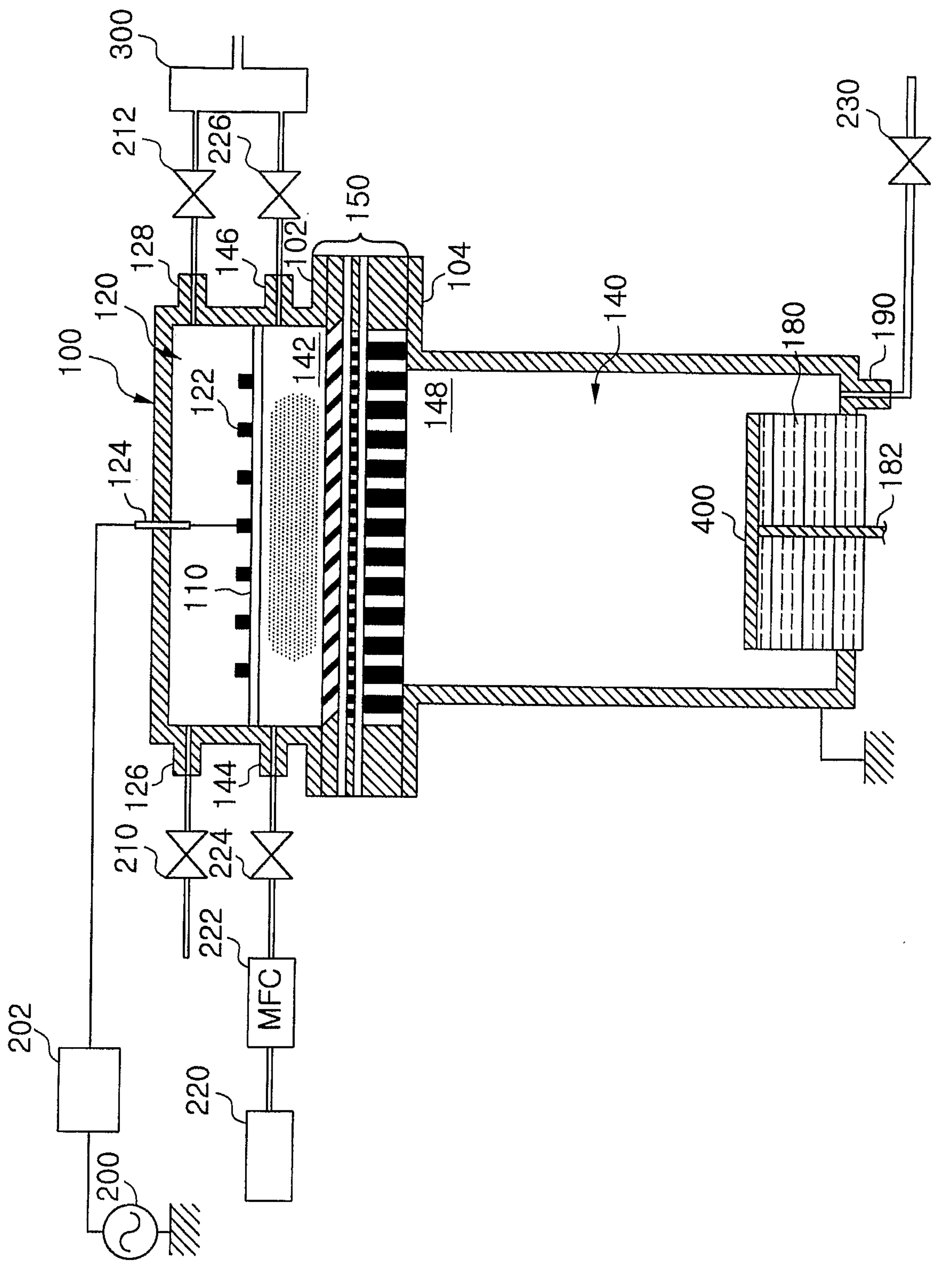
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FIG. 6

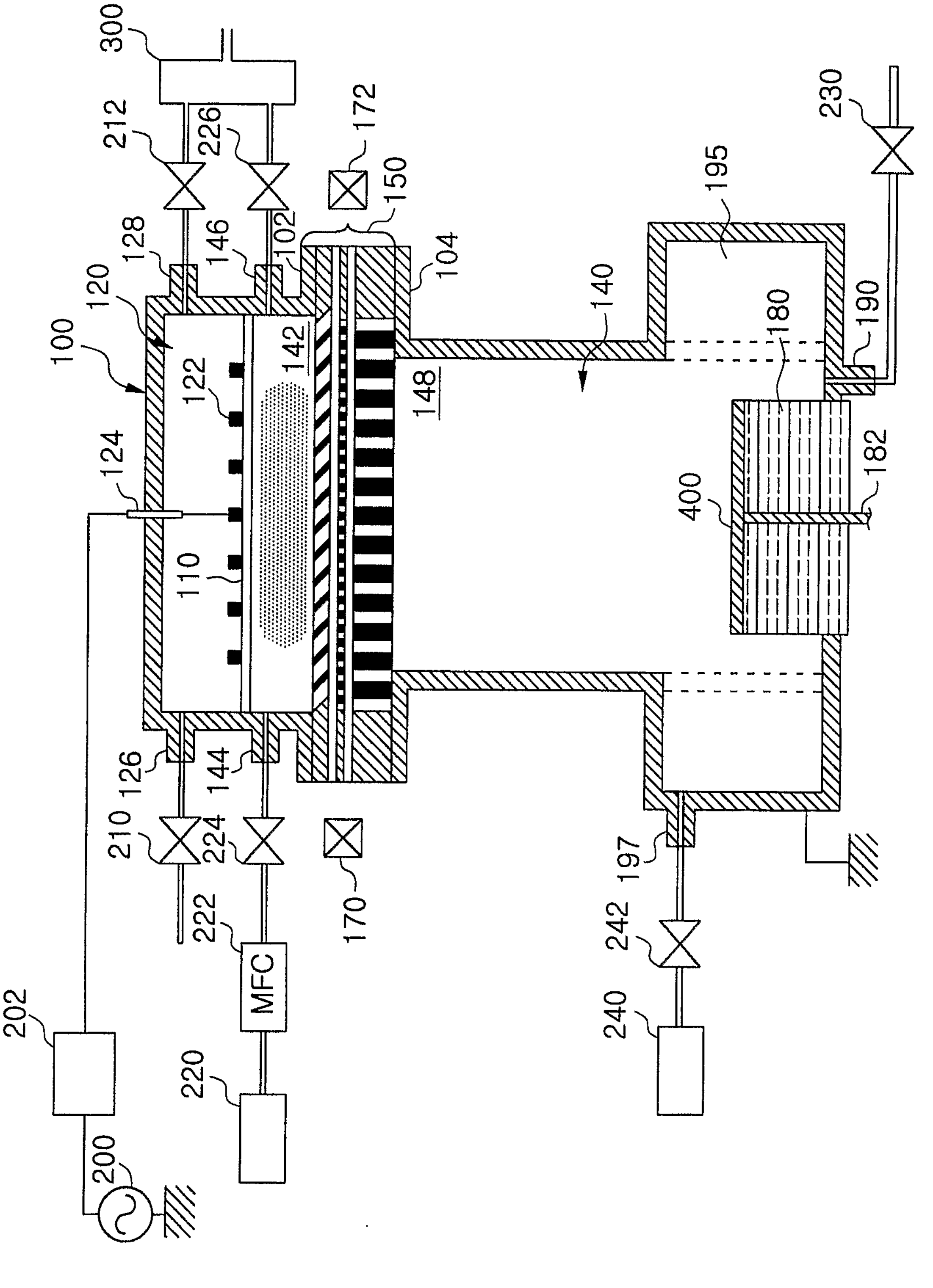
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FIG. 7

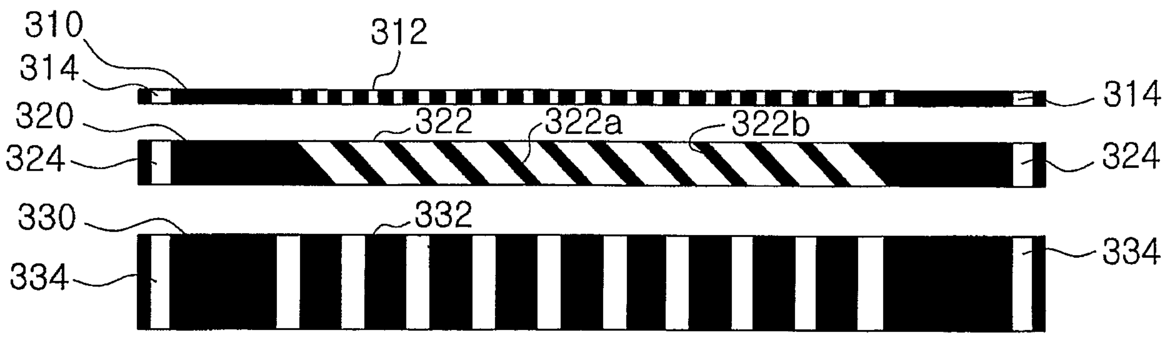
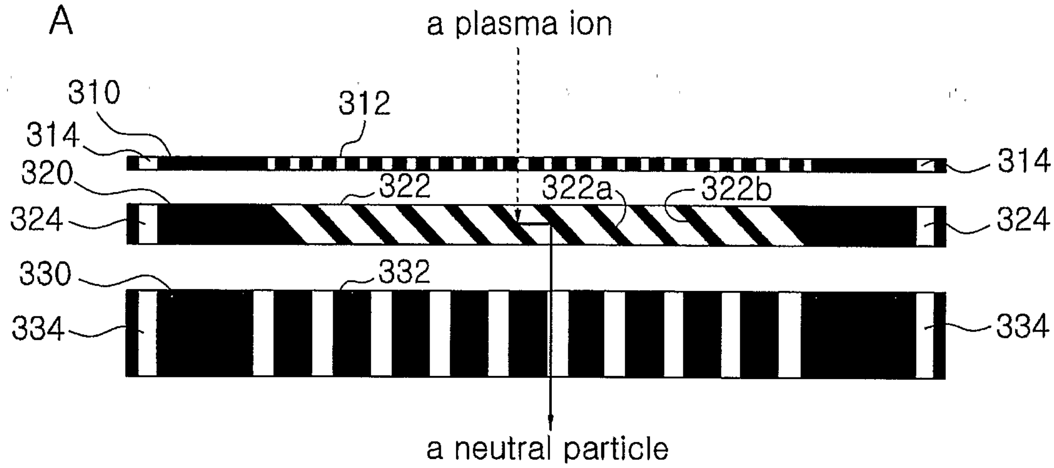


FIG. 8

A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334
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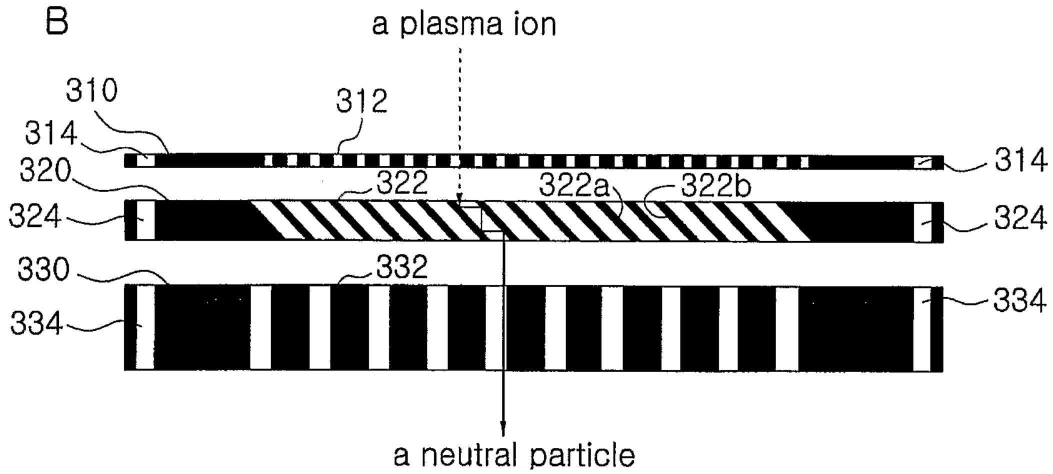
B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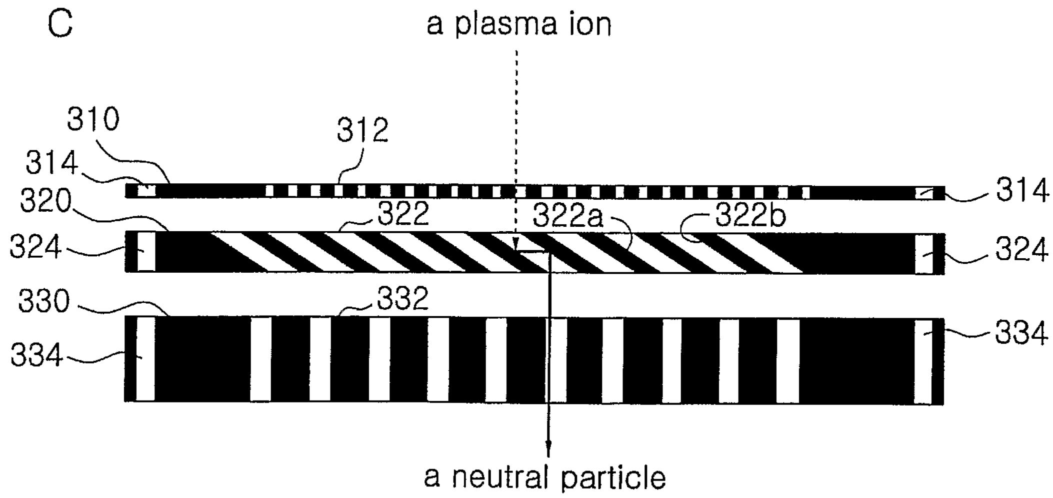
C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a neutral particle

FIG. 9

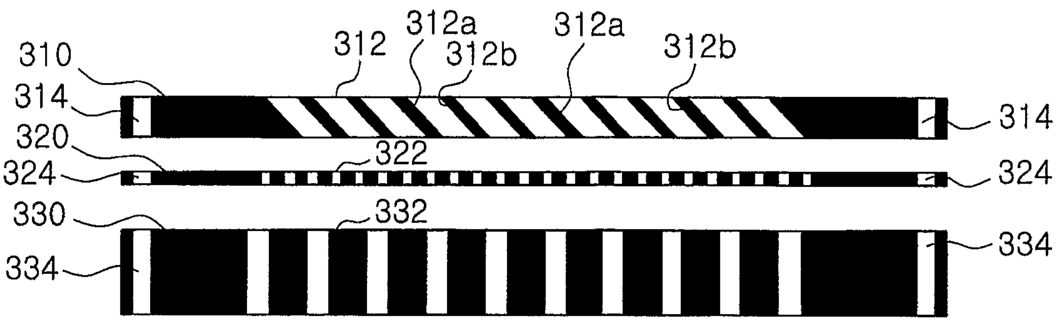
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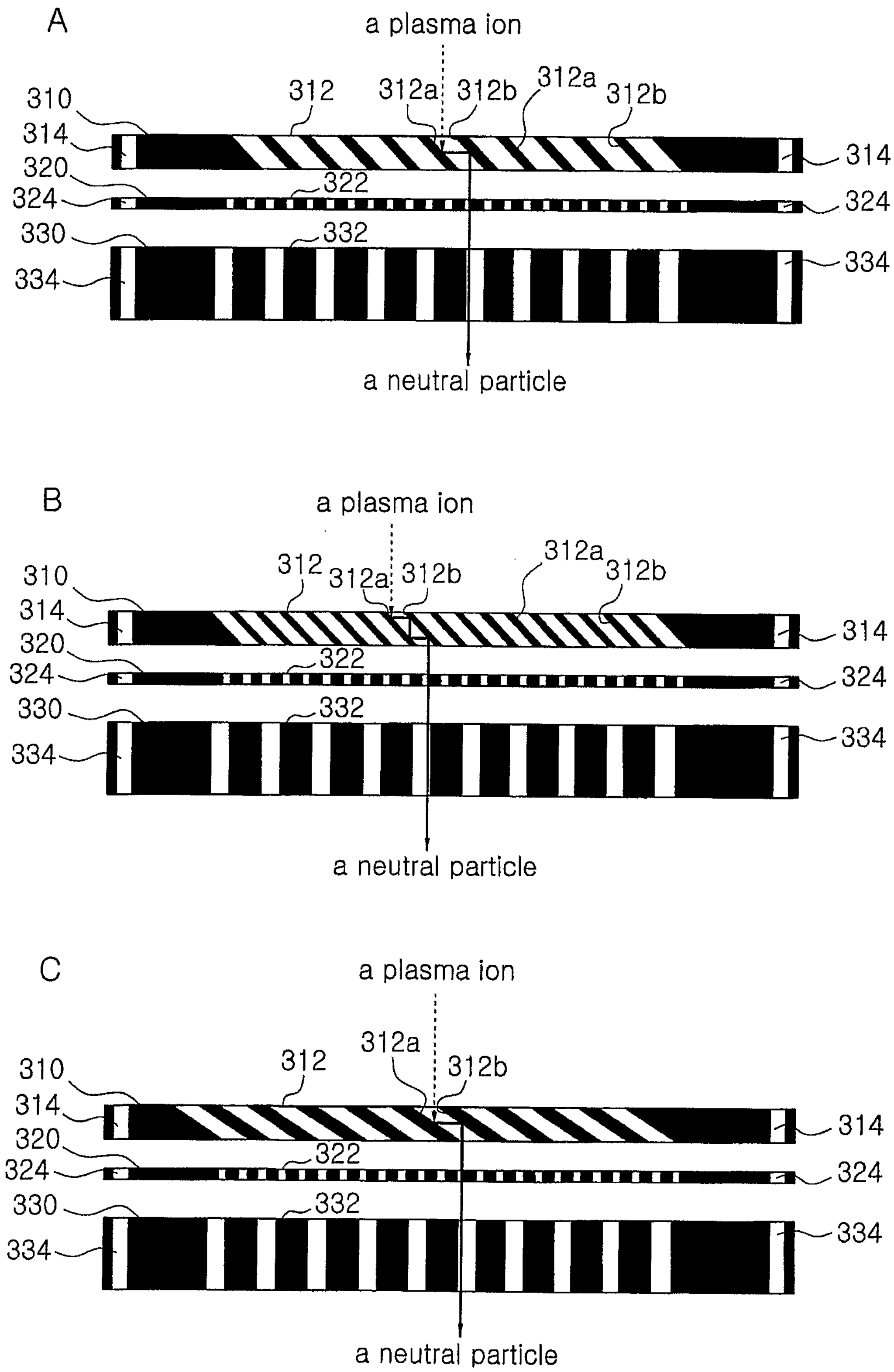
FIG. 10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a neutral particle