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(54) **RADIO FREQUENCY TUNED SUBSTRATE BIASED PHYSICAL VAPOR DEPOSITION APPARATUS AND METHOD OF OPERATION**

(76) Inventors: **Youming Li**, San Jose, CA (US); **Jeffrey Birkmeyer**, San Jose, CA (US)

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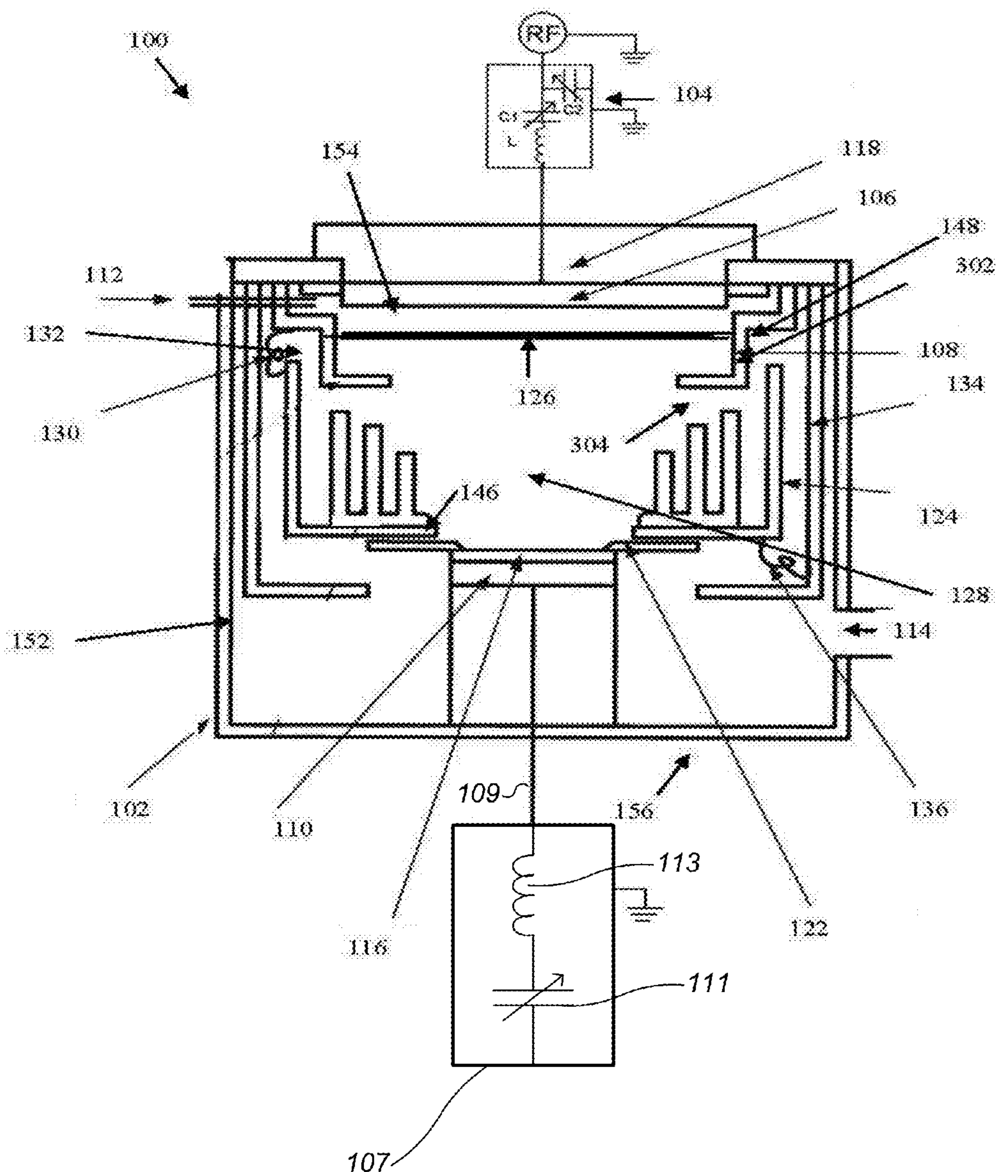
(57) **ABSTRACT**

A method of physical vapor deposition includes applying a radio frequency signal to a cathode in a physical vapor deposition apparatus, wherein the cathode includes a sputtering target, electrically connecting a chuck in the physical vapor deposition apparatus to an impedance matching network, wherein the chuck supports a substrate, and wherein the impedance matching network includes at least one capacitor, and depositing material from the sputtering target onto the substrate.



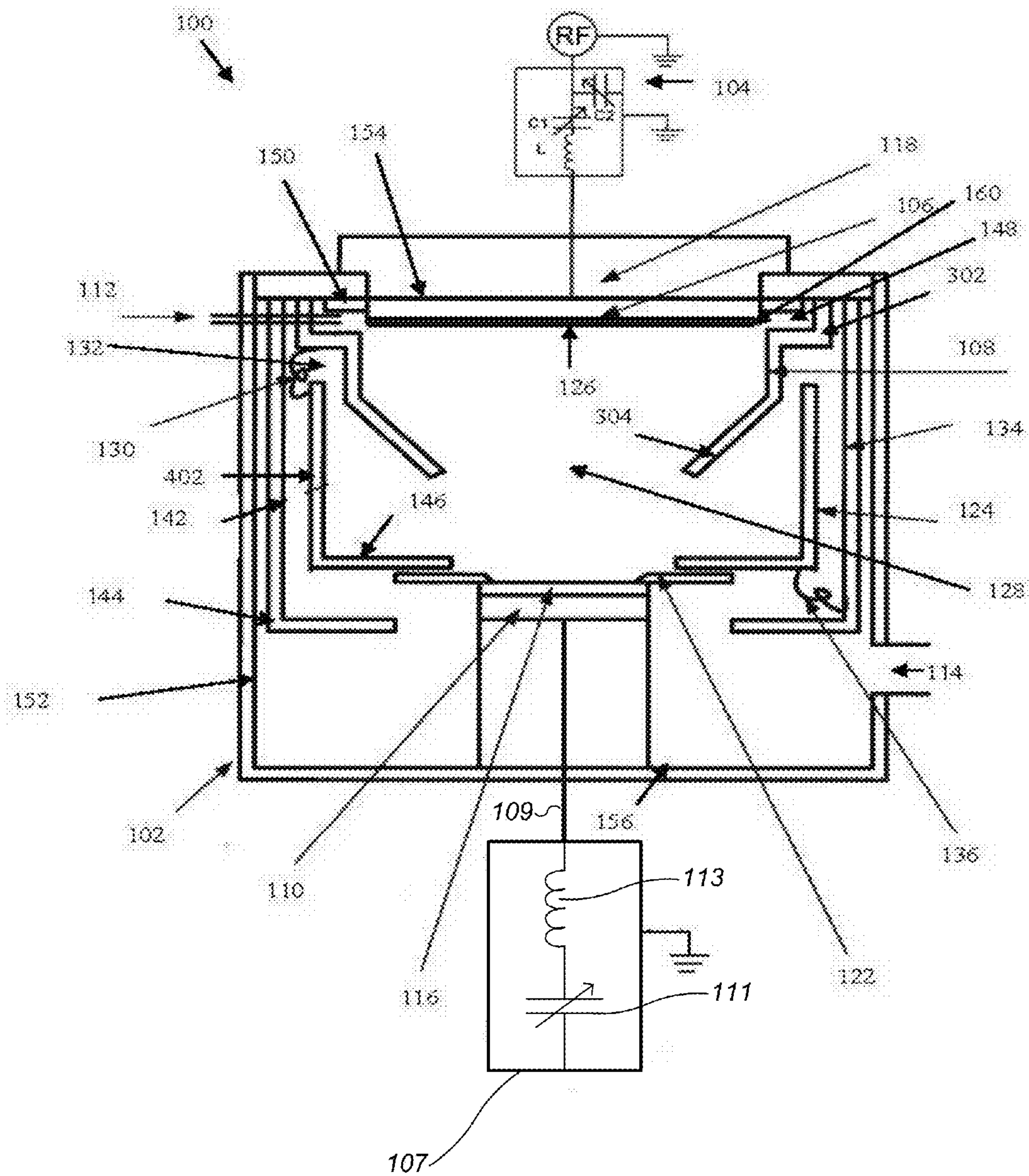


FIG. 1

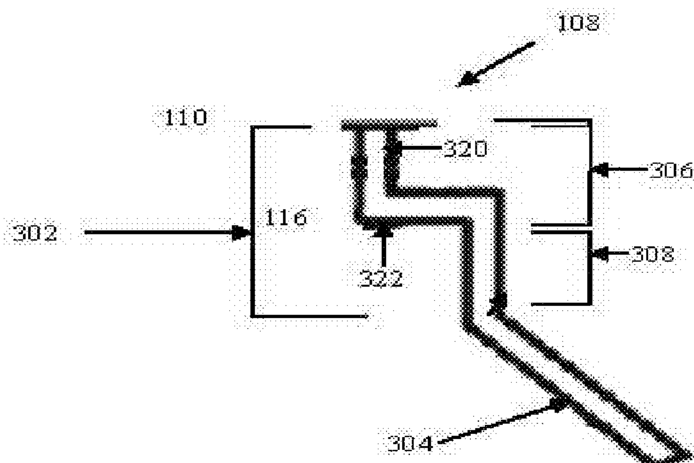


FIG. 2A

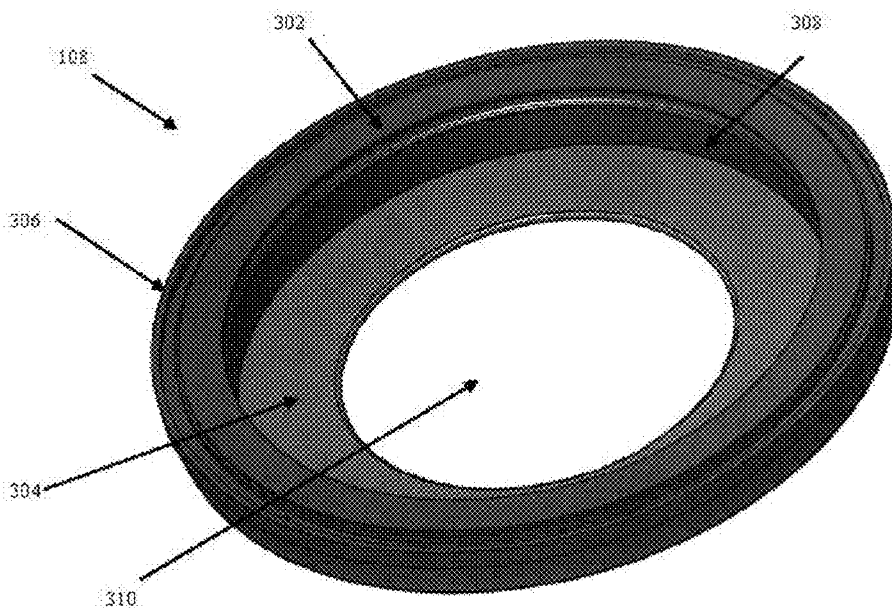


FIG. 2B

FIG. 3

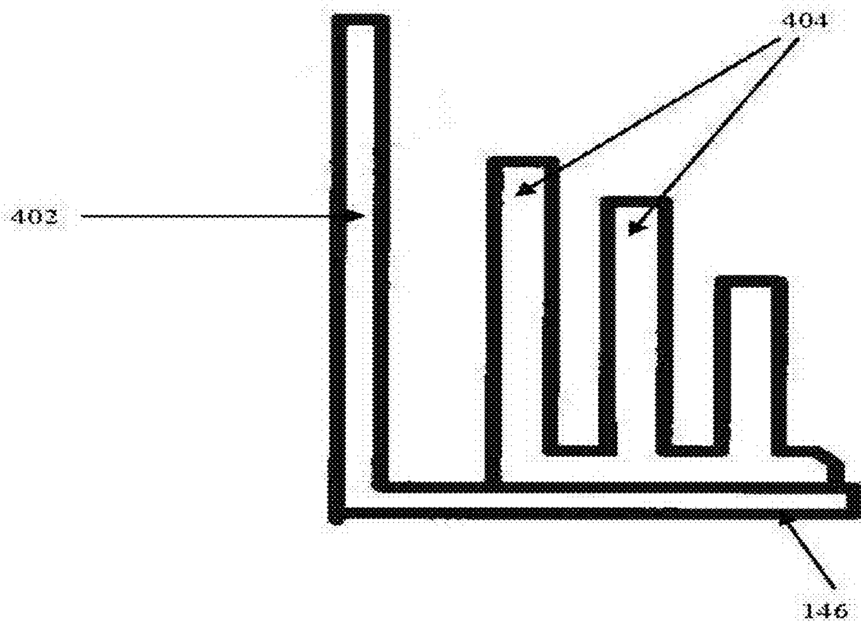


FIG. 4A

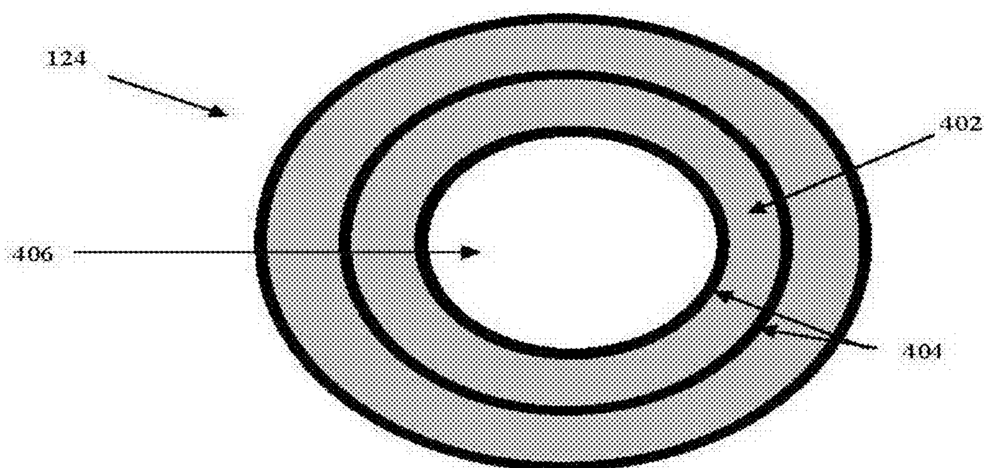


FIG. 4B

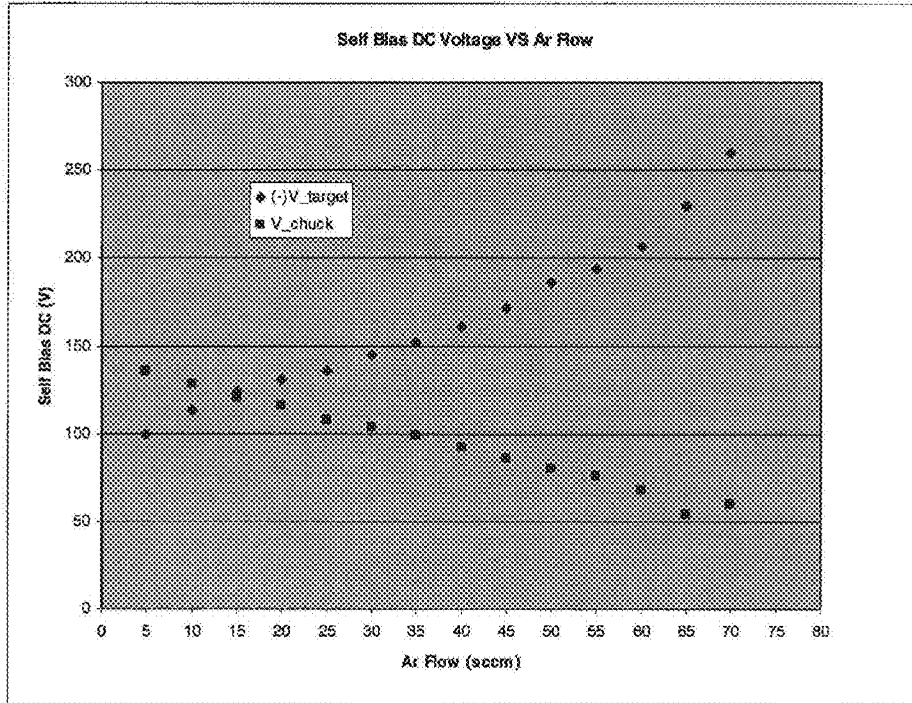


FIG. 5

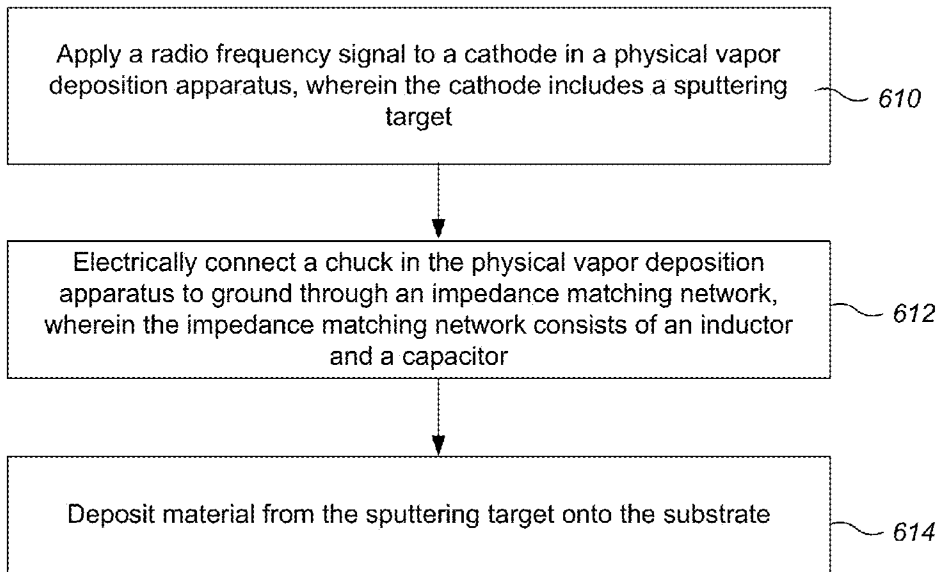


FIG. 6

RADIO FREQUENCY TUNED SUBSTRATE BIASED PHYSICAL VAPOR DEPOSITION APPARATUS AND METHOD OF OPERATION

TECHNICAL FIELD

[0001] The present disclosure relates generally to radio frequency (RF) sputtering physical vapor deposition (PVD).

BACKGROUND

[0002] Radio frequency sputtering PVD is a method for depositing a thin film on a substrate. The substrate is placed in a vacuum chamber facing a target that is connected to an RF power supply. When the RF power is initiated, a plasma is formed. Positive gas ions are pulled to the target surface, strike the target, and remove target atoms by momentum transfer. The removed target atoms then deposit on the substrate to form a thin film layer. During physical vapor deposition, it can be important to control the properties of the deposited thin film.

SUMMARY

[0003] In general, in one aspect, a method of physical vapor deposition includes applying a radio frequency signal to a cathode in a physical vapor deposition apparatus, wherein the cathode includes a sputtering target electrically connecting a chuck in the physical vapor deposition apparatus to ground through an impedance matching network, wherein the chuck supports a substrate, and wherein the impedance matching network consists of an inductor in series with a capacitor, and depositing material from the sputtering target onto the substrate.

[0004] Implementations can include one or more of the following features. A capacitance of the capacitor may be selected or adjusted such that a positive self bias direct current voltage is generated on the substrate. The positive self bias direct current voltage may be between 10 and 100V, e.g., between 60 and 75V. Selecting or adjusting the capacitance of the capacitor may include selecting or adjusting the capacitance to have a magnitude of between 10 pF and 1200 pF. An inductance of the inductor may have a magnitude of between 300 and 600 micro Henry. The radio frequency signal may have a radio frequency power having a magnitude of between 1000 W and 5000 W. The target may be a dielectric material, e.g., lead zirconate titanate ("PZT"). Depositing material from the sputtering target onto the substrate may include creating a thin film having a thickness of between 2000 Å and 10 μm. The thin film may have a thickness of between 2 μm and 4 μm. Depositing material from the sputtering target onto the substrate comprises creating a thin film having a (100) crystalline structure.

[0005] In general, in another aspect, a physical vapor deposition apparatus includes a vacuum chamber having side walls, a cathode inside the vacuum chamber, wherein the cathode is configured to include a sputtering target, a radio frequency power supply configured to apply a radio frequency signal to the cathode, an anode inside and electrically connected to the side walls of the vacuum chamber, a chuck inside the vacuum chamber, wherein the chuck is configured to support a substrate, and an impedance matching network electrically connecting the chuck to ground, wherein the impedance matching network consists of an inductor in series with a capacitor.

[0006] Implementations can include one or more of the following features. The inductor may be connected between the capacitor and the chuck. The capacitor may be connected between the inductor and ground. The capacitor may have a capacitance between 10 pF and 1200 pF. The inductor may have an inductance between 300 and 600 micro Henry. The target may be a dielectric material, e.g., lead zirconate titanate ("PZT"). The cathode may include comprises a magnetron assembly. The impedance matching network may have a resonant frequency about 1 to 2 MHz lower than a frequency of the of the radio frequency signal applied to the cathode. The impedance matching network may have a resonant frequency about 1 to 2 MHz higher than a frequency of the of the radio frequency signal applied to the cathode.

[0007] A simplified LC circuit can be more stable and easier to tune to provide the desired bias. Since the simplified LC circuit includes fewer components, and there are fewer sources of variation, and consistency in tuning can be improved. In addition, the simplified LC circuit has a single path for current; it should not experience circular currents.

[0008] Creating a positive self bias DC voltage by connecting an impedance network to the chuck can result in the formation of thin films having advantageous piezoelectric and dielectric properties, such as PZT thin films having a dielectric constant in the range of 1000 to 1700, a high d31 coefficient, and a high break-down voltage. Likewise, creating a negative self bias using an impedance matching network can be advantageous for re-sputtering, or etching, of deposited thin films, particularly PZT thin films.

[0009] The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, aspects, and advantages will become apparent from the description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** is a schematic of a cross-section of an embodiment of a physical vapor deposition apparatus including an impedance matching network.

[0011] FIG. **2**A is an enlarged view of the extended anode of FIG. **1**

[0012] FIG. **2**B shows a perspective view of the extended anode of FIG. **2**A.

[0013] FIG. **3** is a schematic of a cross-section of an embodiment of a physical vapor deposition apparatus including an impedance matching network and an extended shield.

[0014] FIG. **4**A is an enlarged view of the extended shield of FIG. **3**

[0015] FIG. **4**B is a schematic view of the top of an extended shield of FIG. **4**A.

[0016] FIG. **5** is an example graph of self bias DC voltage vs. air flow for a chuck and a cathode.

[0017] FIG. **6** is an example flow chart of a process for depositing a thin film on a substrate using a physical vapor deposition having an impedance matching network connected to a chuck.

[0018] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0019] When RF physical vapor deposition, or sputtering, is used to create a thin film on a substrate, it can be difficult to control the properties of the deposited film. By altering the DC self bias of the substrate, for example by connecting the

chuck to ground through an impedance matching network to the chuck, the properties of the film can be better controlled.

[0020] Referring to FIG. **1**, a physical vapor deposition apparatus **100** can include a vacuum chamber **102**. The vacuum chamber **102** can be cylindrical and have side walls **152**, a top surface **154**, and bottom surface **156**. A magnetron assembly **118** can be located at the top of vacuum chamber **102**. The magnetron assembly **118** can include a set of magnets having alternating magnetic poles. The magnetron assembly **118** can be stationary or can rotate about an axis perpendicular to a radius of vacuum chamber **102**. The physical vapor deposition apparatus **100** can further include an RF power supply **104** and a corresponding load matching network, which can match the impedance of the power supply **104** to that of vacuum chamber **102**.

[0021] A cathode assembly **106** can be housed inside and near the top surface **154** of vacuum chamber **102**. Cathode assembly **106** can include a target **126** that can be bonded to a metallic backing plate (not shown). The target **126** can be generally circular, with an outer edge **160**. The target can be made of, for example, a dielectric material such as lead zirconate titanate ("PZT"). Cathode **106** can act as an electrode for RF current when RF power is applied by RF power supply **104**. Cathode assembly **106** can be electrically isolated from the vacuum chamber **102** by an insulator ring **150**.

[0022] A substrate support or chuck **110** to support one or more substrates can be housed inside vacuum chamber **102** near, but spaced above, the bottom surface **156** of the vacuum chamber **102**. The chuck **110** can include a substrate holding mechanism **122**, such as a substrate clamping plate, configured to hold substrate **116** such that substrate **116** can be coated with a thin film during the PVD process. Substrate **116** can be, for example, a microelectromechanical system (MEMS) wafer. A temperature control (not shown) can be located on the chuck **110** to, for example, maintain the temperature of substrate **116** at a prescribed temperature between 25° C. and 800° C., such as 650° C. to 700° C.

[0023] In one embodiment, shown in FIG. **1**, the chuck **110** can be electrically connected to ground through an impedance matching network **107**. The chuck **110** itself can be considered isolated or floating relative to ground, depending on the properties of the impedance matching network). For example, the chuck **110** can be isolated from ground for DC current, but still electrically connected to ground in terms of RF current, with RF impedance depending of the inductance and capacitance of the circuit elements. No secondary RF power supply is connected to chuck **110**. An input terminal **109** can electrically connect the impedance matching network **107** to the chuck **110**.

[0024] The impedance matching network **107** can include a variable tune capacitor **111** and an inductor **113**. The variable tune capacitor **111** and an inductor **113** can be connected in series. The variable tune capacitor **111** can be electrically connected to ground. The inductor **113** can be electrically connected between the input terminal **109** and the variable tune capacitor **111**. The inductor can have an inductance of about 300 to 600 micro Henry. The impedance matching network **107** can be tuned to a frequency of about 5 to 100 MHz.

[0025] In some implementations, the impedance matching network **107** consists of only the variable tune capacitor **111** and the inductor **113**. Having additional electrical elements can introduce additional sources of variation in the electrical performance of the apparatus **100**, and therefore a simplified LC circuit with only the variable tune capacitor **111** and the inductor **113** can be more stable and easier to tune to provide the desired bias. In addition, the simplified LC circuit has a single path for current from the input terminal **109** to ground, so it should not experience circular currents.

[0026] An anode **108** can also be housed inside vacuum chamber **102**. The anode **108** can provide a counterpart electrode to the cathode **106** so as to provide an RF current return path. In some embodiments, the anode **108** and the chuck **110** can be the same component. In other embodiments, however, as described herein, the anode **108** may be electrically isolated from the chuck **110** so that the chuck **110** can be floating or held at a different potential than the anode **108**. The anode can be grounded, i.e., electrically connected in this context (the anode need not be actually connected to ground), to the vacuum chamber sidewalls **152**.

[0027] Referring to FIGS. **1** and **2A-2B**, the anode **108** can have an annular body **302** and can be extended by an annular flange **304** projecting inwardly from the annular body **302**. The annular flange **304** can define an intended discharge space **128** (see FIG. **1**) in which plasma can be retained during the PVD process. As shown in FIGS. **1C** and **2**, the annular body **302** can comprise an upper portion **306** and a lower portion **308**. The upper portion **306** can be closer to the cathode **106** than the lower portion **308**. The spacing **148** (see FIG. **1**) between the upper portion **306** and the top surface **154** of vacuum chamber **102** can be configured to prevent plasma formation therebetween.

[0028] Shown in FIG. **2A**, a top portion **320** of the upper portion **306** of the anode can extend vertically, e.g., it can be a cylinder, from the top surface **154** of the vacuum chamber. The top portion **320** can be parallel to and surround edge **160** of target **126**. A bottom portion **322** of the upper portion **306** can extend, e.g. perpendicularly, inwardly from an inside surface at the bottom edge of top portion **320**. Bottom portion **322** can extend substantially horizontally inwardly, e.g., as a horizontal ring. The inner radius of the ring **322** can have approximately the same radius as the outer edge **160** of the target **126**. Lower portion **308** can extend from a lower surface and an inner edge of bottom portion **322**. Lower portion **308** can extend perpendicularly from bottom portion **322** and can extend vertically, e.g. as a cylinder. An inside wall of the cylinder can have approximately the same radius as the outer edge **160** of the target **126**. Although not shown, another projection can extend downwardly from the lower surface of bottom portion **322** near the outside edge such that a gap is formed for the placement of an upper portion of shield **124**.

[0029] The annular flange **304** can project inwardly from the lower portion **308** such that at least some of the flange extends below target **126**. As shown in FIG. **1**, the flange **304** can extend inwardly and downwardly from the annular body **302** such that the radius of the flange **304** closer to the cathode **106** is larger than the radius of the flange **304** further from the cathode **106**, i.e. the flange can have a funnel shape. Alternatively, as shown in FIG. **3**, the flange **304** can extend horizontally from the annular body **302**. In some embodiments, the flange **304** extends from the lowermost edge of the lower portion **308**.

[0030] An annular opening **310** (see FIG. **2B**) can have approximately the same radius as the chuck **110** such that there is no substantial shadowing of the substrate **116** during the PVD process, i.e. such that the entire top surface of substrate **116** can be covered with a thin film.

[0031] The vacuum chamber **102** can also include an RF shield **124** to protect the sidewalls of vacuum chamber **102** from being coated with thin film material. The shield **124** can be made, for example, of non-magnetic stainless steel or aluminum and can be grounded to the sidewalls **152** of the vacuum chamber **102**.

[0032] In some implementation shown in FIG. **1**, the shield **124** can include an annular body **402** that extends vertically, e.g. in a cylindrical shape. A horizontally extending flange **146** can extend inwardly from a bottom edge of the annular body **402**. The horizontally extending flange **146** can be located near the bottom of the vacuum chamber **102** and can extend past the flange **304** to surround and partially vertically overlap the lower portion **308** of the anode **108**. In some embodiments, the vertically extending flange **146** can extend into a gap between the lower portion **308** of the anode **108** and substrate holding mechanism **122**. The flange **146** can partially horizontally overlap the substrate holding mechanism **122**.

[0033] The annular opening **406**, in FIG. **4**B, inside the annular flange **146** of the shield **124** can have approximately the same radius as the chuck such that there is no substantial shadowing of the substrate **116**. A gap **132** can exist between the shield **124** and the anode **108** in order to permit process gas to be evacuated from the intended discharge space **128**.

[0034] In some embodiments, shown in FIGS. **3** and **4**A-**4**B the shield can be extended such that a set of concentric annular projections **404** projects from the annular flange **146**, for example towards the cathode **106**. The annular projections **404** can extend parallel to annular body **402**. As shown in FIGS. **3** and **4**A-**4**B, the height of the annular projections **404** can increase along a radius from the center of the vacuum chamber **102** to the sidewalls **152**. The annular body **402** can have a height that is taller than the height of the annular projections **404**.

[0035] The physical vapor deposition apparatus **100** can further include an electrically conductive body **130**, for example a strap, that directly connects the anode **108** and the shield **124**. The electrically conductive body **130** can be flexible and can be configured to permit gas flow between the anode **108** and shield **124**. For example, the electrically conductive body **130** can be a mesh or a wire strap. The electrically conductive body **130** can be made, for example, of copper or aluminum.

[0036] There can be a number of connections between the anode **108** and shield **124**. For example, the electrically conductive body **130** can be connected to the anode **108** and the shield **124** at at least four points. The electrically conductive body **130** can be connected between a lower surface of the anode **108** and a top portion of the shield **124**. The electrically conductive body **130** can also be connected between a top portion of the anode **108** and an outer surface of the shield **124**.

[0037] The physical vapor deposition apparatus **100** can further include a secondary chamber shield **134**. The chamber shield can be made of, for example, non-magnetic stainless steel or aluminum. An upper portion of the chamber shield can be positioned between the anode **108** and the sidewalls of the vacuum chamber **102**. A lower portion of the chamber shield **134** can be positioned between the sidewalls of the vacuum chamber **102** and shield **124**. The chamber shield **134** can be concentric with and surround shield **124** and/or anode **108**. The height of the chamber shield **134** can be equal to or greater than the height of shield **124**. The chamber shield **134** can include a vertical annular body **142** and an annular flange **144** (shown in FIG. **1**) extending inwardly from the annular body **142**, e.g., from the lower edge of the vertical annular body **142**. The annular flange **144** of the chamber shield **134** can extend below the annular flange **146** of shield **124**, but can have a radial length that is shorter than the annular flange **146**. The annular flange **144** can be closer to the bottom of the chamber than the chuck **110**. The inner edge of the flange **144** of the chamber shield can be vertically aligned with the outer edge of the chuck **110**.

[0038] The physical vapor deposition apparatus **100** can further include a process gas inlet **112**, process gas control devices (not shown), a vacuum outlet **114**, pressure measurement and control devices (not shown), and vacuum pumps (not shown). The chamber shield **134** can be configured such that process gases may still be pumped into and out of the vacuum chamber **102**. For example, the chamber shield **134** may be short enough so as not to cover a process gas inlet **112** or the vacuum outlet **114**. Alternatively, the chamber shield **134** may have holes (not shown) in locations corresponding to the locations of the process gas inlet **112** and vacuum outlet **114**. Furthermore, the chamber shield **134** can be separately removable and can be cleaned easily and reused over time.

[0039] The chamber shield **134** can be electrically bonded to shield **124** with an electrically conductive body **136**. The electrically conductive body **136** can be of similar material and shape as electrically conductive body **130**. Thus, the electrically conductive body **136** can be configured to permit gas flow between shield **124** and chamber shield **134**. Likewise, the electrically conductive body **136** can be composed of mesh, can be one or more straps, and can comprise copper or aluminum. Moreover, the electrically conductive body **136** can be connected between a bottom surface of shield **124** and an inner surface of chamber shield **134**.

[0040] During the sputtering or PVD process, gases, such as argon and oxygen, are supplied through the process gas inlet **112** at a flow rate of 10-200 sccm/0.2 to 4 sccm, such as 10 to 60 sccm/0.5 to 2 sccm. A vacuum pump (not shown) maintains a base vacuum, for example, of 10^{-7} Ton or below, and a plasma operation pressure, for example, of 0.5 mTorr to 20 mTorr, particularly 4 mTorr, through vacuum outlet **114**. When the RF power from RF power supply **104** is applied on the order of 500 W to 5,000 W, for example 2000W to 4,000 W, or 3000 W, to the cathode assembly **106**, the target **126** is negatively biased and the anode **108** is positively biased, causing plasma to form in the intended discharge space **128** between the cathode **106** and the anode **108**. The magnetron assembly **118** creates a magnetic field of, for example, 50 Gauss to 400 Gauss, such as 200 Gauss to 300 Gauss, at and near the front surface of the cathode **106**. The magnetic field confines the electrons to a helical motion parallel to the front surface of target **126**.

[0041] The negative selfbias DC voltage on target **126**, in conjunction with the electrons confined near the surface of target **126** by the magnetic field, facilitates bombardment of the target **126** by energetic positive ions of the plasma. Momentum transfer causes neutral target material, such as PZT molecules, to dislocate from the target **126** and deposit on substrate **116**, creating a thin film on substrate **116**. The resulting thin film can have a thickness of 2000 Å to 10 μm, for example 2-4 μm.

[0042] In the embodiment shown in FIGS. **1** and **3**, when RF power supply **104** is applied to cathode **106**, and an impedance matching network **107** is connected to the chuck **110**, a

DC self bias can develop on the substrate. The capacitances of the variable tune capacitor **111** can be selected or adjusted, for example to between 10 pF and 1200 pF, such that the desired DC self bias is developed on the substrate. As in the embodiment described above, the substrate can have a resulting negative, positive, or zero charge, for example −300V to +300V, in particular −100V to +100V.

[0043] As an example, a graph of a positive self bias of a substrate vs. gas flow is shown in FIG. **5**.

[0044] The charge of the DC self bias can be controlled by the amount of RF power applied to the substrate **116** in addition to the impedance of the impedance matching network **107**. In general, to get a positive DC self-bias with the impedance matching network, the resonant frequency should be set slightly smaller than the critical resonant frequency. For example, the resonant frequency can be set 1-2 MHz smaller than the critical resonant frequency. The frequency of the RF power to the cathode can be the same as the critical resonant frequency, e.g., 13.56 MHz. With the resonant frequency of the impedance matching network set slightly smaller than critical resonant frequency, a positive DC self-bias, e.g. of 10V-100V, such as 60V, can develop on the substrate **116**. On the other hand, the impedance matching network **107** should not be set to have a resonant frequency that is the same as or too close to that of the target RF frequency, because this may resulting in an unstable condition where the bias DC voltage oscillates between positive and negative.

[0045] A positive voltage results in attracting and accelerating electrons from the plasma to the surface of substrate **116**. Those electrons with sufficient energies will cause modification of the sputtered material properties without causing any substantial re-sputtering due to their low momentum. Moreover, a positive voltage can prevent plasma ions from bombarding the surface of substrate **116** and thus avoid etching of the surface. A negative voltage can cause plasma ions to be attracted and accelerated towards the substrate, which can result in re-sputtering of the surface. Re-sputtering can be useful, for example, for etching the substrate surface. For a given implementation, such as chamber configuration, gas composition and flow rate, pressure, magnetic field, and voltage, experimentation may be required to obtain the RF power and impedance values of the elements in the impedance matching network **107** necessary to generate a positive or negative self bias voltage.

[0046] A flow chart for a process of forming a thin film using the apparatus of FIGS. **1** and **3** is shown in FIG. **6**. A radio frequency signal is applied to a cathode in a physical vapor deposition apparatus (step **610**). The cathode includes a sputtering target. A chuck supporting a substrate in the physical vapor deposition apparatus is electrically connected to an impedance matching network (step **612**). The impedance matching network consists of an inductor and a capacitor. Material from the sputtering target is deposited onto the substrate (step **614**). Although not shown in FIG. **6**, the process can further include selecting or adjusting a capacitance of the capacitors such that a positive self bias DC voltage is generated on the substrate.

[0047] Use of either an impedance matching network in a physical vapor deposition apparatus can be particularly advantageous for the creation of piezoelectric thin films, such as PZT thin films. In particular, use of an impedance matching network **107** to create an indirect bias on the substrate or deposited film is advantageous because an external DC bias cannot be directly applied to a dielectric material such as PZT. Furthermore, the impedance matching network **107** can modify the electric field strength in the dark space between substrate **116** and the intended discharge space **128**, thereby changing the re-sputtering effects of the deposition process. In contrast, while directly biasing a substrate can shift the overall system voltages into an offset value to both the target and/or the substrate, it cannot modify the dark space between substrate **116** and the intended discharge space **128**.

[0048] If PZT films are sputtered using a physical vapor deposition apparatus having a substrate with a positive DC self bias as described herein, the electrons that are attracted to the surface of the substrate can cause electron heating, which can increase the mobility of the thin films atoms. Further, the electrons on the surface can help reject plasma ions from the surface to avoid re-sputtering of the surface. As a result, a film having a preferable structure, for example, a thin film having a (100) crystalline structure, can be formed. Such films sputtered on a substrate having a positive DC self bias, for example a PZT film having a Perovskite PZT (100)/(200) crystal orientation, can have advantageous dielectric and piezoelectric properties, such as a dielectric constant in the range of 1000 to 1700, a high d31 coefficient (e.g., about 250 pm/V or greater), and a high break-down strength (e.g., 1 MV/cm or greater). For example, PZT thin films having a (100) crystal orientation can be used as MEMS devices, such as actuators for ink dispensing devices.

[0049] A number of embodiments have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of what is described. For example, it should be understood that terms of positioning and orientation (e.g., top, vertical) have been used to describe the relative positioning and orientation of components within the physical vapor deposition apparatus, but the physical vapor deposition apparatus itself can be held in a vertical or horizontal orientation or some other orientation. As another example, the steps of the exemplary flow chart of FIG. **6** may be performed in other orders, some steps may be removed, and other steps may be added. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A method of physical vapor deposition comprising:

applying a radio frequency signal to a cathode in a physical vapor deposition apparatus, wherein the cathode includes a sputtering target;

electrically connecting a chuck in the physical vapor deposition apparatus to ground through an impedance matching network, wherein the chuck supports a substrate, and wherein the impedance matching network consists of an inductor in series with a capacitor; and

depositing material from the sputtering target onto the substrate.

2. The method of claim **1**, further comprising selecting or adjusting a capacitance of the capacitor such that a positive self bias direct current voltage is generated on the substrate.

3. The method of claim **2**, wherein the positive self bias direct current voltage is between 10 and 100V.

4. The method of claim **3**, wherein the positive self bias direct current voltage is between 60 and 75V.

5. The method of claim **2**, wherein selecting or adjusting the capacitance of the capacitor comprises selecting or adjusting the capacitance to have a magnitude of between 10 pF and 1200 pF.

6. The method of claim **5**, wherein an inductance of the inductor has a magnitude of between 300 and 600 micro Henry.

7. The method of claim **1**, wherein the radio frequency signal has a radio frequency power having a magnitude of between 1000 W and 5000 W.

8. The method of claim **1**, wherein the target comprises a dielectric material.

9. The method of claim **8**, wherein the dielectric material comprises lead zirconate titanate ("PZT").

10. The method of claim **1**, wherein depositing material from the sputtering target onto the substrate comprises creating a thin film having a thickness of between 2000 Å and 10 μm.

11. The method of claim **10**, wherein the thin film has a thickness of between 2 μm and 4 μm.

12. The method of claim **1**, wherein depositing material from the sputtering target onto the substrate comprises creating a thin film having a (100) crystalline structure.

13. A physical vapor deposition apparatus comprising:

a vacuum chamber having side walls;

a cathode inside the vacuum chamber, wherein the cathode is configured to include a sputtering target;

a radio frequency power supply configured to apply a radio frequency signal to the cathode;

an anode inside and electrically connected to the side walls of the vacuum chamber;

a chuck inside the vacuum chamber, wherein the chuck is configured to support a substrate; and

an impedance matching network electrically connecting the chuck to ground, wherein the impedance matching network consists of an inductor in series with a capacitor.

14. The apparatus of claim **13**, wherein the inductor is connected between the capacitor and the chuck.

15. The apparatus of claim **13**, wherein the capacitor is connected between the inductor and ground.

16. The apparatus of claim **13**, wherein the capacitor has a capacitance between 10 pF and 1200 pF.

17. The apparatus of claim **13**, wherein the inductor has an inductance between 300 and 600 micro Henry.

18. The apparatus of claim **13**, wherein the target comprises a dielectric material.

19. The apparatus of claim **18**, wherein the dielectric material comprises lead zirconate titanate ("PZT").

20. The apparatus of claim **13**, wherein the cathode further comprises a magnetron assembly.

21. The apparatus of claim **13**, wherein the impedance matching network has a resonant frequency about 1 to 2 MHz lower than a frequency of the of the radio frequency signal applied to the cathode.

22. The apparatus of claim **13**, wherein the impedance matching network has a resonant frequency about 1 to 2 MHz higher than a frequency of the of the radio frequency signal applied to the cathode.

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