US 20230282451A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2023/0282451 A1**

(43) **Pub. Date: Sep. 7, 2023**

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(54) **COVER RING TO MITIGATE CARBON CONTAMINATION IN PLASMA DOPING CHAMBER**

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(21) Appl. No.: **17/687,620**

(22) Filed: **Mar. 5, 2022**

Publication Classification

(51) **Int. Cl.**
H01J 37/32 (2006.01)

(52) **U.S. Cl.**
CPC .. ***H01J 37/32642*** (2013.01); ***H01J 37/32651*** (2013.01); ***H01J 37/32412*** (2013.01); ***H01J 37/32935*** (2013.01)

(57) **ABSTRACT**

A plasma doping system including a plasma doping chamber, a platen mounted in the plasma doping chamber for supporting a workpiece, a source of ionizable gas coupled to the chamber, the ionizable gas containing a desired dopant for implantation into the workpiece, a plasma source for producing a plasma having a plasma sheath in a vicinity of the workpiece, the plasma containing positive ions of the ionizable gas, and accelerating said positive ions across the plasma sheath toward the platen for implantation into the workpiece, a shield ring surrounding the platen and adapted to extend the plasma sheath beyond an edge of the workpiece, and a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

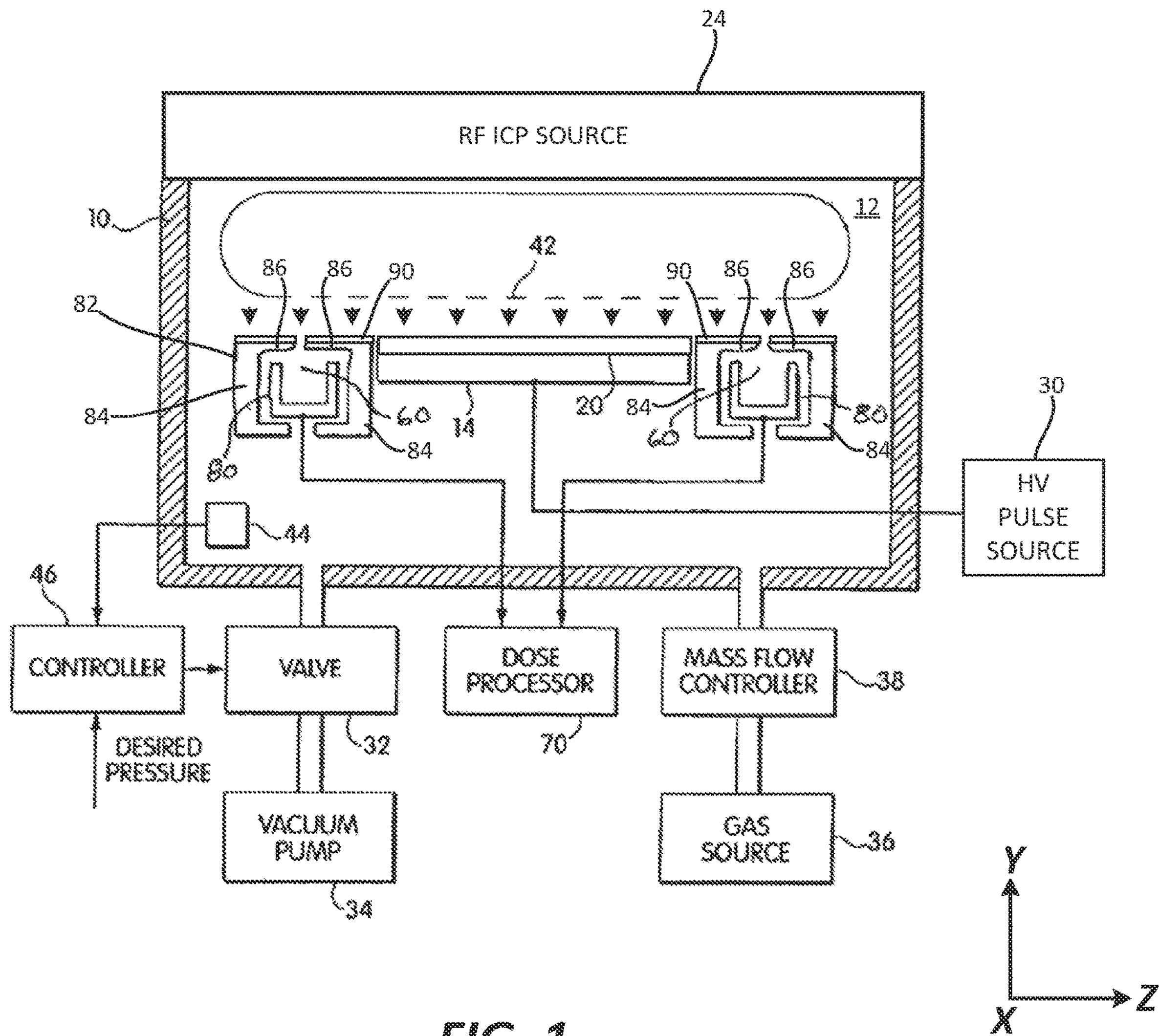

FIG. 1

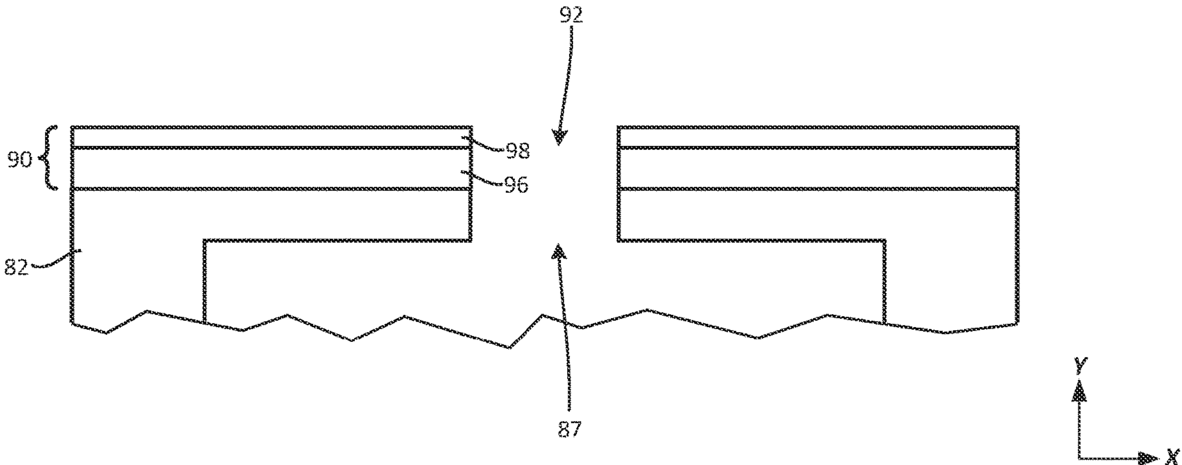

FIG. 2

COVER RING TO MITIGATE CARBON CONTAMINATION IN PLASMA DOPING CHAMBER

FIELD

[0001] Embodiments of the present disclosure relate to plasma doping systems and, more particularly, to a device for mitigating sputter contamination within plasma doping systems.

BACKGROUND

[0002] Ion implantation is a standard technique for introducing conductivity-altering impurities into semiconductor wafers. In a conventional ion implantation system, a desired impurity material is ionized in an ion source, the ions are accelerated to form an ion beam of prescribed energy, and the ion beam is directed at the surface of a wafer. The energetic ions in the beam penetrate into the bulk of the semiconductor material and are embedded into the crystalline lattice of the semiconductor material to form a region of desired conductivity.

[0003] In some applications, it is necessary to form shallow junctions in a semiconductor wafer, where the impurity material is confined to a region near the surface of the wafer. In these applications, the high energy acceleration and the related beam forming hardware of conventional ion implanters are unnecessary. Accordingly, plasma doping systems are used for forming shallow junctions in semiconductor wafers. In a plasma doping system, a semiconductor wafer is placed on a platen within a chamber, wherein the platen is adapted to function as a cathode. An ionizable gas containing the desired dopant material is introduced into the chamber, and a high voltage pulse is applied between the platen and an inductively couple plasma source, causing formation of a plasma having a plasma sheath in the vicinity of the wafer. The applied voltage causes ions in the plasma to cross the plasma sheath and to be implanted into the wafer. The depth of implantation is related to the voltage applied to the wafer.

[0004] In plasma doping systems such as the one described above, an annular “shield ring” surrounding the platen is commonly provided. The shield ring, typically formed of silicon carbide, is positioned in a radially close-clearance relationship with a wafer disposed on the platen and is biased to extend the plasma sheath beyond the edge of the wafer. While generally effective for its intended purpose, this configuration is associated with certain shortcomings. For example, during an implantation process, ions may strike the shield ring, causing carbon atoms to be sputtered into the chamber, resulting in undesirable carbon contamination of the wafer being processed. Thus, there is a need to mitigate such contamination while preserving the functionality of the shield ring.

[0005] With respect to these and other considerations the present disclosure is provided.

BRIEF SUMMARY

[0006] This Summary is provided to introduce a selection of concepts in a simplified form further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is the summary intended as an aid in determining the scope of the claimed subject matter.

[0007] An embodiment of a plasma doping system in accordance with the present disclosure may include a plasma doping chamber, a platen mounted in the plasma doping chamber for supporting a workpiece, a source of ionizable gas coupled to the plasma doping chamber, the ionizable gas containing a desired dopant for implantation into the workpiece, a plasma source for producing a plasma having a plasma sheath in a vicinity of the workpiece, the plasma containing positive ions of the ionizable gas, and accelerating said positive ions across the plasma sheath toward the platen for implantation into the workpiece, a shield ring surrounding the platen and adapted to extend the plasma sheath beyond an edge of the workpiece, and a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

[0008] Another embodiment of a plasma doping system in accordance with the present disclosure may include a plasma doping chamber, a platen mounted in the plasma doping chamber for supporting a workpiece, a source of ionizable gas coupled to the plasma doping chamber, the ionizable gas containing a desired dopant for implantation into the workpiece, a plasma source for producing a plasma having a plasma sheath in a vicinity of the workpiece, the plasma containing positive ions of the ionizable gas, and accelerating said positive ions across the plasma sheath toward the platen for implantation into the workpiece, a shield ring surrounding the platen and adapted to extend the plasma sheath beyond an edge of the workpiece, and a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

[0009] An embodiment of shield ring assembly for a plasma doping system in accordance with the present disclosure may include a shield ring adapted to surround a platen of the plasma doping system and to extend a plasma sheath beyond an edge of a workpiece, and a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings illustrate example approaches of the disclosure, including the practical application of the principles thereof, as follows:

[0011] FIG. **1** is a cross-sectional side view illustrating a plasma doping system in accordance with exemplary embodiments of the present disclosure;

[0012] FIG. **2** is a detailed cutaway view illustrating a portion of a shield ring and cover ring of the plasma doping system shown in FIG. **1**.

[0013] The drawings are not necessarily to scale. The drawings are merely representations, not intended to portray specific parameters of the disclosure. The drawings are intended to depict example embodiments of the disclosure, and therefore are not be considered as limiting in scope. In the drawings, like numbering represents like elements.

DETAILED DESCRIPTION

[0014] The present embodiments will now be described more fully hereinafter with reference to the accompanying drawings, where some embodiments are shown. The subject matter of the present disclosure may be embodied in many

different forms and are not to be construed as limited to the embodiments set forth herein. These embodiments are provided so this disclosure will be thorough and complete, and will fully convey the scope of the subject matter to those skilled in the art. In the drawings, like numbers refer to like elements throughout.

[0015] As used herein, an element or operation recited in the singular and proceeded with the word "a" or "an" are understood as possibly including plural elements or operations, except as otherwise indicated. Furthermore, various embodiments herein have been described in the context of one or more elements or components. An element or component may comprise any structure arranged to perform certain operations. Although an embodiment may be described with a limited number of elements in a certain topology by way of example, the embodiment may include more or less elements in alternate topologies as desired for a given implementation. Note any reference to "one embodiment" or "an embodiment" means a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrases "in one embodiment," "in some embodiments," and "in various embodiments" in various places in the specification are not necessarily all referring to the same embodiment.

[0016] Referring to FIG. **1**, an exemplary embodiment of a plasma doping system in accordance with the present disclosure is shown. The system may include a plasma doping chamber **10** defining an enclosed volume **12**. A platen **14** may be positioned within the chamber **10** to provide a surface for holding a workpiece, such as a semiconductor wafer **20**. The wafer **20** may, for example, be clamped at its periphery to a flat surface of the platen **14**. The platen **14** may support the wafer **20** and may provide an electrical connection to the wafer **20**. In another embodiment, the platen **14** may include conductive pins for providing electrical connection to wafer **20**. The present disclosure is not limited in this regard.

[0017] The wafer **20** may be electrically connected to a first high voltage pulse generator **30** via the platen **14**, and the wafer **20** may function as a cathode. The pulse generator **30** may typically provide pulses in a range of about 20 to 20,000 volts, about 5 to 200 microseconds in duration, and at a pulse repetition rate of about 500 Hz to 20 KHz, for example. The pulse parameter values are given by way of example only and other values and ranges can be contemplated within the scope of the invention.

[0018] The enclosed volume **12** of chamber **10** may be coupled through a controllable valve **32** to a vacuum pump **34**. A gas source **36** may be coupled through a mass flow controller **38** to the chamber **10**. A pressure sensor **44** located within chamber **10** may provide a signal indicative of chamber pressure to a controller **46**. The controller **46** may compare the sensed chamber pressure with a desired pressure input and may provide a control signal to the valve **32**. The control signal my control the valve **32** so as to minimize the difference between the chamber pressure and the desired pressure. The vacuum pump **34**, valve **32**, pressure sensor **44**, and controller **46** may constitute a closed loop pressure control system. The pressure is typically controlled in a range of about one millitorr to about 500 millitorr. The present disclosure is not limited in this regard. The gas source **36** may supply an ionizable gas containing a desired dopant for implantation into the wafer **20**. Examples of ionizable gases include BF_3, N_2, Xe, Ne, He, H_2, D_2, Ar, PF_5, PH_3, AsH_3, AsF_5, AsF_3, and B_2H_6. The present disclosure is not limited in this regard. The mass flow controller **38** may regulate the rate gas is supplied to the chamber **10**. The configuration shown in FIG. **1** may provide a continuous flow of process gas at a constant gas flow rate and constant pressure. The pressure and gas flow rate are preferably regulated to provide repeatable results.

[0019] During operation of the system, the wafer **20** may be positioned on the platen **14**. Then the pressure control system, the mass flow controller **38**, and the gas source **36** may produce the desired pressure and gas flow rate within the chamber **10**. By way of example, the chamber **10** may operate with He gas at a pressure of 10 millitorr. The pulse generator **30** may apply a series of high voltage pulses to the wafer **20**, causing formation of a plasma **40** between the wafer **20** and a radio frequency inductively coupled plasma (RF ICP) source **24** above the wafer **20**. As known in the art, the plasma **40** contains positive ions of the ionizable gas from the gas source **36**. The plasma **40** further includes a plasma sheath **42** in the vicinity of the platen **14**. The electric field present between the RF ICP source **24** and the platen **14** during the high voltage pulse accelerates positive ions from the plasma **40** across the plasma sheath **42** toward the platen **14**. The accelerated ions are implanted into the wafer **20** to form regions of impurity material. The pulse voltage is selected to implant the positive ions to a desired depth in the wafer **20**. The number of pulses and the pulse duration are selected to provide a desired dose of impurity material in the wafer **20**.

[0020] The system may further include an annular Faraday cup **80** positioned around the wafer **20** and the platen **14**. The Faraday cup **80** may be positioned in an annular shield ring **82** (described in greater detail below) and may be located as close as is practical to the wafer **20** and the platen **14** and may intercept a sample of the positive ions accelerated from the plasma **40** toward the platen **14**. In various alternative embodiments the Faraday cup **80** may have other positions relative to the wafer **20** to provide a measurement representative of ion current implanted into the wafer **20**. The Faraday cup **80** may include a conductive enclosure having an entrance **60** facing the plasma **40**.

[0021] The Faraday cup **80** may be electrically connected to a dose processor **70** or other dose monitoring circuit. Positive ions entering the Faraday cup **80** through the entrance **60** may produce a current in the electrical circuit connected to the Faraday cup **80**. The electrical current is indicative of the number of positive ions received per unit time, or ion current density. The ion current density received by Faraday cup **80** may have a fixed relation to the number of ions implanted in the wafer **20** per unit time. Depending on the uniformity of the plasma **40** and the uniformity of ion acceleration toward the platen **14**, the ion current per unit area received by the Faraday cup **80** may be equal to, or a fixed fraction of, the ion current per unit area implanted in the wafer **20**. Since the electrical current output of the Faraday cup **80** is representative of the ion current implanted in the wafer **20**, the Faraday cup **80** may provide a measurement of the ion dose implanted in the wafer **20**.

[0022] The shield ring **82** may surround the platen **14** and may be biased to extend the plasma sheath beyond the edge of the wafer **20**. As described previously, the Faraday cup **80** can be positioned within the shield ring **82** near the periphery of the wafer **20** and the platen **14**. Side walls **84** of the

shield ring **82** may include horizontal projections **86** extending over entrance **60** of the Faraday cup **80** to provide a narrow opening **87** (best shown in FIG. **2**) over the Faraday cup **80**. Secondary electrons can be produced by ions striking the sidewalls **88** of the Faraday cup **80** and cause discharges inside the Faraday cup **80**. The narrow opening **87** can decrease the potential drop in the Faraday cup **80** and can improve electron confinement in the Faraday cup **80**.

[0023] The system may further include an annular cover ring **90** disposed atop, and positioned concentric with, the shield ring **82**. The shield ring **82** and the cover ring **90** may be collectively referred to herein as "the shield ring assembly." The cover ring **90** may have an inner diameter and an outer diameter equal to or nearly equal to an inner diameter and an outer diameter of the shield ring **82**. The cover ring **90** may further have an annular opening **92** (best shown in FIG. **2**) formed therethrough. The annular opening **92** may be aligned with, and may have a width equal to or nearly equal to a width of, the narrow opening **87** defined by the shield ring **82**. The cover ring **90** may thus block accelerated ions emanating from the plasma **40** from striking the shield ring **82** while allowing the ions to enter the Faraday cup **80**.

[0024] Referring now to FIG. **2**, a detailed cutaway view illustrating a segment of the cover ring **90** and a top portion of the shield ring **82** is shown. The shield ring **82** may be formed of silicon carbide (SiC), such material being familiar to those of ordinary skill in the art as a standard material used in the construction of shield rings. The cover ring **90** may be formed primarily of silicon or another material known to have low sputter yields (as described in greater detail below). As described above, the cover ring **90** may prevent accelerated ions emanating from the plasma **40** (see FIG. **1**) from striking the shield ring **82**, thus preventing carbon atoms from being sputtered therefrom. Carbon contamination within the chamber **10** is resultingly mitigated or prevented and the quality of implantation processes performed within the chamber **10** is improved.

[0025] In some instances, crystalline silicon (c-Si) may be prone to "bubbling" or other forms of degradation when subjected to ionic bombardment. The cover ring **90** may thus be formed of a crystalline base layer **96** and may have an insulating, non-crystalline top layer **98** adapted to resist such bubbling or degradation. For example, in one non-limiting embodiment of the present disclosure, the top layer **98** may be formed of an oxide. Such oxide may be thermally grown on the top surface of the silicon base layer **96**, may be sprayed onto the top surface of the crystalline base layer **96**, or may be deposited onto the top surface of the crystalline base layer **96** using chemical vapor deposition (CVD) or atomic layer deposition (ALD). The present disclosure is not limited in this regard. In another embodiment of the present disclosure, the insulating top layer **98** may be formed by amorphizing the top of the crystalline base layer **96** using any suitable amorphization process. The amorphization process can be performed on the cover ring prior to installation on the shield ring **82**, or in-situ after installation on the shield ring **82**. The present disclosure is not limited in this regard. In yet another embodiment of the present disclosure, the top layer **98** may be formed of silicon nitride (SiN_x). The silicon nitride may be sprayed onto the top surface of the crystalline base layer **96** or may be deposited onto the top surface of the crystalline base layer **96** using chemical vapor deposition (CVD) or atomic layer deposition (ALD). The present disclosure is not limited in this regard. Thus, the insulating, non-crystalline top layer **98** may be formed by applying a separate layer of material atop the base layer **96** (e.g., as in the case of applying an oxide or silicon nitride via spraying), or by altering the composition of the top portion of the base layer **96** (e.g., as in the case of amorphization).

[0026] In various, non-limiting embodiments of the present disclosure, the top layer **98** of the cover ring **90** may have a thickness in a range of 1000 angstroms-2000 angstroms as measured along the Y-axis of the illustrated Cartesian coordinate system. Notably, if the top layer **98** is not thick enough, the underlying silicon base layer **96** will not be sufficiently protected from ionic bombardment and will be prone to bubbling or may otherwise degrade prematurely. Conversely, if the top layer **98** is too thick, it can produce numerous undesirable effects, including, and not limited to, voltage degradation/drop within the chamber **10**, sheath bending, charging and arcing, etc. Thus, the specific thickness of the top layer **98** of the cover ring **90** may be tailored to the energy of the implantation process being performed (i.e., the higher the energy of the implant, the greater the thickness of the top layer **98**).

[0027] The cover ring **90** can be conveniently removed and replaced, such as when the cover ring **90** is "spent" (i.e., etched or degraded beyond further usefulness), or if a cover ring formed of a different material or having a top layer (insulating layer) with a different thickness is desired. The cover ring **90** has been described above as being formed primarily of silicon. The present disclosure is not limited in this regard. In alternative embodiments, the cover ring **90** may be formed of various metallic materials known to have low sputter yields. Such metallic materials include, and are not limited to, titanium (Ti), yttrium (Y), yttrium oxide (Y_2O_3), etc. For example, if the wafer **20** (FIG. **1**) has been implanted with titanium nitride, the cover ring **90** may be formed of titanium since the wafer **20** would be less sensitive to contamination from titanium sputtered from the cover ring **90** during a subsequent implantation process.

[0028] In summation, the embodiments described herein provide at least the following technical advantages. For a first advantage, the cover ring **90** of the present embodiments reduces the occurrence of carbon being sputter-etched from a conventional shield ring formed of silicon carbide during ion implantation processes, thus reducing carbon contamination of a wafer being processed. For a second advantage, the cover ring **90** is easily replaceable and can be implemented at a relatively low cost.

[0029] 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. Furthermore, 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 the usefulness is not limited thereto and the present disclosure may be beneficially implemented in any number of environments for any number of purposes. Thus, the claims set forth below are to be construed in view of the full breadth and spirit of the present disclosure as described herein.

What is claimed is:

1. A plasma doping system comprising:
- a plasma doping chamber;
- a platen mounted in the plasma doping chamber for supporting a workpiece;
- a source of ionizable gas coupled to the plasma doping chamber, the ionizable gas containing a desired dopant for implantation into the workpiece;
- a plasma source for producing a plasma having a plasma sheath in a vicinity of the workpiece, the plasma containing positive ions of the ionizable gas, and accelerating said positive ions across the plasma sheath toward the platen for implantation into the workpiece;
- a shield ring surrounding the platen and adapted to extend the plasma sheath beyond an edge of the workpiece; and
- a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring.

2. The plasma doping system of claim **1**, wherein the cover ring is formed of silicon.

3. The plasma doping system of claim **1**, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

4. The plasma doping system of claim **3**, wherein the non-crystalline top layer is formed of an oxide.

5. The plasma doping system of claim **3**, wherein the non-crystalline top layer is an amorphized portion of the crystalline base layer.

6. The plasma doping system of claim **3**, wherein the non-crystalline top layer has a thickness in a range of 1000 angstroms-2000 angstroms.

7. The plasma doping system of claim **1**, further comprising a Faraday cup positioned around the platen.

8. The plasma doping system of claim **7**, wherein the Faraday cup is disposed within the shield ring, the shield ring having an opening formed therein for allowing ions to enter the Faraday cup.

9. The plasma doping system of claim **8**, wherein cover ring has an annular opening formed therein, the annular opening being aligned with the opening in the shield ring.

10. A plasma doping system comprising:
- a plasma doping chamber;
- a platen mounted in the plasma doping chamber for supporting a workpiece;
- a source of ionizable gas coupled to the plasma doping chamber, the ionizable gas containing a desired dopant for implantation into the workpiece;
- a plasma source for producing a plasma having a plasma sheath in a vicinity of the workpiece, the plasma containing positive ions of the ionizable gas, and accelerating said positive ions across the plasma sheath toward the platen for implantation into the workpiece;
- a shield ring surrounding the platen and adapted to extend the plasma sheath beyond an edge of the workpiece; and
- a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

11. The plasma doping system of claim **10**, wherein the cover ring is formed of silicon.

12. The plasma doping system of claim **10**, wherein the non-crystalline top layer is formed of an oxide.

13. The plasma doping system of claim **10**, wherein the non-crystalline top layer is an amorphized portion of the crystalline base layer.

14. The plasma doping system of claim **10**, wherein the non-crystalline top layer has a thickness in a range of 1000 angstroms-2000 angstroms.

15. The plasma doping system of claim **10**, further comprising a Faraday cup positioned around the platen and disposed within the shield ring, the shield ring having an opening formed therein for allowing ions to enter the Faraday cup.

16. The plasma doping system of claim **15**, wherein cover ring has an annular opening formed therein, the annular opening being aligned with the opening in the shield ring.

17. A shield ring assembly for a plasma doping system, the shield ring assembly comprising:
- a shield ring adapted to surround a platen of the plasma doping system and to extend a plasma sheath beyond an edge of a workpiece; and
- a cover ring disposed on top of the shield ring and adapted to mitigate sputtering of the shield ring, wherein the cover ring comprises a crystalline base layer and a non-crystalline top layer.

18. The plasma doping system of claim **17**, wherein the cover ring is formed of silicon.

19. The plasma doping system of claim **17**, wherein the non-crystalline top layer is formed of an oxide.

20. The plasma doping system of claim **17**, wherein the non-crystalline top layer is an amorphized portion of the crystalline base layer.

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