US 20120213941A1

(19) **United States**
(12) **Patent Application Publication**
Steen et al.

(10) **Pub. No.: US 2012/0213941 A1**
(43) **Pub. Date: Aug. 23, 2012**

(54) ION-ASSISTED PLASMA TREATMENT OF A THREE-DIMENSIONAL STRUCTURE

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(21) Appl. No.: **13/401,168**

(22) Filed: **Feb. 21, 2012**

Related U.S. Application Data

(60) Provisional application No. 61/445,174, filed on Feb. 22, 2011.

Publication Classification

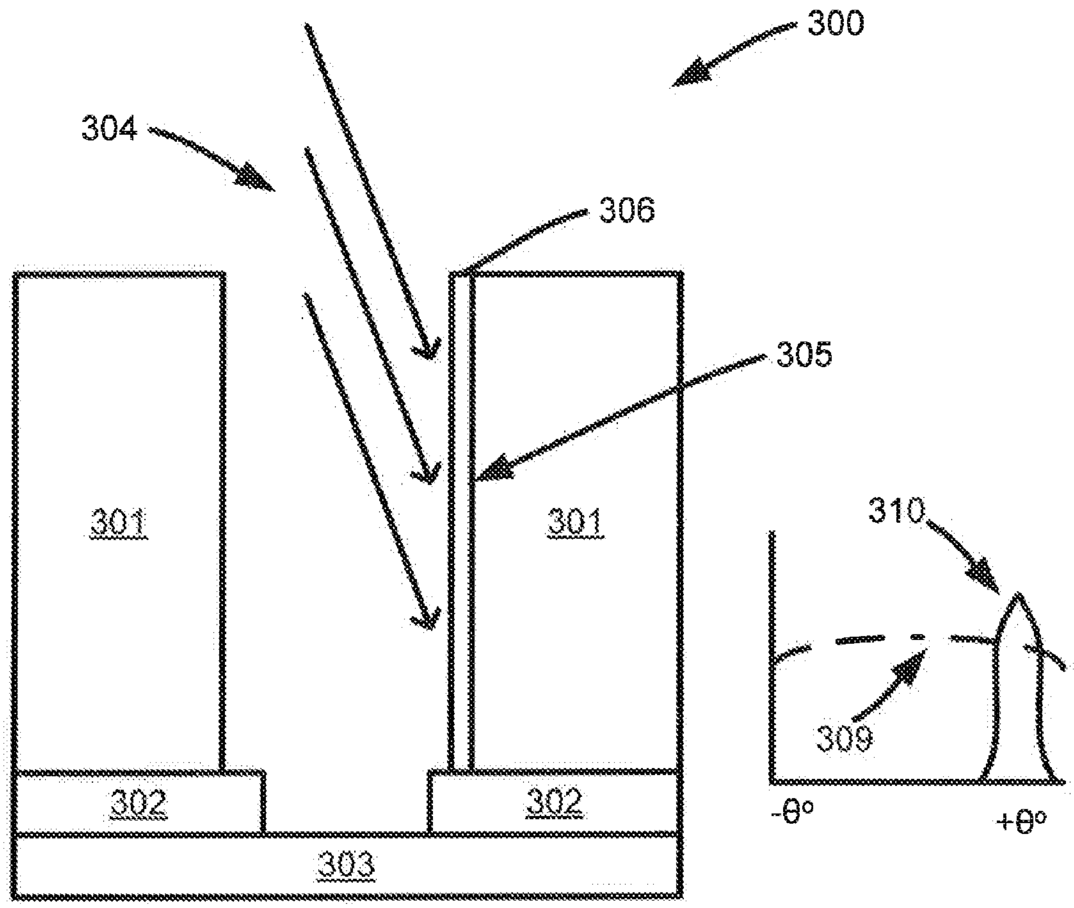
(51) **Int. Cl.**

C23C 16/50	(2006.01)
B08B 7/00	(2006.01)
C23C 16/02	(2006.01)
C23C 16/52	(2006.01)
C23C 16/06	(2006.01)

(52) **U.S. Cl.** **427/535**; 427/569; 427/8; 427/576; 134/1.1

(57) ABSTRACT

A boundary between a plasma and a plasma sheath is controlled such that a portion of the shape is not parallel to a plane defined by a front surface of the workpiece facing the plasma. Ions in the plasma are directed toward the workpiece. These ions can either seal pores or clean a material from a structure on the workpiece. This structure may, for example, have multiple sidewalls. A process that both cleans a material and seals pores in the structure may be performed.



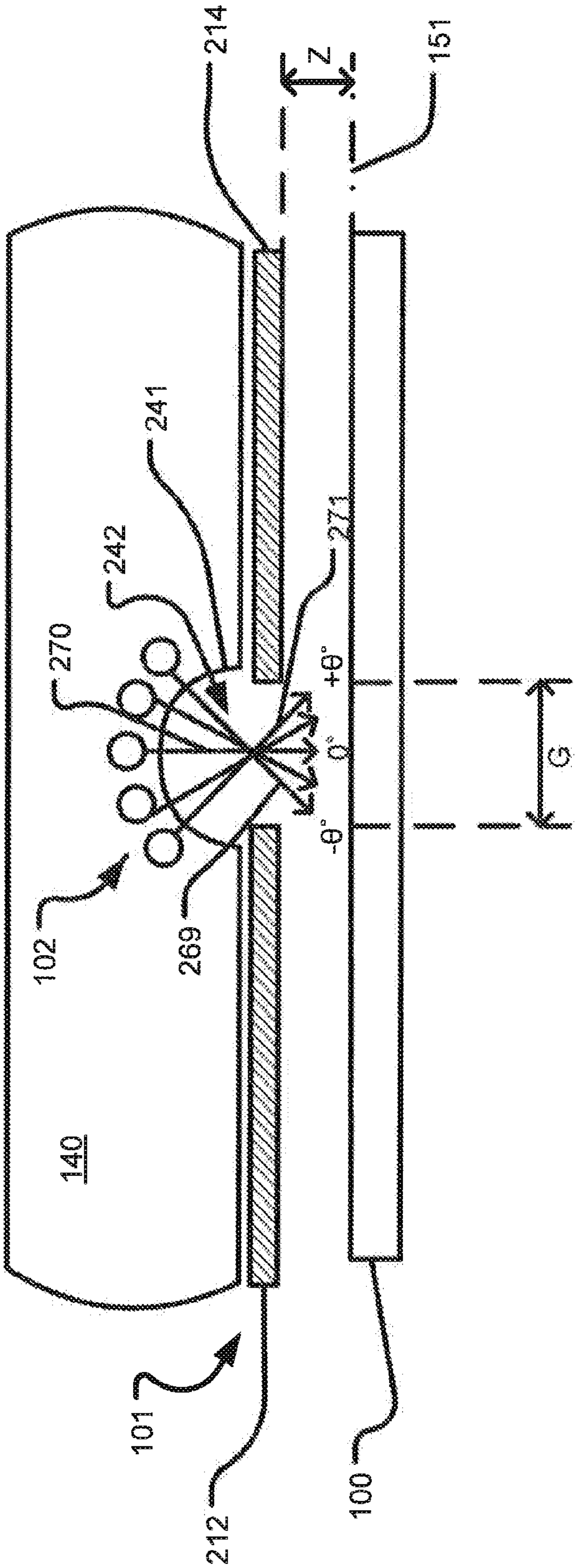


FIG. 1

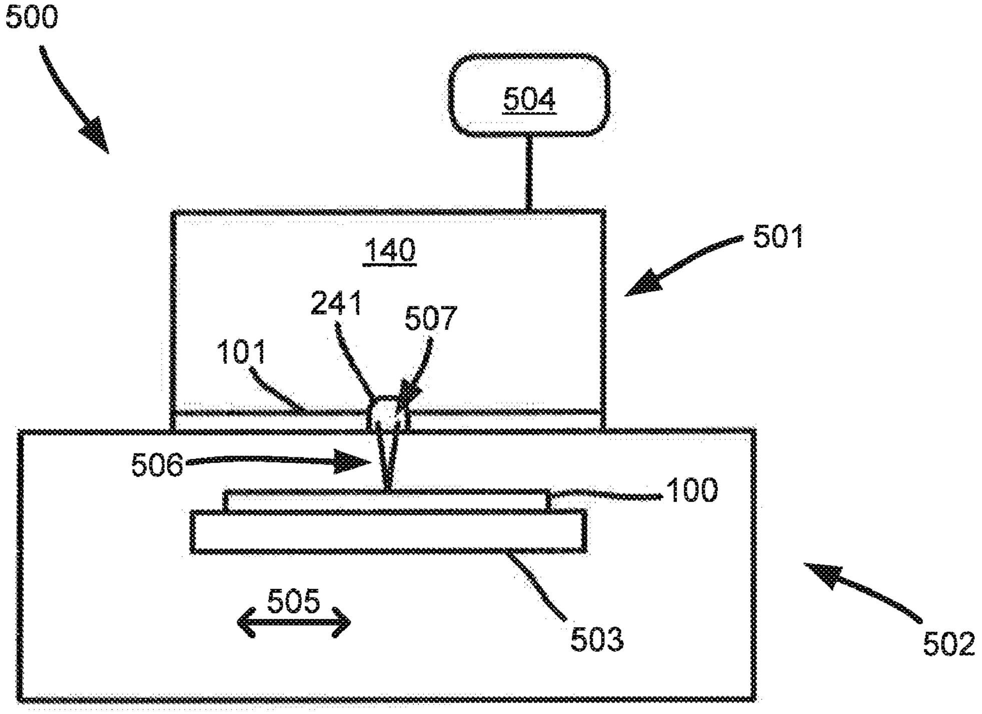


FIG. 2

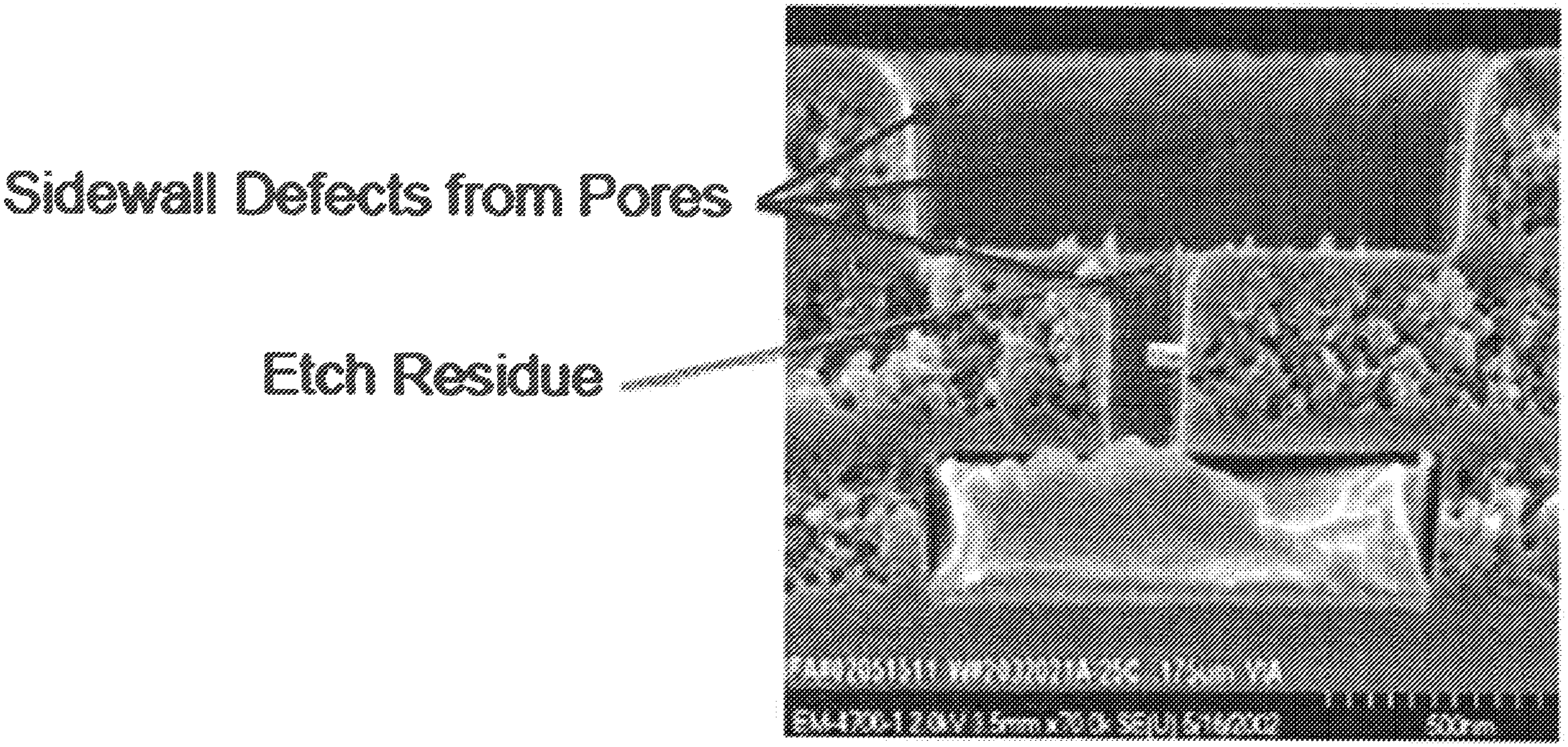


FIG. 3

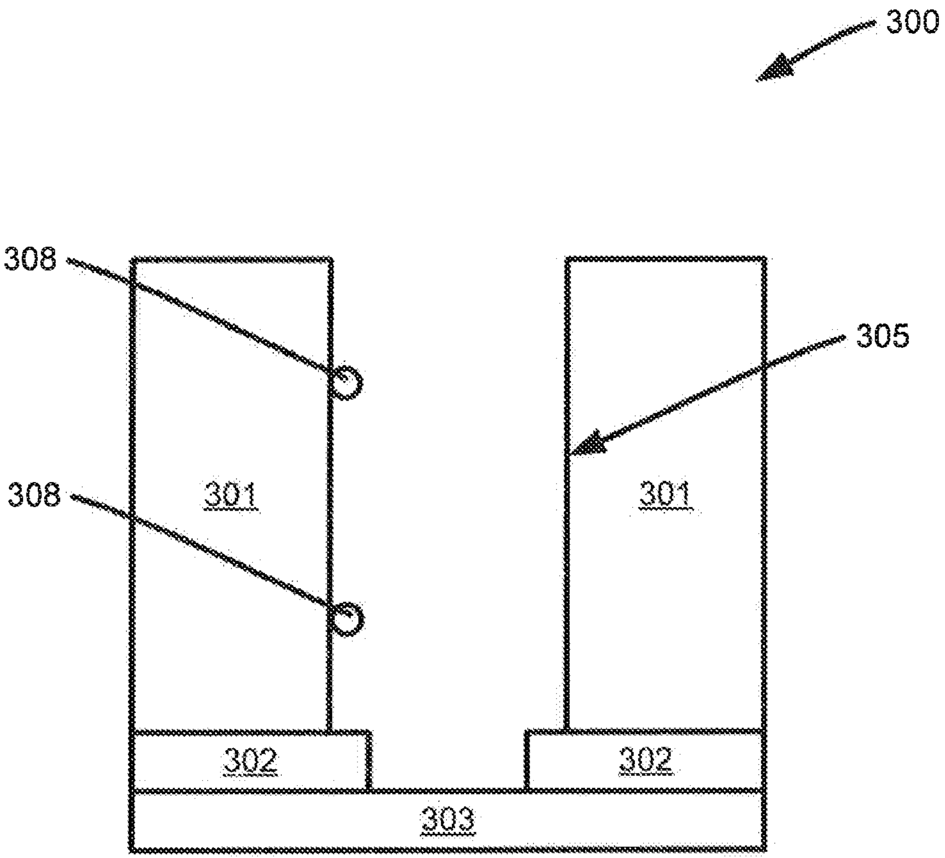


FIG. 4

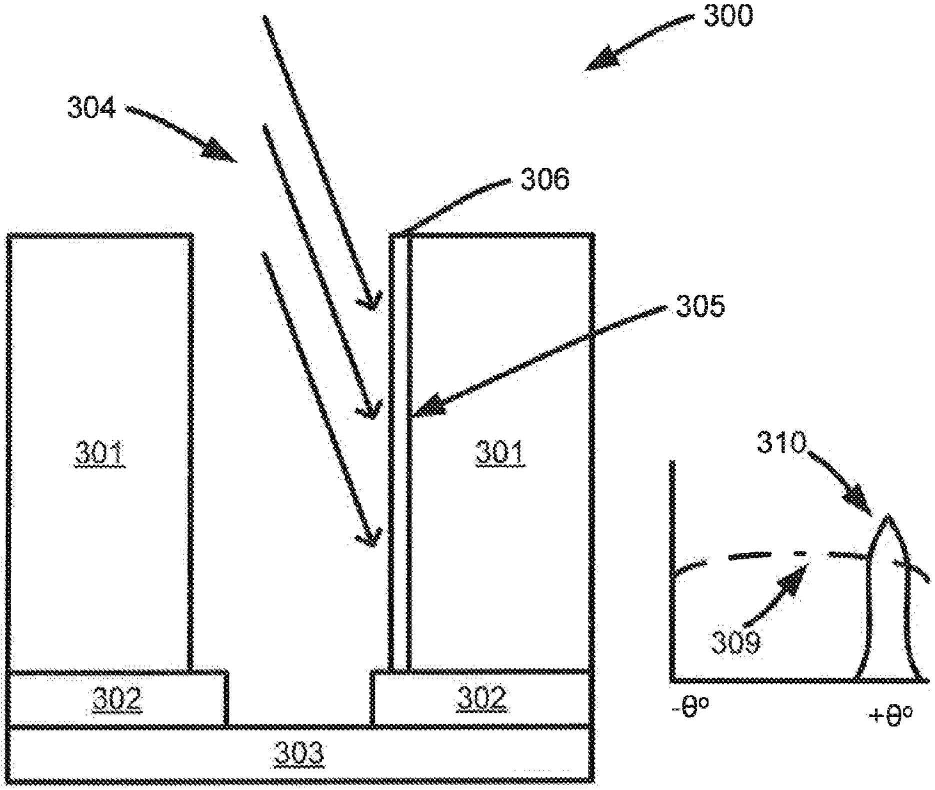


FIG. 5

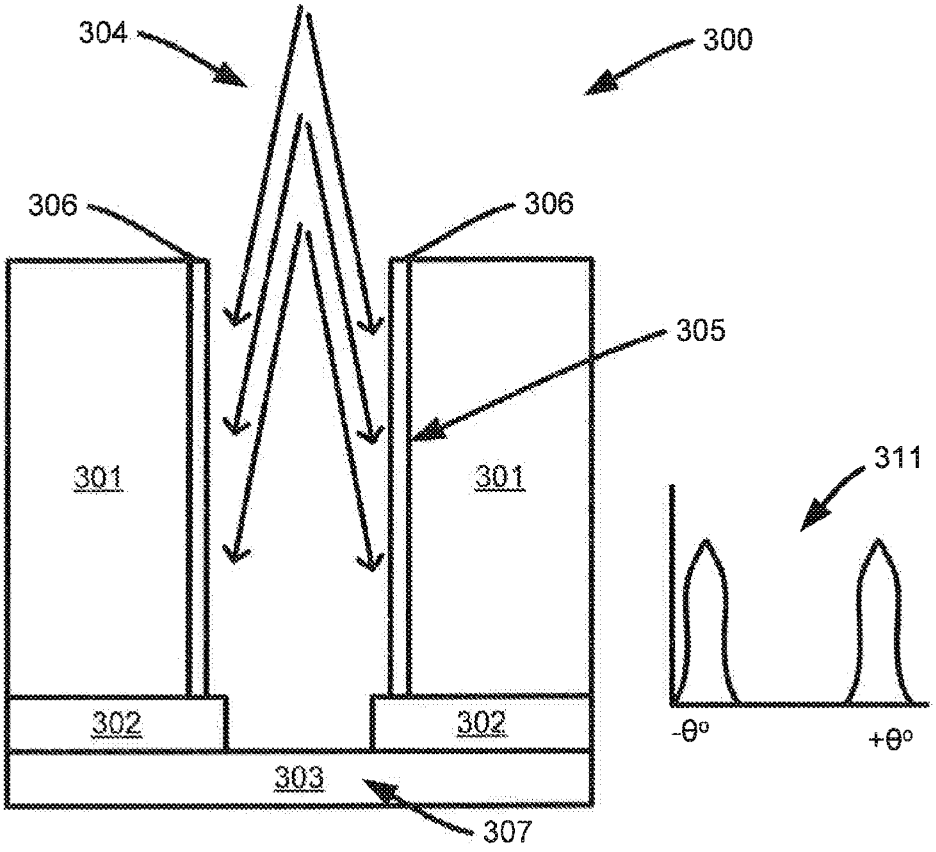


FIG. 6

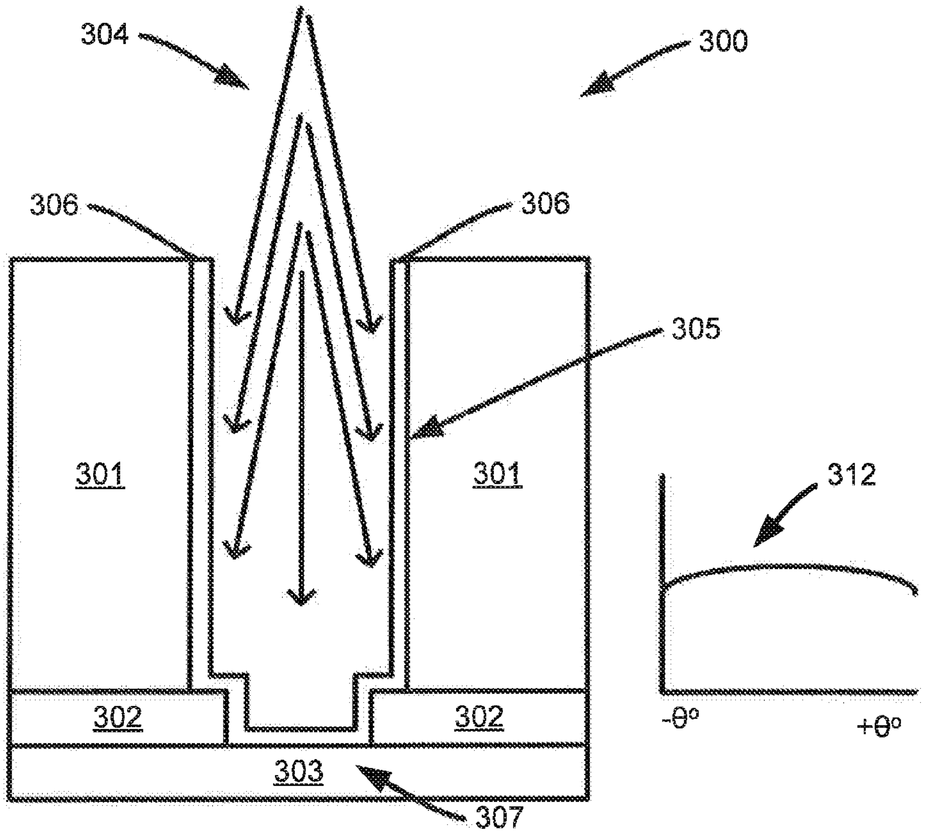


FIG. 7

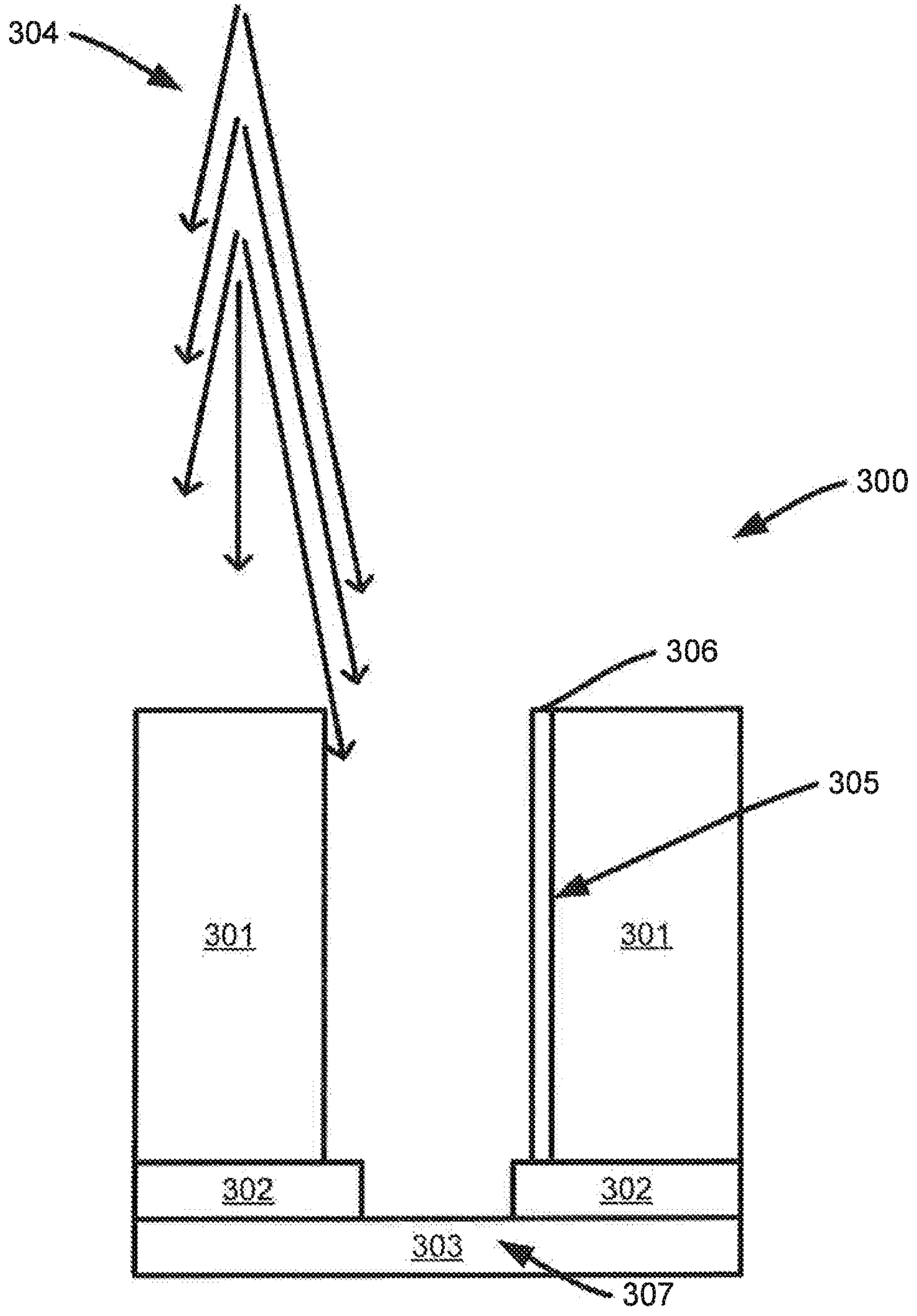


FIG. 8

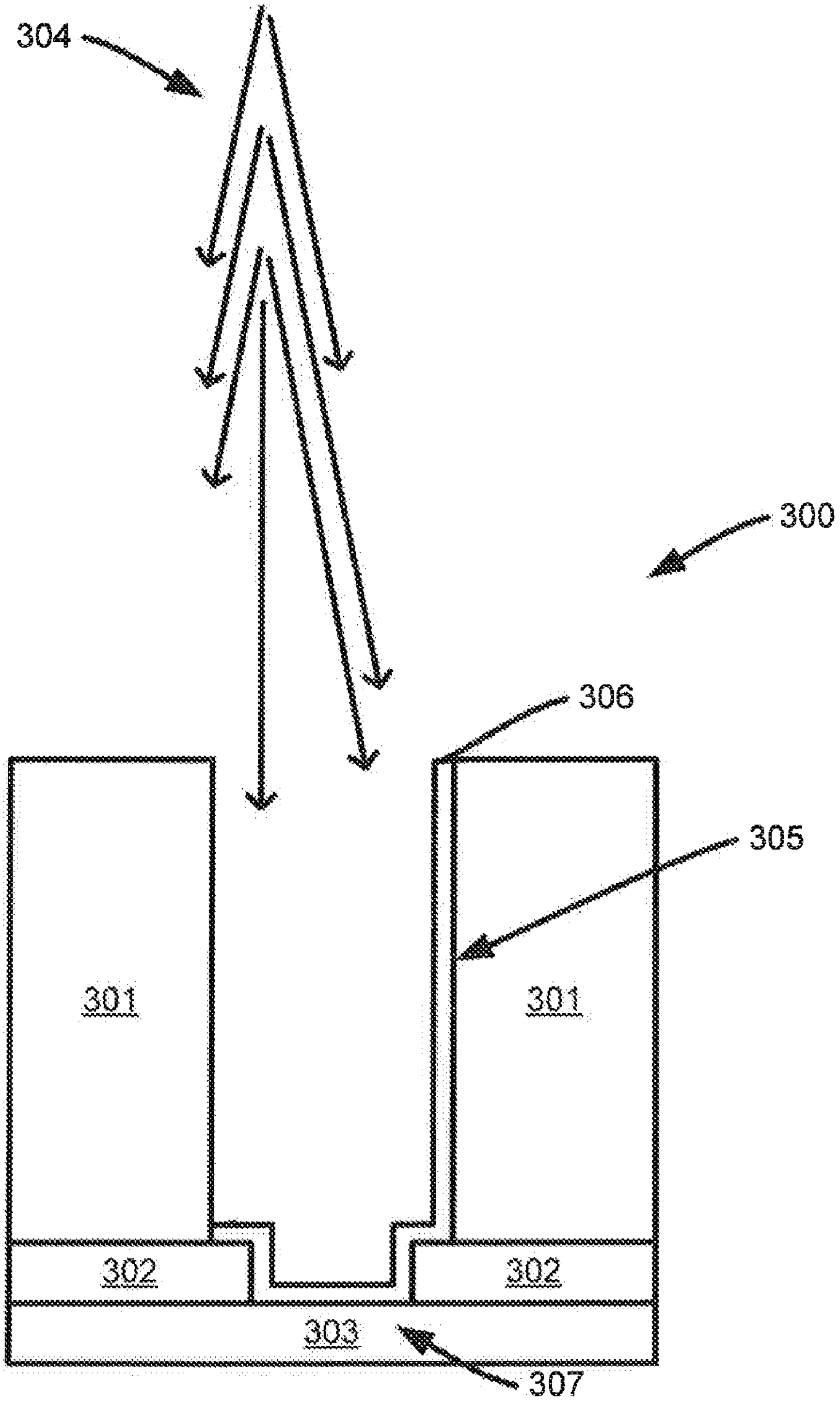


FIG. 9

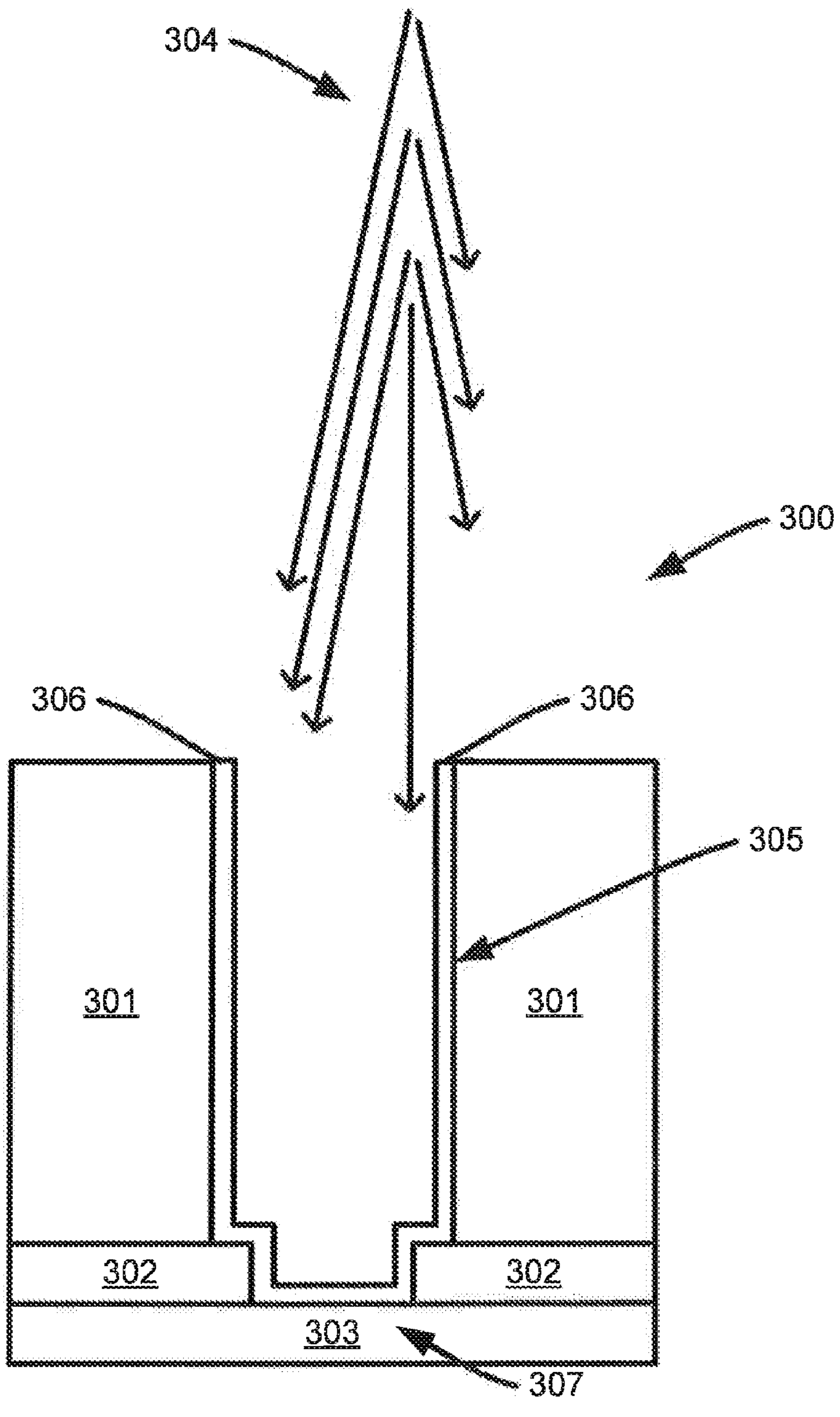


FIG. 10

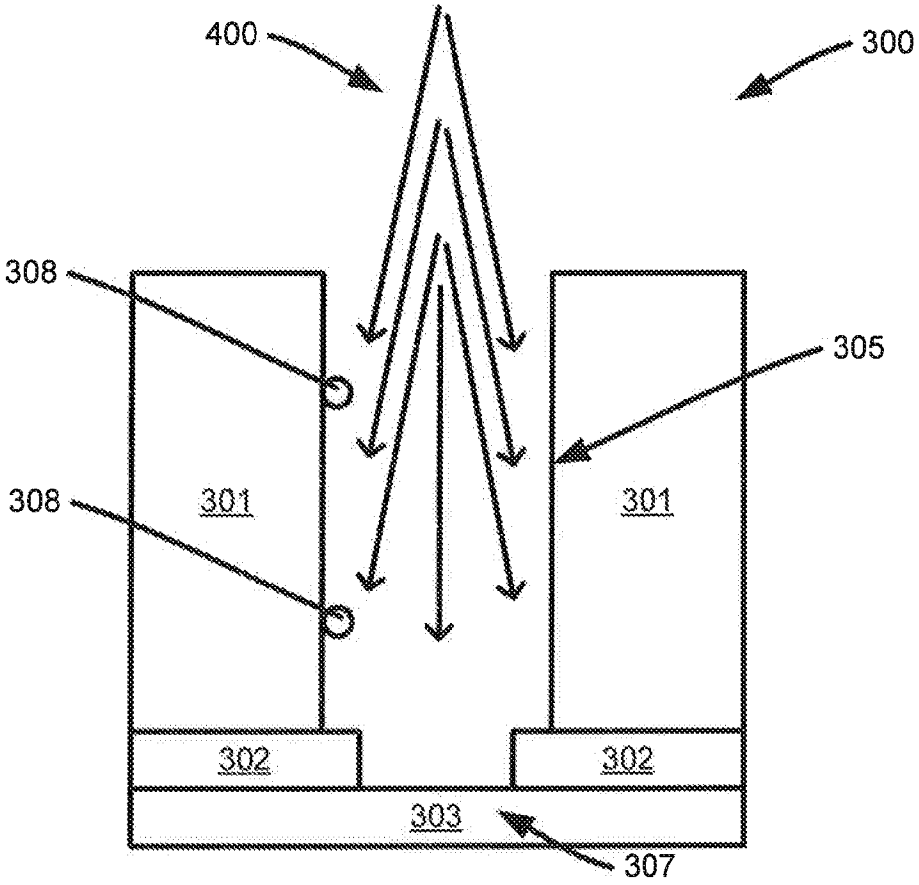


FIG. 11

ION-ASSISTED PLASMA TREATMENT OF A THREE-DIMENSIONAL STRUCTURE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to the provisional patent application entitled "Three-Dimensional Ion Beam Assisted Pore Sealing," filed Feb. 22, 2011 and assigned U.S. App. No. 61/445,174, the disclosure of which is hereby incorporated by reference.

FIELD

[0002] This invention relates to three-dimensional structures and, more particularly, to ion-assisted plasma treatment of three-dimensional structures.

BACKGROUND

[0003] Three-dimensional structures are used in the semiconductor industry for advanced interconnects in logic and memory chip fabrication. The material for these devices may be a porous dielectric material such as, for example, SiCOH. The porosity of this material is used to achieve the lowest capacitance of the structure, but these pores have drawbacks. First, the pores serve as traps for etch residue. Second, the pores allow moisture to penetrate the dielectric and lead to leakage or time dependent dielectric breakdown (TDDB) failures. Third, the pores have a negative effect on the uniform nucleation of the barrier metal and lead to point defects in the barrier metal or defects in the copper seed layer that reduce the reliability of the copper interconnect line. Sealing the pores prior to deposition of the barrier metal eliminates these problems. However, sealing pores on a three-dimensional surface is challenging. What are needed are an improved method of ion-assisted plasma treatment for three-dimensional structures and, more particularly, an improved method of pore sealing or cleaning for three-dimensional structures.

SUMMARY

[0004] According to a first aspect of the invention, a method of workpiece processing is provided. The method comprises generating a plasma having a plasma sheath proximate a surface of the workpiece. The workpiece defines a structure with a plurality of sidewalls. A shape of a boundary between the plasma and the plasma sheath is controlled whereby a portion of the shape is not parallel to a plane defined by a front surface of the workpiece facing the plasma. The ions in the plasma are directed toward the workpiece. The pores on one of the sidewalls are sealed with the ions.

[0005] According to a second aspect of the invention, a method of workpiece processing is provided. The method comprises generating a plasma having a plasma sheath proximate a surface of the workpiece. The workpiece defines a structure with a plurality of sidewalls. A shape of a boundary between the plasma and the plasma sheath is controlled whereby a portion of the shape is not parallel to a plane defined by a front surface of the workpiece facing the plasma. The ions in the plasma are directed toward the workpiece. A material is removed from one of the sidewalls of the structure with the ions.

[0006] According to a third aspect of the invention, a method of workpiece processing is provided. The method comprises generating a first plasma having a first plasma sheath proximate a surface of the workpiece. The workpiece defines a trench with a plurality of sidewalls. A first shape of a first boundary between the first plasma and the first plasma sheath is controlled whereby a portion of the first shape is not parallel to a plane defined by a front surface of the workpiece facing the first plasma. The first ions in the first plasma are directed toward the workpiece. Etch residue is removed from one of the sidewalls of the trench with the first ions. A second plasma is generated having a plasma sheath proximate the surface. A second shape of a second boundary between the second plasma and the second plasma sheath is controlled whereby a portion of the second shape is not parallel to the plane. The second ions in the second plasma are directed toward the workpiece. Pores on one of the sidewalls are sealed with the second ions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For a better understanding of the present disclosure, reference is made to the accompanying drawings, which are incorporated herein by reference and in which:

[0008] FIG. **1** is a block diagram of a plasma processing apparatus;

[0009] FIG. **2** is a block diagram of a plasma processing apparatus consistent with an embodiment of the disclosure;

[0010] FIG. **3** is a SEM photograph of a first three-dimensional structure;

[0011] FIG. **4** is a cross-sectional diagram of a second three-dimensional structure;

[0012] FIG. **5** illustrates a first embodiment of pore sealing;

[0013] FIG. **6** illustrates a second embodiment of pore sealing;

[0014] FIG. **7** illustrates a third embodiment of pore sealing;

[0015] FIGS. **8-10** illustrate a fourth embodiment of pore sealing; and

[0016] FIG. **11** illustrates a first embodiment of cleaning.

DETAILED DESCRIPTION

[0017] These embodiments are described herein in connection with an ion implanter or plasma system. However, the embodiments can be used with other systems and processes involved in semiconductor manufacturing or other systems that use ions. Thus, the invention is not limited to the specific embodiments described below.

[0018] FIG. **1** is a block diagram of a plasma processing apparatus. The plasma **140** is generated as is known in the art. This plasma **140** is generally a quasi-neutral collection of ions and electrons. The ions typically have a positive charge while the electrons have a negative charge. The plasma **140** may have an electric field of, for example, approximately 0 V/cm in the bulk of the plasma **140**. In a system containing the plasma **140**, ions **102** from the plasma **140** are attracted toward a workpiece **100**. These ions **102** may be attracted with sufficient energy to be implanted into the workpiece **100**. The plasma **140** is bounded by a region proximate the workpiece **100** referred to as a plasma sheath **242**. The plasma sheath **242** is a region that has fewer electrons than the plasma **140**. Hence, the differences between the negative and positive charges cause a sheath potential in the plasma sheath **242**. The light emission from this plasma sheath **242** is less intense than the plasma **140** because fewer electrons are present and, hence, fewer excitation-relaxation collisions occur. Thus, the plasma sheath **242** is sometimes referred to as "dark space."

[0019] The sheath modifier **101** is configured to modify an electric field within the plasma sheath **242** to control a shape of a boundary **241** between the plasma **140** and the plasma sheath **242**. Accordingly, ions **102** that are attracted from the plasma **140** across the plasma sheath **242** may strike the workpiece **100** at a large range of incident angles. This sheath modifier **101** also may he referred to as, for example, a focusing plate or sheath engineering plate and may be a semiconductor, insulator, or conductor.

[0020] In the embodiment of FIG. **1**, the sheath modifier **101** includes a pair of panels **212** and **214** defining an aperture therebetween having a horizontal spacing (G). In other embodiments, the sheath modifier **101** may include only one panel or more than two panels. The panels **212** and **214** may be a pair of sheets having a thin, flat shape. In other embodiments, the panels **212** and **214** may be other shapes such as tube-shaped, wedge-shaped, and/or have a beveled edge proximate the aperture. The panels **212** and **214** also may be positioned a vertical spacing (Z) above the plane **151** defined by the front surface of the workpiece **100**. In one embodiment, the vertical spacing (Z) may be about 1.0 to 10.0 mm.

[0021] Ions **102** may be attracted from the plasma **140** across the plasma sheath **242** by different mechanisms. In one instance, the workpiece **100** is biased to attract ions **102** from the plasma **140** across the plasma sheath **242**. In another instance, a plasma source that generates the plasma **140** and walls surrounding the plasma **140** are biased positively and the workpiece **100** may be grounded. The biasing may be pulsed in one particular embodiment. In yet another instance, electric or magnetic fields are used to attract ions **102** from the plasma **140** toward the workpiece **100**.

[0022] Advantageously, the sheath modifier **101** modifies the electric field within the plasma sheath **242** to control a shape of the boundary **241** between the plasma **140** and the plasma sheath **242**. The boundary **241** between the plasma **140** and the plasma sheath **242** may have a convex shape relative to the plane **151** or another shape not parallel to the plane **151**. When the workpiece **100** is biased, for example, the ions **102** are attracted across the plasma sheath **242** through the aperture between the panels **212** and **214** at a large range of incident angles. For instance, ions **102** following trajectory path **271** may strike the workpiece **100** at an angle of $+\theta°$ relative to the plane **151**. Ions **102** following trajectory path **270** may strike the workpiece **100** at about an angle of 0° relative to the same plane **151**. Ions **102** following trajectory path **269** may strike the workpiece **100** an angle of $-\theta°$ relative to the plane **151**. Accordingly, the range of incident angles may be between $+\theta°$ and $-\theta°$ centered about 0°. In addition, some ion trajectories paths such as paths **269** and **271** may cross each other. Depending on a number of factors including, but not limited to, the horizontal spacing (G) between the panels **212** and **214**, the vertical spacing (Z) of the panels **212** and **214** above the plane **151**, the dielectric constant of the panels **212** and **214**, or other process parameters of the plasma **140**, the range of incident angles (θ) may be between +60° and −60° centered about 0°, though other ranges of θ are possible. In another embodiment, the panels **212** and **214** may each have different vertical spacing (Z) relative to the workpiece **100**, which may allow the ions **102** to primarily follow trajectories at an angle relative to the plane **151**.

[0023] FIG. **2** is a block diagram of a plasma processing apparatus consistent with an embodiment of the disclosure. The system **500** includes a plasma source **501**, a sheath modifier **101**, and a process chamber **502**. A gas source **504** is connected to the plasma source **501**. The plasma source **501** or other components of the system **500** also may be connected to a pump, such as a turbopump. The plasma source **501** that generates the plasma **140** may be, for example, an RF plasma source, inductively-coupled plasma (ICP) source, indirectly heated cathode (IHC), capacitively-coupled plasma (CCP) source, helicon plasma source, microwave plasma source, or other plasma sources known to those skilled in the art. The process chamber **502**, plasma source **501**, or platen **503** may be grounded.

[0024] The sheath modifier **101** is used to focus ions **506** for implantation of a workpiece **100**. This extraction of the plasma **140** from the plasma source **501** into the ions **506** may be continuous (DC) or pulsed. The plasma source **501** may be biased in one instance, Alternatively, an RF bias in the system **500** may or may not be pulsed. The sheath modifier **101** has at least one aperture **507**, though multiple apertures **507** are possible. Adding more than one aperture **507** may increase throughput of the system **500**. Thus, the sheath modifier **101** design is not limited solely to the design illustrated in FIG. **2**.

[0025] One or more workpieces **100**, which may be semiconductor wafers, are arranged on a platen **503** in the process chamber **502**. The platen **503** may use electrostatic clamping, mechanical clamping, or a combination of electrostatic and mechanical clamping to retain the workpiece **100**. The workpiece **100** may be scanned using the platen **503**. In the embodiment of FIG. **2**, the platen **503** can scan in the direction **505**. The platen **503**, however, may perform either 1D, 2D, or 3D scanning or rotation depending on the desired implant pattern on the workpiece **100**. In an alternate embodiment, the sheath modifier **101** translates with respect to the workpiece **100**. Various load and unload mechanisms may be used to place the workpiece **100** on the platen **503**. The platen **503** may be configured to provide backside gas cooling to the workpiece **100** in one instance. The workpiece **100** may be heated or cooled to various temperatures before or during implantation using the platen **503** or some other apparatus.

[0026] FIG. **3** is a SEM photograph of a first three-dimensional structure. Etch residue remains in the three-dimensional structure and there are sidewall defects from the pores. FIG. **4** is a cross-sectional diagram of a second three-dimensional structure. The structure **300**, which may be part of the workpiece **100**, includes a porous low-k material **301**, such as SiCOH, though other materials may be used. The structure **300** also includes a dielectric barrier **302** and a copper layer **303**. Water can enter the porous low-k material **301**. The structure **300** also has material **308**, which may be etch residue, on a sidewall **305**. Variations of the structure **300** are possible and the embodiments herein are not merely limited to the structure **300**.

[0027] The embodiments herein may perform pore sealing on one sidewall, more than one sidewall, or all surfaces (including the bottom) of a structure. FIG. **5** illustrates a first embodiment of pore sealing. Ions **304**, which may correspond to ions **506** or ions **102**, are used to seal pores on a sidewall **305** and form sealing layer **306**. In this embodiment, only one sidewall **305** is processed at a time. In this embodiment, the top of the structure **300** is impacted by ions **304**. If the top of the structure **300** blocks enough of the ions **304**, it may shadow the ions **304** such that not all of the sidewall **305** is processed. This shadowing effect depends on the angle of the ions **304** relative to the shape of the structure **300**. Thus, the ions **304** either may be directed primarily at a particular angle (e.g., +60°) or may have an incident angle range but be shadowed by the structure **300**. These two possibilities are illustrated in the angle distribution **309** (illustrated with the dotted line in FIG. **5**) and angle distribution **310**. Only one of the angle distribution **309** or angle distribution **310** may be used at once.

[0028] Multi-angle control of the ions **304**, such as by modifying a plasma sheath as illustrated in, for example, FIGS. **1-2**, enables the structure **300** to he processed as desired. The sidewall **305** of the structure **300** is amorphized or densified to a particular depth based on the energy and species of the ions **304**. The sealing layer **306** may be formed using a low energy implant or plasma process in one instance. For example, an energy of approximately 100 eV to 750 eV may be used, though other energies are possible. The ions **304** may be inert ions, metal ions, reactive ions, carbon-containing ions, or combinations thereof. The inerts may be Ar, He, Ne, other noble gases, N, or H for example. The reactive ions may be C_xF_y or another halogen-containing species and the metal ions may be Ti or Cu. A combination of the ions **304** may be, for example, an inert used with CH_4 and C_2H_2, N_2 and H_2, Ar and H_2, or Ar and He. Of course, other species, combinations, or mixtures known to those skilled in the art may be used.

[0029] FIG. **6** illustrates a second embodiment of pore sealing. In this embodiment, the sealing layer **306** is formed on both sidewalls **306**. This may be performed simultaneously by forming a spread of ions **304**. The ions **304** may have a bimodal distribution in one example. In one instance, the distribution is not centered at 0° but instead is offset to +25° and −25° with a minimal amount of normal ions at 0°. This is illustrated in angle distribution **311**. Thus, there are few or no ions **304** that implant the bottom **307** of the structure **300** because the spread of the ions **304** is controlled. To generate the ion distribution **311**, in one embodiment the panels of the sheath modifier may be disposed at different distances from the surface of the workpiece (Z) containing the structure **300**.

[0030] FIG. **7** illustrates a third embodiment of pore sealing. In this embodiment, the sealing layer **306** is formed on all surfaces of the structure **300** including the bottom **307**. The ions **304** may be centered around 0° in this embodiment, as illustrated by ion distribution **312**. Thus, the sealing layer **306** is formed on the dielectric barrier **302** and copper layer **303**. In one instance, the sealing layer **306** has a uniform thickness. In another instance, the thickness on the sidewalls **305** or the bottom **307** is different. This may be performed by changing the relative weights of ions **304** in the spread or distribution so that more implant the sidewalls **305** than the bottom **307** or vice versa. The desired distribution of ions **304** may be at least partly based on the material makeup of the low-k material **301**.

[0031] The pore sealing in the embodiments disclosed herein may physically close pores in the structure **300**. These closed pores may be part of the sealing layer **306** in one instance. Thus, the sealing layer **306** may include additional material added to the structure **300**, may be material modification of the structure **300**, or may be a combination of these two. If additional material is added to the structure **300**, it may close or fill any pores that are open. Material modification of the structure **300** may include, for example, mechanisms such as densification, deposition, amorphization, or sputter and redeposition. Any amorphization may be to a controlled depth. Enough energy may be provided using material modification that the pores mechanically close.

[0032] The particular angles of the ions **304** may be configured using, for example, the systems illustrated in FIGS. **1-2**. Of course, other systems known to those skilled in the art also may be used. The systems of FIGS. **1-2** may enable low divergence of the ions **304** other than the desired angle spread. The particular angles or distribution of angles may be selected or controlled in these or other systems.

[0033] In an alternate embodiment, metal ions such as Ti, Cu, W, Al, Co, or other species are implanted into all or some of the sealing layer **306** or structure **300** after or partly during formation of the sealing layer **306**. These metal ions may be used to form a dielectric-metal interface and serve as a nucleation layer or seed layer for a later-formed barrier metal in the structure **300**. If the ions **304** contain the metal ions alone or with another species as part of a combination, then this may be performed in one step. The metal ions also may be implanted during a separate step.

[0034] FIGS. **8-10** illustrate a fourth embodiment of pore sealing. In this embodiment, the structure **300** is scanned with respect to the ions **304**. The ions **304** have an angle spread such that some of the ions **304** impact the structure **300** at non-perpendicular angles. In FIG. **8**, only some of the ions **304** (illustrated with longer lines) reach the sidewalls **305** or bottom **307** of the structure **300**. Thus, a sealing layer **306** is formed on or in only part of the structure **300**. As the structure **300** and ions **304** are scanned with respect to each other, some of the ions **304** form a sealing layer **306** on the bottom **307** of the structure **300** as seen in FIG. **9**. Then in FIG. **10**, ions **304** form a sealing layer **306** on the other sidewall **305**. In one example, the ions **304** have a range of incident angles between +60° and −60° centered about 0°. Initially one of the sidewall **305** sees angles at +60° but not −60°. Over the course of the scan the other sidewall **305** eventually sees angles at −60° but not +60°.

[0035] In one embodiment, the process illustrated in FIGS. **8-10** may be performed in a single scan or pass. In another embodiment, the process illustrated in FIGS. **8-10** may be performed with multiple scans or passes. The relative speed between the ions **304** and the structure **300** or the energy of the ions **304** may vary with each scan or pass.

[0036] Some species of ions **304** can repair or change the properties of the structure **300** in the sealing layer **306**. Repair of damage or imperfections may include mechanisms such as amorphization, sputter and redeposition, or deposition. Certain ions **304** also can render the sealing layer **306** hydrophobic. In one instance, implanting a CF_2^+ ion may render the sealing layer **306** hydrophobic. This may help prevent water from entering the low-k material **301**. The species of ions **304** that are implanted may in part affect the hydrophobicity. Certain energy levels or doses during implantation may modify the structure **300**, which also may in part affect the hydrophobicity. Other mechanisms that affect the hydrophobicity may be possible.

[0037] The ions also may remove any material, such as etch residue, that remains on the sidewall **305**. FIG. **11** illustrates a first embodiment of cleaning. Material **308**, which may be etch residue, is on one of the sidewalls **305**. While only two pieces of material **308** are illustrated, in another embodiment the material **308** coats one or more surfaces of the structure **300**.

[0038] A low energy treatment of ions **400**, which may correspond to ions **506** or ions **102**, into the structure **300** using an inert or reactive species may be used to perform this cleaning process. Systems such as those illustrated in FIGS.

1-2 may be used. This low energy treatment may be approximately 50 eV to 1.5 keV. In one particular example, the low energy treatment was performed at 750 eV. The ions **400** may be the same or different from the ions **304**. This cleaning may entail either physical removal or chemical removal of the material **308**. For example, a noble gas, H, mixture of a noble gas with H, or other species known to those skilled in the art may be used to form ions **400** that enable physical removal of any material **308**. This physical removal may involve a sputtering mechanism. A halogen, a hydride molecule, a halide molecule, or other species known to those skilled in the art may be used to form ions **400** that enable chemical removal of any material **308**. This chemical removal may involve an ion-assisted sputtering or etching mechanism. Combinations of the ions **400** may involve both physical removal with chemical removal of the material **308**.

[0039] The angle control of the ions **400** may enable complete cleaning of the structure **300** because all surfaces may be impacted by the ions **400**. However, the ions **400** may be of varying angle spreads. For example, the ions **400** may have a bimodal distribution to only or primarily clean the sidewalls **305**. In another embodiment, only one sidewall **305** is cleaned or the bottom **307** of the structure **300** is cleaned using the ions **400**.

[0040] The energy of the ions **400** is configured during cleaning to control the depth of removal of material **308**. This energy may be configured to prevent damage to the sidewalls **305**. In one instance, a sensor detects components of the structure **300** in the plasma containing the ions **400**, which may signal that the cleaning process should stop. This energy also may be configured to prevent amorphization or densification of, for example, the low-k material **301**. In one example, material on the sidewalls of a trench was removed using an approximately 750V Ar ion treatment. The material removed was approximately 6 nm thick.

[0041] In one embodiment, cleaning the structure may be performed using a process similar to that illustrated in FIGS. **8-10**. One or more scans or passes may be used to clean the structure **300**. The relative speed between the ions **400** and the structure **300** or the energy of the ions **400** may vary with each scan or pass.

[0042] The structure **300** may be cleaned before pore sealing occurs. This may use one or more different plasmas and may be performed as a chained process without breaking vacuum around the workpiece. Of course, these also may be separate steps where vacuum is broken around the workpiece between steps.

[0043] In one particular embodiment, a cleaning process is performed on the structure **300** prior to sealing pores in the structure **300**. A first plasma is formed using a noble gas, a halogen, H, a hydride molecule, a halide molecule, or other species known to those skilled in the art. This first plasma is used to remove etch residue from one of the sidewalls **305** of the structure **300**. A second plasma is then formed using a carbon-containing species, a noble gas, H, N, or other species known to those skilled in the art. This second plasma also may contain a metal. The second plasma is used to seal pores on one of the sidewalls **305** of the structure **300**. This process also may be performed on multiple sidewalls **305** or the bottom **307** of the structure **300**. While two different ions may be used in these steps, in another example a single plasma of a noble gas or H is used for both the cleaning and pore sealing processes. Various plasma parameters or the implant energy may be changed between the cleaning and pore sealing steps.

[0044] Pore sealing and cleaning also may be used to correct center-to-edge non-uniformity that was caused by etching the structure **300**. In one instance, the dose of the ions may vary over the surface of the workpiece. Thus, the dose in the center of the workpiece may be different from the dose on the edges of the workpiece to compensate for any such non-uniformities.

[0045] For either pore sealing or cleaning, if the structure **300** has four sidewalls, the workpiece containing the structure **300** may be rotated with respect to the ions. For example, the workpiece may be rotated 90° with respect to the ions. This will allow the ions **304** or ions **400** to impact all four sidewalls of such a structure. Three 90° rotations may be used or rotations up to a full 360° may be used. Different ion distributions may be used at different steps if the workpiece is rotated. Of course, the ion angle distribution may be configured to impact all four sidewalls of the structure **300** without rotation. The ions may be extracted to have angle distributions across both dimensions of the surface of the workpiece.

[0046] The pulse during formation of the ions **304** or ions **400** also may affect pore sealing or cleaning. For example, at the beginning of the pulse the ions **304** or ions **400** may all be parallel to the bottom **307** of the structure **300**. Later during the pulse, a wider angle spread of the ions **304** or ions **400** may be formed. This may enable treatment of the sidewalls **305** and bottom **307** of the structure **300**.

[0047] The embodiments disclosed herein can be applied to many different kinds of structures **300** and are not limited just to the structure **300** illustrated herein. For example, these embodiments can be applied to 3D semiconductor structures such as finFETs or trenches, magnetoresistive random-access memory (MRAM) structures, solar structures, microelectromechanical systems (MEMS) structures, or other structures known to those skilled in the art.

[0048] 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. These other embodiments and modifications are intended to fall within the scope of the present disclosure. Furthermore, 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 method of workpiece processing comprising:

generating a plasma having a plasma sheath proximate a surface of said workpiece, wherein said workpiece defines a structure with a plurality of sidewalls;

controlling a shape of a boundary between said plasma and said plasma sheath whereby a portion of said shape is not parallel to a plane defined by a front surface of said workpiece facing said plasma;

directing ions in said plasma toward said workpiece; and

sealing pores on one of said sidewalls with said ions.

2. The method of claim **1**, further comprising sealing pores on another of said sidewalls of said structure with said ions.

3. The method of claim **2**, wherein said structure is a trench that also defines a bottom and further comprising sealing pores on said bottom of said structure with said ions.

4. The method of claim **3**, further comprising scanning said workpiece with respect to said ions during at least one pass.

5. The method of claim **4**, wherein said scanning comprises at least two of said passes and each of said passes has a different speed.

6. The method of claim **4**, wherein said sealing pores occurs on said one of said sidewalls before said bottom and said sealing pores occurs on said bottom before said another of said sidewalls during said scanning.

7. The method of claim **2**, wherein said ions have a bimodal distribution.

8. The method of claim **1**, wherein said ions comprise a metal.

9. The method of claim **1**, wherein said ions form a sealing layer on said structure and said sealing layer is configured to be hydrophobic.

10. The method of claim **1**, wherein said ions comprise at least one of a carbon-containing species, hydrogen, nitrogen, or a noble gas.

11. A method of workpiece processing comprising:

generating a plasma having a plasma sheath proximate a surface of said workpiece, wherein said workpiece defines a structure with a plurality of sidewalls;

controlling a shape of a boundary between said plasma and said plasma sheath whereby a portion of said shape is not parallel to a plane defined by a front surface of said workpiece facing said plasma;

directing ions in said plasma toward said workpiece; and

removing a material from one of said sidewalls of said structure with said ions.

12. The method of claim **11**, further comprising removing said material from another of said sidewalls of said structure with said ions.

13. The method of claim **12**, wherein said structure is a trench that also defines a bottom and further comprising removing said material from said bottom of said structure with said ions.

14. The method of claim **13**, further comprising scanning said workpiece with respect to said ions in at least one pass.

15. The method of claim **14**, wherein said scanning comprises at least two of said passes and said ions have a different energy during each of said passes.

16. The method of claim **14**, wherein said removing occurs on said one of said sidewalls before said bottom and said removing occurs on said bottom before said another of said sidewalls during said scanning.

17. The method of claim **12**, wherein said ions have a bimodal distribution.

18. The method of claim **11**, wherein said ions comprise at least one of a noble gas, a halogen, hydrogen, a hydride molecule, or a halide molecule.

19. The method of claim **11**, wherein said material comprises etch residue.

20. A method of workpiece processing comprising:

generating a first plasma having a first plasma sheath proximate a surface of said workpiece, wherein said workpiece defines a trench with a plurality of sidewalls;

controlling a first shape of a first boundary between said first plasma and said first plasma sheath whereby a portion of said first shape is not parallel to a plane defined by a front surface of said workpiece facing said first plasma;

directing first ions in said first plasma toward said workpiece;

removing etch residue from one of said sidewalls of said trench with said first ions;

generating a second plasma having a second plasma sheath proximate said surface;

controlling a second shape of a second boundary between said second plasma and said second plasma sheath whereby a portion of said second shape is not parallel to said plane;

directing second ions in said second plasma toward said workpiece; and

sealing pores on one of said sidewalls with said second ions.

21. The method of claim **20**, wherein said first ions comprise at least one of a noble gas, a halogen, hydrogen, a hydride molecule, or a halide molecule and said second ions comprise at least one of a carbon-containing species, a noble gas, hydrogen, nitrogen, or a metal.

22. The method of claim **20**, wherein said first ions and said second ions comprise a noble gas and wherein said first plasma is said second plasma.

23. The method of claim **20**, wherein a vacuum is formed around said workpiece prior to generating said first plasma and said vacuum is maintained through said sealing.

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