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(54) **CHARGE NEUTRALIZATION IN A PLASMA PROCESSING APPARATUS**

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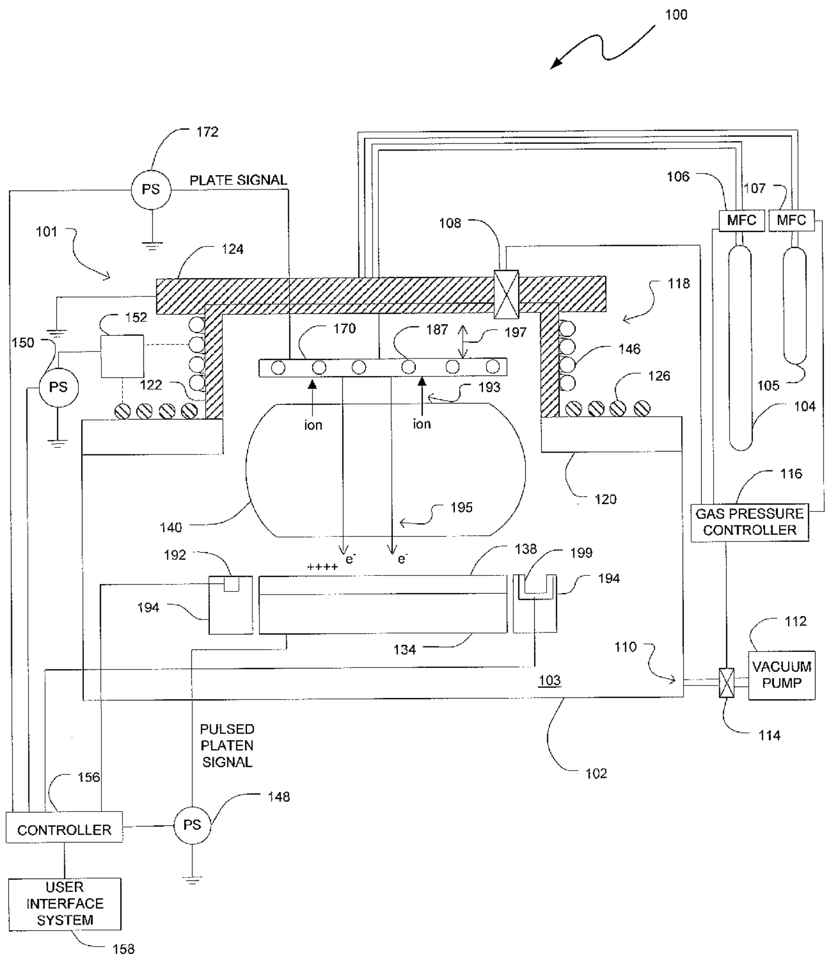
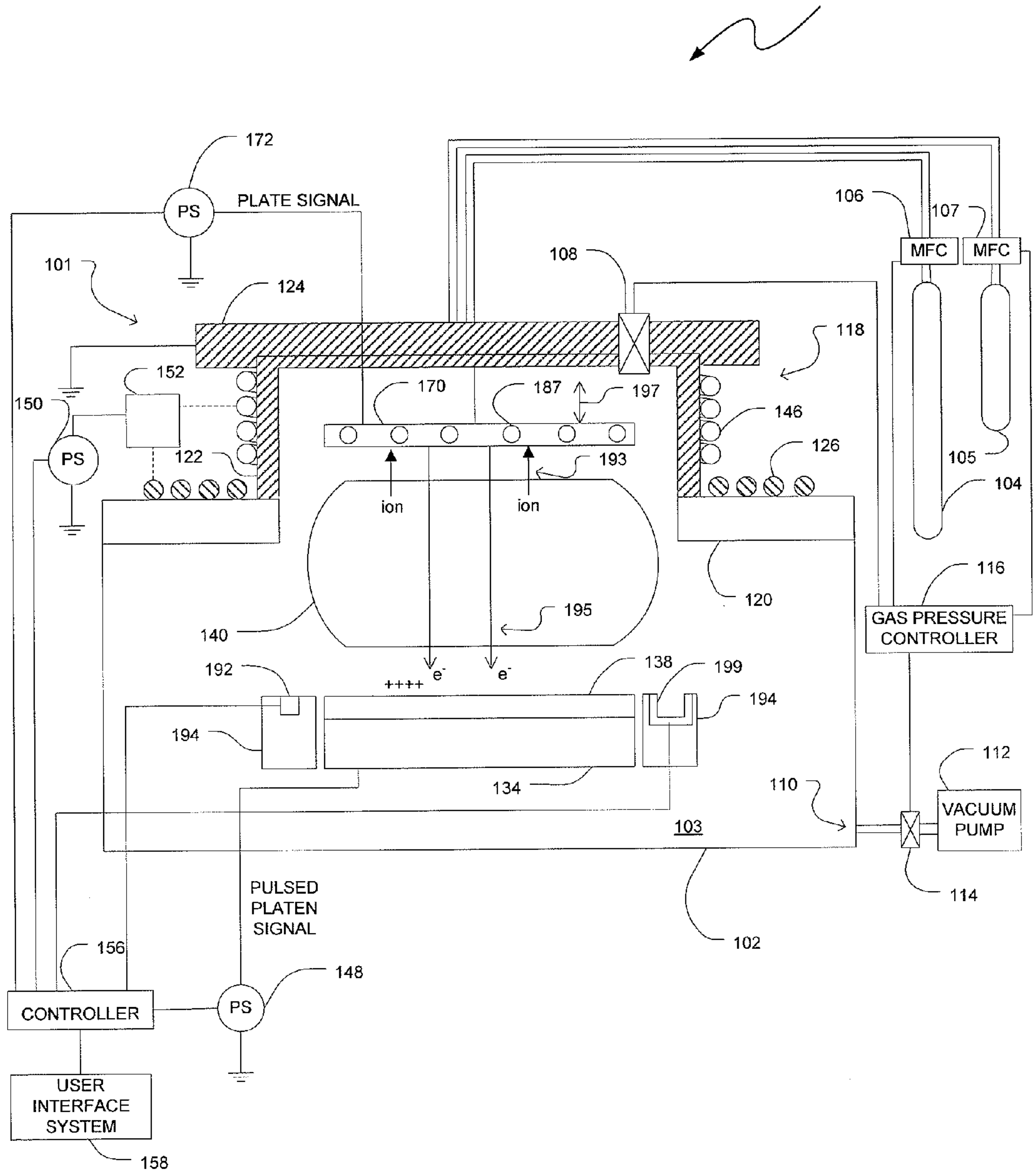
(57) **ABSTRACT**

A plasma processing apparatus includes a process chamber, a source configured to generate a plasma in the process chamber, and a platen configured to support a workpiece in the process chamber. The platen is biased with a pulsed platen signal having pulse ON and OFF time periods to accelerate ions from the plasma towards the workpiece during the pulse ON time periods and not the pulse OFF time periods. A plate is positioned in the process chamber. The plate is biased with a plate signal to accelerate ions from the plasma towards the plate to cause an emission of secondary electrons from the plate during at least a portion of one of the pulse OFF time periods of the pulsed platen signal to at least partially neutralize charge accumulation on the workpiece.

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172
PS
PLATE SIGNAL
106
107
MFC
MFC
101
108
124
118
150
152
170
187
197
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PS
122
193
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105
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ion
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116
GAS PRESSURE
CONTROLLER
120
195
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e⁻
e⁻
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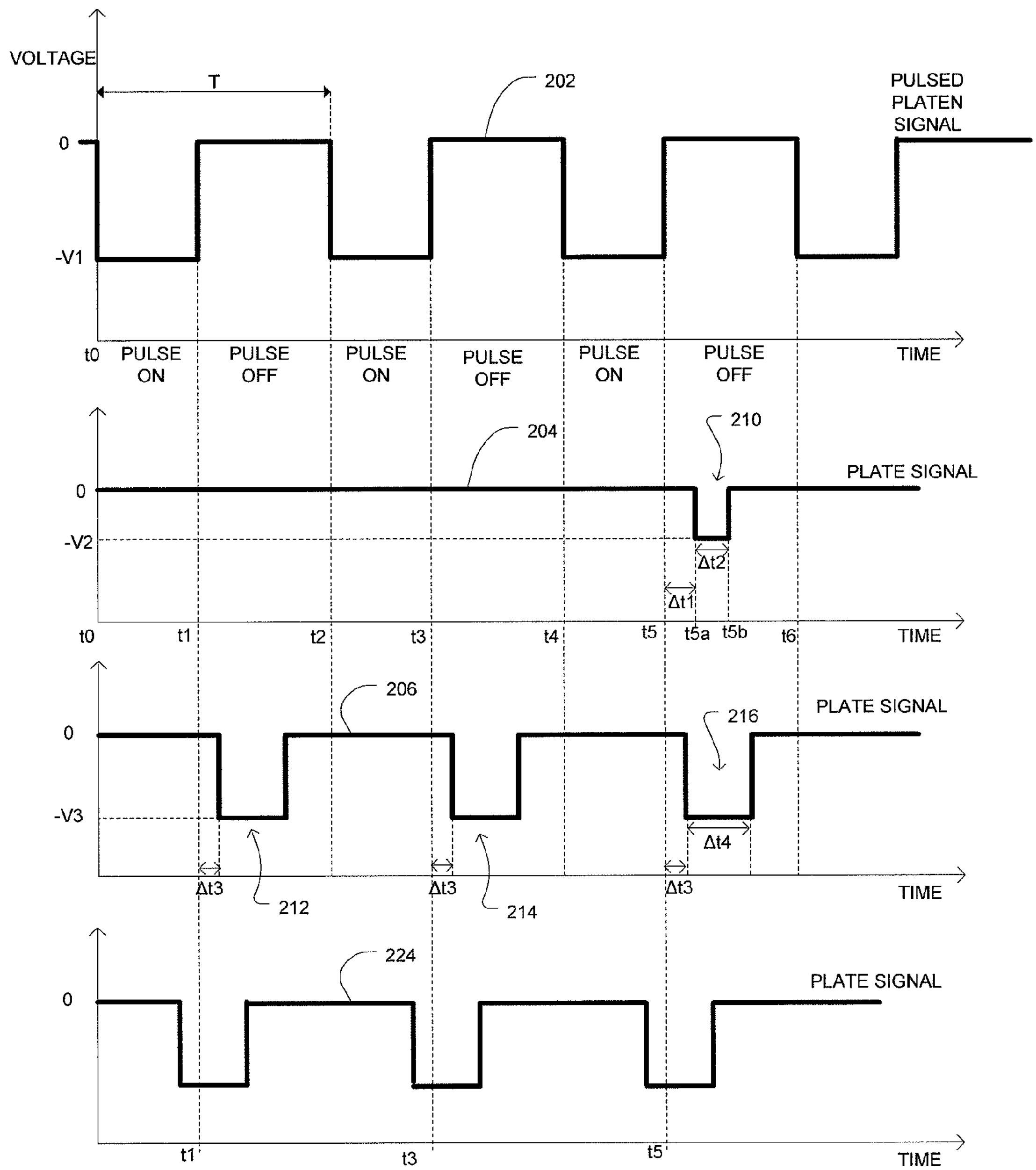
134
112
110
VACUUM
PUMP
103
114
PULSED
PLATEN
SIGNAL
102
156
148
CONTROLLER
PS
USER
INTERFACE
SYSTEM
158

FIG. 1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PULSE ON
PULSE OFF
TIME
204
210
PLATE SIGNAL
0
-V2
Δt2
Δt1
t0
t1
t2
t3
t4
t5
t5a
t5b
t6
TIME
206
PLATE SIGNAL
216
0
-V3
Δt4
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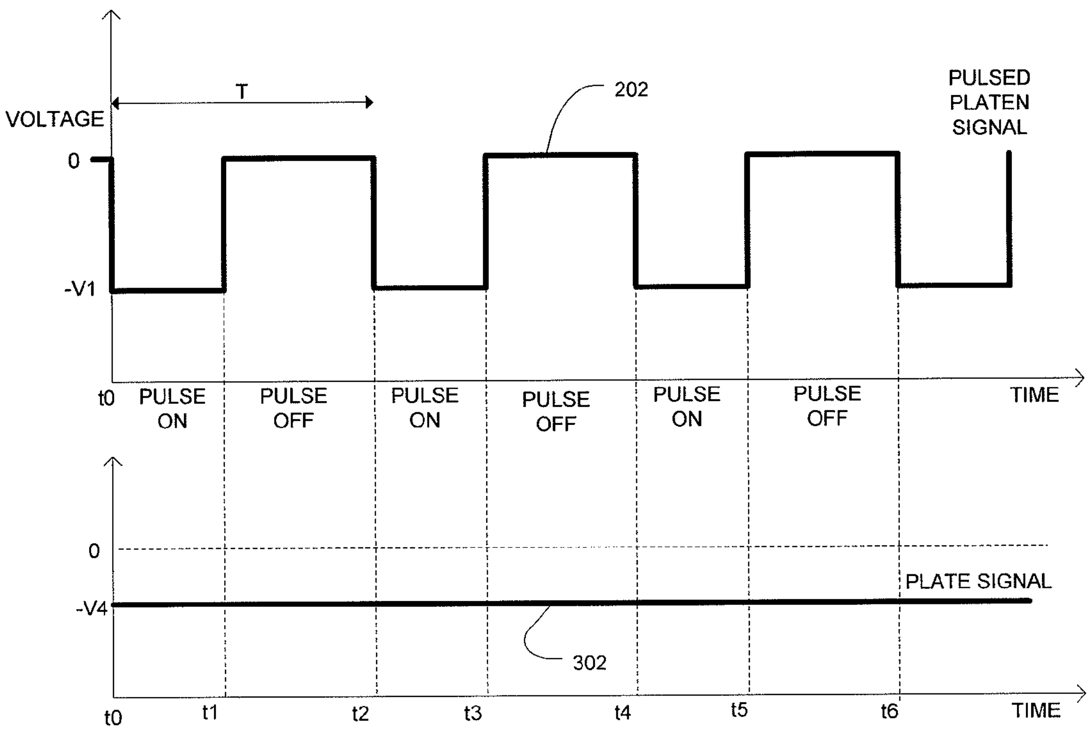
Δt3
212
214
TIME
224
PLATE SIGNAL
0
t1
t3
t5
TIME

FIG. 2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PULSE ON
PULSE OFF
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PLATE SIGNAL
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t2
t3
t4
t5
t6
TIME

FIG. 3

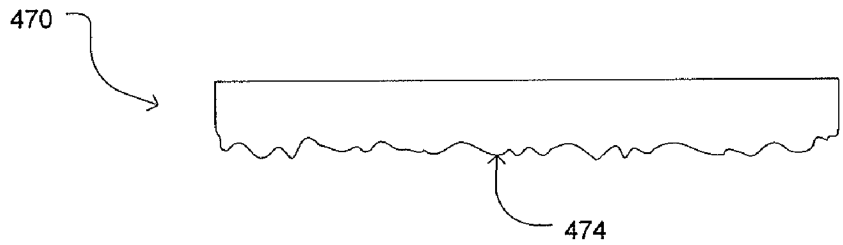

FIG. 4

FIG. 5

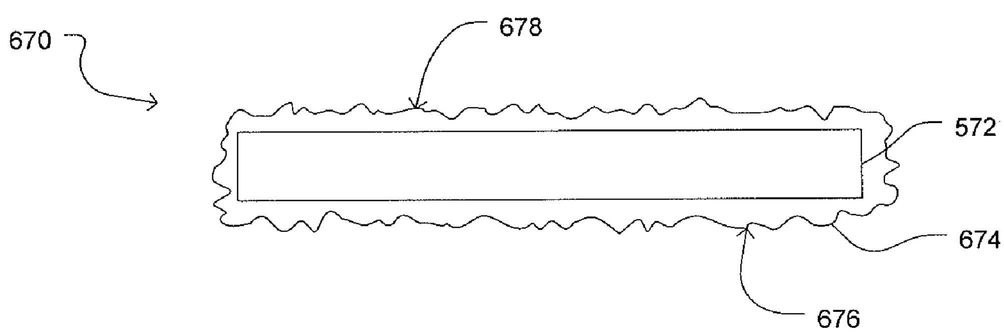

FIG. 6

CHARGE NEUTRALIZATION IN A PLASMA PROCESSING APPARATUS

FIELD

[0001] This disclosure relates to plasma processing, and more particularly to charge neutralization in a plasma processing apparatus.

BACKGROUND

[0002] A plasma processing apparatus generates a plasma in a process chamber for treating a workpiece supported by a platen in the process chamber. A plasma processing apparatus may include, but not be limited to, doping systems, etching systems, and deposition systems. The plasma processing apparatus may have a pulsed mode operation where the platen is biased with a pulsed platen signal having pulse ON and OFF time periods. Ions from the plasma are accelerated towards the workpiece during the pulse ON periods. As the ions strike the workpiece, charge may accumulate on the workpiece during the pulse ON periods.

[0003] In plasma doping systems continually having a plasma, any positive charge accumulation during the pulse ON periods tends to be efficiently neutralized during the pulse OFF periods by electrons in the plasma when the duty cycle of the pulsed platen signal is relatively low. However, there is a need to increase the duty cycle of the pulsed platen signal in order to increase throughput and maintain the doping levels required for some modern devices. For example, it is desirable to perform poly gate doping and counter doping of some state-of-the art devices by plasma doping with a duty cycle greater than 40%.

[0004] As the duty cycle of the pulsed platen signal increases above about 40%, there is a shorter period of time for neutralizing the charge accumulated on the workpiece during the pulse OFF periods. In addition, in plasma systems where plasma is not formed during the pulse OFF periods, there are no electrons to neutralize the charge accumulated. Hence, charge can accumulate in such systems even at relatively lower duty cycles of the pulsed platen signal. Consequently, excessive charge accumulation may occur in either system. This can result in the development of a relatively high potential on the workpiece that can cause doping non-uniformities, arcing, micro-loading, and device damage. For example, thin gate dielectrics can be easily damaged by excess charge build up.

[0005] Accordingly, there is a need to provide techniques for charge neutralization in a plasma processing apparatus which overcomes the above-described inadequacies and shortcomings.

SUMMARY

[0006] According to a first aspect of the disclosure, a plasma processing apparatus is provided. The plasma processing apparatus includes a process chamber, a source configured to generate a plasma in the process chamber, a platen configured to support a workpiece in the process chamber, the platen being biased with a pulsed platen signal having pulse ON and OFF time periods to accelerate ions from the plasma towards the workpiece during the pulse ON time periods and not the pulse OFF time periods, and a plate positioned in the process chamber. The plate is biased with a plate signal to accelerate ions from the plasma towards the plate to cause an emission of secondary electrons from the plate during at least a portion of one of the pulse OFF time periods of the pulsed platen signal to at least partially neutralize charge accumulation on the workpiece.

[0007] According to another aspect of the disclosure, a method of controlling charge accumulation is provided. The method includes accelerating ions from a plasma in a process chamber towards a workpiece supported by a platen within the process chamber during pulse ON periods and not during pulse OFF periods of a pulsed platen signal provided to the platen, and accelerating ions from the plasma towards a plate during at least a portion of one of the pulse OFF periods of the pulsed platen signal to cause emission of secondary electrons from the plate to at least partially neutralize charge accumulation on the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a better understanding of the present disclosure, reference is made to the accompanying drawings, in which like elements are referenced with like numerals, and in which:

[0009] FIG. **1** is a block diagram of a plasma processing apparatus consistent with an embodiment of the disclosure;

[0010] FIG. **2** are plots of a pulsed platen signal and differing plate signals for the plasma processing apparatus of FIG. **1**;

[0011] FIG. **3** is a plot of another plate signal for the plasma processing apparatus of FIG. **1**; and

[0012] FIGS. **4-6** are schematic cross sectional views of differing embodiments of the plate of FIG. **1**.

DETAILED DESCRIPTION

[0013] FIG. **1** is a block diagram of one plasma processing apparatus **100** having charge neutralization consistent with the present invention. In the embodiment of FIG. **1**, the plasma processing apparatus **100** is a plasma doping system and will be described as such herein. The charge neutralization configuration described herein may also be utilized in other plasma processing apparatus including, but not limited to, etching and deposition systems where charge may accumulate on a workpiece. Furthermore, the plasma doping system of FIG. **1** is only one of many possible plasma doping systems that can perform ion implantation with charge neutralization according to the present invention.

[0014] The plasma doping system includes a process chamber **102** defining an enclosed volume **103**. The process chamber **102** may be cooled or heated by a temperature regulation system (not illustrated). A platen **134** may be positioned in the process chamber **102** to support a workpiece **138**. In one instance, the workpiece **138** may be a semiconductor wafer having a disk shape, e.g., a 300 millimeter (mm) diameter silicon wafer in one embodiment. The workpiece **138** may be clamped to a flat surface of the platen **134** by electrostatic or mechanical forces. In one embodiment, the platen **134** may include conductive pins (not shown) for making connection to the workpiece **138**.

[0015] A gas source **104** provides a primary dopant gas to the interior volume **103** of the process chamber **102** through the mass flow controller **106**. There may be a plurality of additional gas sources to provide a plurality of additional gases. In one instance, a secondary gas source **105** may provide a secondary gas to the interior volume **103** of the process chamber **102** through the mass flow controller **107**.

[0016] A plate **170** is positioned in the process chamber **102**. The plate **170** is biased to at least partially neutralize charge accumulation on the workpiece **138** during certain times. The plate **170** may also serve as a gas baffle to deflect the flow of gas from the gas sources **104** and **105**. The plate **170** may also be movable in a direction perpendicular to the platen **134** as indicated by arrow **197**. The plate **170** may have any desired shape and in one instance may have a disk shape. Although illustrated as having planar surfaces, the plate **170** may alternatively have arcuate or other shaped surfaces. Although the plate **170** is illustrated as being positioned directly above the workpiece **138**, the plate **170** may be positioned in differing locations within the process chamber **102**. The plate **170** may also optionally include a temperature regulation system to regulate the temperature of the plate **170**. This may include passages **187** in the plate **170** to circulate fluid. The fluid may be cooling fluid or heating fluid.

[0017] A pressure gauge **108** measures the pressure inside the process chamber **102**. A vacuum pump **112** evacuates exhausts from the process chamber **102** through an exhaust port **110** in the process chamber **102**. An exhaust valve **114** controls the exhaust conductance through the exhaust port **110**.

[0018] The plasma doping system may further includes a gas pressure controller **116** that is electrically connected to the mass flow controllers **106**, **107**, the pressure gauge **108**, and the exhaust valve **114**. The gas pressure controller **116** may be configured to maintain a desired pressure in the process chamber **102** by controlling either the exhaust conductance with the exhaust valve **114** or a process gas flow rate with the mass flow controller **106** in a feedback loop that is responsive to the pressure gauge **108**.

[0019] The process chamber **102** may have a chamber top **118** that includes a first section **120** formed of a dielectric material that extends in a generally horizontal direction. The chamber top **118** also includes a second section **122** formed of a dielectric material that extends a height from the first section **120** in a generally vertical direction. The chamber top **118** further includes a lid **124** formed of an electrically and thermally conductive material that extends across the second section **122** in a horizontal direction. In some embodiments, the lid **124** may include a cooling system in order to dissipate a heat load generated during processing.

[0020] The plasma doping system may further include a source **101** configured to generate a plasma **140** within the process chamber **102**. The source **101** may include a RF source **150** such as a power supply to supply RF power to either one or both of the planar antenna **126** and the helical antenna **146** to generate the plasma **140**. The RF source **150** may be coupled to the antennas **126**, **146** by an impedance matching network **152** that matches the output impedance of the RF source **150** to the impedance of the RF antennas **126**, **146** in order to maximize the power transferred from the RF source **150** to the RF antennas **126**, **146**.

[0021] The plasma doping system may also include a bias power supply **148** electrically coupled to the platen **134**. The bias power supply **148** is configured to provide a pulsed platen signal having pulse ON and OFF time periods to bias the platen **134**, and hence the workpiece **138**, to accelerate ions from the plasma **140** towards the workpiece **138** during the pulse ON time periods and not during the pulse OFF periods. The bias power supply **148** may be a DC or an RF power supply.

[0022] Another bias power supply **172** may be electrically coupled to the plate **170** to provide a plate signal to the plate **170**. The plate **170** is biased with the plate signal to accelerate ions from the plasma **140** towards the plate **170** as indicated by arrows **193**. Advantageously, ions striking the plate **170** cause an emission of secondary electrons (as illustrated by arrows **195**) to at least partially neutralize a positive charge accumulation on the workpiece **138**. Although illustrated as different power supplies, the power supplies **172** and **148**, and even **150** may physically be the same power supply.

[0023] The plasma doping system may further include a charge monitor **192**, a controller **156**, and a user interface system **158**. The charge monitor **192** may monitor charge accumulation or buildup and provide a charge signal representative of the charge accumulation on the workpiece **138** to the controller **156**. The charge monitor **192** may be any type of charge monitor known in the art such as a capacitive type monitor. The charge monitor **192** may be positioned in a shield ring **194** proximate the workpiece **138**. The shield ring **194** is disposed around the platen **134** in the embodiment of FIG. **1**. As is known in the art, the shield ring **194** may be biased to improve the uniformity of implanted ion distribution near the edge of the workpiece **138**. One or more Faraday sensors such as Faraday cup **199** may also be positioned in the shield ring **194** to sense ion beam current. The Faraday sensor may also include an annular Faraday sensor or segmented annular Faraday sensors positioned around the workpiece **138**. The current level sensed by the Faraday sensor during the time when ions are accelerated towards the plate **170** is representative of the rate of secondary electron emission from the plate **170** and may be utilized by the controller **156** to monitor the actual rate of secondary electron emission. The controller **156** may adjust one or more parameters of the plate signal in response thereto to increase or decrease the rate of secondary electron emission.

[0024] The controller **156** can be or include a general-purpose computer or network of general-purpose computers that may be programmed to perform desired input/output functions. The controller **156** can also include other electronic circuitry or components, such as application specific integrated circuits, other hardwired or programmable electronic devices, discrete element circuits, etc. The controller **156** may also include communication devices, data storage devices, and software. For clarity of illustration, the controller **156** is illustrated as providing only an output signal to the power supplies **148**, **150**, **172** and receiving input signals from the charge monitor **192** and the Faraday cup **199**. Those skilled in the art will recognize that the controller **156** may provide output signals to other components of the plasma doping system and receive input signals from the same. The user interface system **158** may include devices such as touch screens, keyboards, user pointing devices, displays, printers, etc. to allow a user to input commands and/or data and/or to monitor the plasma doping system via the controller **156**.

[0025] In operation, the gas source **104** supplies a primary dopant gas containing a desired dopant for implantation into the workpiece **138**. Examples of primary dopant gas include, but are not limited to, BF_3, BI_3, N_2, Ar, PH_3, AsH_3, B_2H_6, H_2, Xe, Kr, Ne, He, SiH_4, SiF_4, GeH_4, GeF_4, CH_4, CF_4, AsF_5, PF_3, and PF_5. The gas pressure controller **116** regulates the rate at which the primary dopant gas is supplied to the process chamber **102**. The source **101** is configured to generate the plasma **140** within the process chamber **102**. The source **101** may be controlled by the controller **156**. To generate the plasma **140**, the RF source **150** resonates RF currents in at least one of the RF antennas **126**, **146** to produce an oscillating magnetic field. The oscillating magnetic field induces RF currents into the process chamber **102**. The RF currents in the process chamber **102** excite and ionize the primary dopant gas to generate the plasma **140**.

[0026] The secondary gas source **105** may also supply a secondary gas to the process chamber **102**. The secondary gas may be an inert gas to have minimal effect on the doping process. The secondary gas may be a heavier gas than the primary dopant gas. In addition, the quantity of secondary gas provided may be relatively small compared to the quantity of primary dopant gas provided. The secondary gas may be selected to alter the emission of secondary electrons from the plate **170**. For instance, some secondary gases may promote a greater amount of secondary electron emission with all other parameters being equal.

[0027] The bias power supply **148** provides a pulsed platen signal to bias the platen **134** and hence the workpiece **138** to accelerate ions from the plasma **140** towards the workpiece **138** during the pulse ON periods of the pulsed platen signal and not during the pulse OFF periods. The ions may be positively charged ions and hence the pulse ON periods of the pulsed platen signal may be negative voltage pulses with respect to the process chamber **102** to attract the positively charged ions. The frequency of the pulsed platen signal and/or the duty cycle of the pulses may be selected to provide a desired dose rate. The amplitude of the pulsed platen signal may be selected to provide a desired energy. Depending on the type of processing conditions, e.g., such as with relatively high duty cycles of the pulsed platen signal, excess charge can accumulate on the workpiece **138**. An excess charge accumulation can result in the development of a relatively high potential on the workpiece **138** that can causing doping non-uniformities, arcing, micro-loading, and device damage.

[0028] Another bias power supply **172** provides a plate signal to bias the plate **170** to accelerate ions from the plasma **140** towards the plate **170** as illustrated by arrows **193**. Ions striking the plate **170** cause an emission of secondary electrons as illustrated by arrows **195** to at least partially neutralize a positive charge accumulation on the workpiece **138**. The emission of the secondary electrons from the plate **170** occurs during at least a portion of one of the pulse OFF time periods of the pulsed platen signal. An ancillary benefit of ions striking the plate **170** is that it tends to minimize the formation of a deposition layer on the plate **170**. Therefore, maintenance frequency for the plate **170** can be reduced compared to a plate that is not struck by ions. In addition, better particle performance and process control can be achieved compared to a plate that is not struck by ions.

[0029] Turning to FIG. **2**, a plot of an exemplary pulsed platen signal **202** is illustrated. In this instance, the pulsed platen signal **202** is a pulsed DC signal having a period T defining a frequency. A typical frequency may range between 100 Hz and 10 kHz. The pulsed platen signal **202** has alternating pulse ON and OFF time periods. For example, pulse ON time periods occur between time t**0** and t**1**, t**2** and t**3**, and so on, while pulse OFF time periods occur between times t**1** and t**2**, t**3** and t**4**, and so on. The duty cycle of the pulsed platen signal **202** is given by a ratio of the pulse ON time period to the period T. Therefore, a higher duty cycle results in shorter pulse OFF time periods. The pulsed platen signal **202** has a negative amplitude (−V**1**) with respect to the process chamber **102** during the pulse ON time periods to accelerate positive ions from the plasma **140** towards the workpiece **138**. During the pulse ON time periods, excess charge may accumulate on the workpiece **138**.

[0030] Differing parameters of the plate signal to bias the plate **170** can be varied to vary the quantity of secondary electron emission from the plate **170**. These parameters may include voltage amplitude, pulse width, quantity of pulses, etc. In general, increasing the voltage amplitude would increase the yield of secondary electrons. Increasing the pulse width and the quantity of pulses would also generally increase the yield of secondary electrons with all other parameters being equal.

[0031] Several differing plate signals are illustrated in FIG. **2** to further illustrate how varying parameters of the plate signal can vary secondary electron emission from the plate **170**. A first exemplary plate signal **204** is illustrated on a time axis coincident with the pulsed platen signal **202**. As shown, the plate signal **204** is a pulsed DC signal that has a pulse ON time period **210** during a portion of one pulse OFF time period of the pulsed platen signal **202**, e.g., in this instance during the pulse OFF time period between times t**5** and t**6**. Although illustrated as a pulsed DC signal, those skilled in the art will recognize that the plate signal **204** may also be a pulsed RF signal. During the pulse ON time period **210**, ions from the plasma **140** are accelerated towards the plate **170** to cause emission of secondary electrons. The pulse ON time period **210** has a start time (t**5***a*) and stop time (t**5***b*) defining a pulse width (Δt**2**). The start time (t**5***a*) may be synchronized to start within a particular time interval (Δt**1**) of the end of the previous pulse ON time interval of the pulsed platen signal **202**. In one embodiment, this particular time interval (Δt**1**) may be 0.1 microseconds. The start time (t**5***a*) may also be coincident with the end of the previous pulse ON time interval of the pulsed platen signal **202**. The number of pulse ON time periods, including the start time (t**5***a*), stop time (t**5***b*), and pulse width (Δt**2**) of each pulse ON period may be selected to provide a desired amount of secondary electron emission from the plate **170**. Such parameters may be adjusted in response to an expected charge accumulation for a particular process on the workpiece **138** or a measured condition representative of actual charge accumulation.

[0032] A second exemplary plate signal **206** is also illustrated in FIG. **2**. Similarly to the first plate signal **204**, the second plate signal **206** is also a pulsed DC signal. Compared to the first pulsed plate signal **204**, the second pulsed plate signal **206** is configured to bias the plate **170** to accelerate ions towards the plate during each pulse OFF time period of the pulsed platen signal **202**. For example, the first pulse ON period **212** is synchronized to occur during the first pulse OFF period of the pulsed platen signal **202** between times t**1** and t**2**. Similarly, the other pulse ON periods **214**, **216** are synchronized to occur during the other pulse OFF periods of the pulsed platen signal **202**. Compared to the first plate signal **204**, the second plate signal **206** may result in the emission of more secondary electrons to at least partially neutralize a relatively greater expected or measured charge accumulation. The pulse ON periods **212**, **214**, and **216** may be synchronized to start within a particular time interval (Δt**3**) of an end of the previous pulse ON period periods of the pulsed platen signal **202**. In one embodiment, this particular time interval (Δt**3**) may be 0.1 microseconds. Parameters such as the pulse width (Δt**4**) and amplitude (−V**3**) of the signal **206** may also be varied to control the yield of secondary electrons emitted from the plate **170**.

[0033] A third exemplary plate signal **224** is also illustrated in FIG. **2**. Compared to the second plate signal **206**, the third plate signal may have pulse ON periods that start slightly before the start of the pulse OFF periods of the pulsed platen signal **202**, and continue for at least a portion of the pulse OFF periods.

[0034] Turning to FIG. **3**, yet another plot of a plate signal **302** is illustrated on a time axis coincident with the pulsed platen signal **202** of FIG. **2**. Compared to the plate signals of FIG. **2**, the plate signal **302** is a constant negative voltage (−V**4**) with respect to the process chamber **102** to continuously accelerate ions from the plasma **140** towards the plate **170** during both the pulse ON and OFF time periods of the pulsed platen signal. The voltage amplitude (V**4**) is selected to be much less than the amplitude of the pulsed platen signal (V4<<V1). In this way, ions will still be accelerated to the workpiece **138** during the pulse ON time periods of the pulsed platen signal **202**. By controlling the amplitude (V**4**) of the plate signal **302**, the rate of acceleration of ions from the plasma towards the plate **170** is controllable to control a plasma density of the plasma **140** during the pulse ON time periods of the pulsed platen signal **202**. In general, a relatively higher plasma density can be achieved during the pulse ON time periods with the plate signal **302** than compared to the plate signals **204** and **206** given the greater number of ionizing collisions between electrons and gas molecules of the process gas.

[0035] Turning to FIGS. **4** to **6**, schematic cross sectional views of differing embodiments of plates consistent with the invention are illustrated. The plates **470**, **570**, **670** may have a variety of geometries and in one instance are disk shaped to match a workpiece **138** that may also be disk shaped. Plate materials may be selected as required to increase or decrease the secondary electron yield.

[0036] FIG. **4** illustrates a plate **470** having a roughened surface **474** facing the workpiece **138** to promote the emission of secondary electrons. The roughened surface **474** provides a larger surface area compared to a polished surface to provide for relatively more collisions of ions with the surface **474**.

[0037] FIG. **5** is a schematic cross sectional view of another embodiment where the plate **570** may be fabricated of a conductor **572** coated on a surface of the conductor **572** facing the workpiece **138** with a silicon film **574**. The conductor **572** may include, but not be limited to, aluminum and nickel. The silicon film **574** may also have a roughened surface **576** facing the workpiece.

[0038] FIG. **6** is a schematic cross sectional view of yet another embodiment of a plate **670** that may also be fabricated of the conductor **572**. Compared to the embodiment of FIG. **5**, the silicon film **674** is disposed around the entire exterior surface of the conductor **572**. In this way, the emission of secondary electrons is promoted by the roughened surface **676** facing the workpiece and encapsulating the entire conductor **572** avoids any metal contamination from the conductor **572**.

[0039] Accordingly, there is provided a charge neutralization apparatus and method to at least partially neutralize charge accumulation on a workpiece of a plasma processing apparatus. The duty cycle of the pulsed platen signal that accelerates ions towards the workpiece can therefore be increased without creating excessive charge accumulation. Excessive charge accumulation in a plasma doping system can lead to doping non-uniformities, arcing, and device damage. In addition, this charge neutralization apparatus and method is particularly useful for plasma systems that generate plasma only during certain time intervals. This is because such systems do not have plasma and hence electrons in the plasma to assist with charge neutralization efforts during other time intervals.

[0040] The present disclosure is not to be limited in scope by the specific embodiments described herein. Indeed, other various embodiments of and modifications to the present disclosure, in addition to those described herein, will be apparent to those of ordinary skill in the art from the foregoing description and accompanying drawings. Thus, such other embodiments and modifications are intended to fall within the scope of the present disclosure. Further, although the present disclosure has been described herein in the context of a particular implementation in a particular environment for a particular purpose, those of ordinary skill in the art will recognize that its usefulness is not limited thereto and that the present disclosure may be beneficially implemented in any number of environments for any number of purposes. Accordingly, the claims set forth below should be construed in view of the full breadth and spirit of the present disclosure as described herein.

What is claimed is:

1. A plasma processing apparatus comprising:

a process chamber;

a source configured to generate a plasma in the process chamber;

a platen configured to support a workpiece in the process chamber, the platen being biased with a pulsed platen signal having pulse ON and OFF time periods to accelerate ions from the plasma towards the workpiece during the pulse ON time periods and not the pulse OFF time periods; and

a plate positioned in the process chamber, the plate being biased with a plate signal to accelerate ions from the plasma towards the plate to cause an emission of secondary electrons from the plate during at least a portion of one of the pulse OFF time periods of the pulsed platen signal to at least partially neutralize charge accumulation on the workpiece.

2. The plasma processing apparatus of claim **1**, wherein the plate has a roughened surface to promote the emission of secondary electrons.

3. The plasma processing apparatus of claim **1**, wherein the plate has a disk shape.

4. The plasma processing apparatus of claim **1**, wherein the plate comprises a conductor coated on at least a surface of the conductor with a silicon film, the silicon film having a roughened surface to promote the emission of secondary electrons.

5. The plasma processing apparatus of claim **1**, wherein the plate is biased with the plate signal to accelerate ions from the plasma towards the plate during at least a portion of each of the pulse OFF periods of the pulsed platen signal.

6. The plasma processing apparatus of claim **1**, wherein the plate signal is a pulsed plate signal having pulse ON and OFF time periods to accelerate ions from the plasma towards the plate during the pulse ON time periods and not the pulse OFF time periods, and wherein pulse ON periods of the pulsed plate signal are synchronized to occur during the pulse OFF periods of the pulsed platen signal.

7. The plasma processing apparatus of claim **6**, wherein the pulse ON periods of the pulsed plate signal are synchronized to start within 0.1 microseconds of an end of the pulse ON periods of the pulsed platen signal.

8. The plasma processing apparatus of claim **1**, wherein the plate is biased with the plate signal to continuously accelerate ions from the plasma towards the plate during the pulse ON and OFF periods of the pulsed platen signal.

9. The plasma processing apparatus of claim **8**, wherein a rate of acceleration of ions from the plasma towards the plate is controllable to control a plasma density of the plasma during the pulse ON periods of the pulsed platen signal.

10. The plasma processing apparatus of claim **1**, further comprising a charge monitor configured to provide a charge monitor signal representative of charge accumulation on the workpiece, and a controller responsive to the charge monitor signal to control the plate bias signal in response to the charge monitor signal.

11. The plasma processing apparatus of claim **1**, further comprising a primary gas source configured to provide a primary dopant gas into the process chamber and a secondary gas source configured to provide a secondary gas into the process chamber, wherein the secondary gas is selected to alter the emission of secondary electrons from the plate.

12. A method of controlling charge accumulation comprising:

accelerating ions from a plasma in a process chamber towards a workpiece supported by a platen within the process chamber during pulse ON periods and not during pulse OFF periods of a pulsed platen signal provided to the platen; and

accelerating ions from the plasma towards a plate during at least a portion of one of the pulse OFF periods of the pulsed platen signal to cause emission of secondary electrons from the plate to at least partially neutralize charge accumulation on the workpiece.

13. The method of claim **12**, wherein the accelerating ions from the plasma towards the plate occurs during at least a portion of each of the pulse OFF periods of the pulsed platen signal.

14. The method of claim **13**, wherein the accelerating ions from the plasma towards the plate is synchronized to start within a selected time period of each of the pulse ON periods of the pulsed plasma signal.

15. The method of claim **12**, wherein the accelerating ions from the plasma towards the plate occurs continuously during the pulse ON and OFF periods of the pulsed plasma signal.

16. The method of claim **15**, further comprising controlling a rate of acceleration of the ions from the plasma towards the plate to control a plasma density of the plasma during the pulse ON periods of the pulsed platen signal.

17. The method of claim **12**, further comprising monitoring a condition representative of charge accumulation on the workpiece, and controlling the accelerating of ions from the plasma towards the plate in response to the monitored condition.

18. The method of claim **12**, further comprising providing a primary dopant gas and a secondary gas into the process chamber, wherein the secondary gas is selected to alter the emission of secondary electrons from the plate.

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