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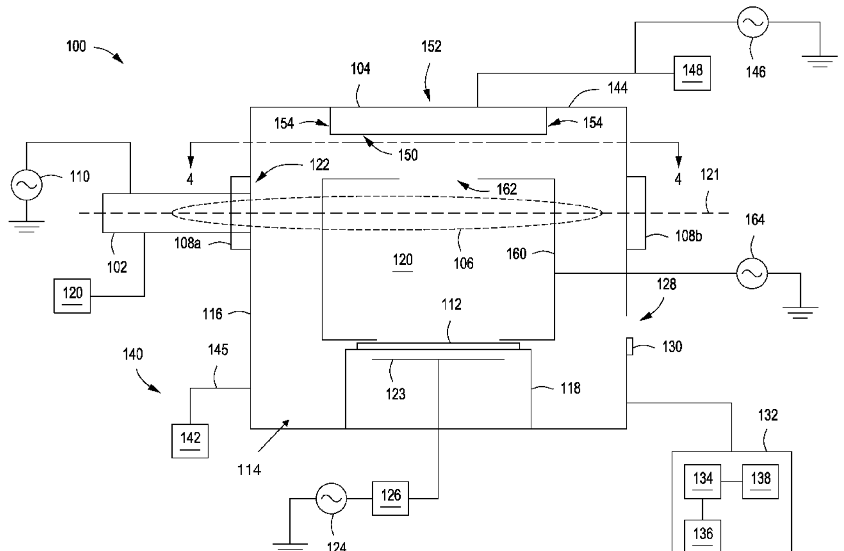

FIG. 1

(57) **Abstract**: Apparatus for processing substrates are provided herein. In some embodiments, a physical vapor deposition chamber may include a chamber body having a first portion to retain a target comprising material to be deposited on a substrate, and a scanning substrate support disposed within the chamber body to support the substrate opposite the target during processing, wherein the scanning substrate support is configured to move the substrate laterally in the chamber body during a deposition process with respect to the target.

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PHYSICAL VAPOR DEPOSITION SYSTEM

FIELD

[0001] Embodiments of the present invention generally relate to substrate processing equipment.

BACKGROUND

[0002] Conventional physical vapor deposition processes (PVD) typically utilize a magnetron to confine a plasma proximate a target having a material to be sputtered from the target and subsequently deposited on a substrate. However, by using a magnetron, varying power densities may be formed across the surface of the target, causing high thermal stresses and/or uneven erosion of the target, resulting in non-uniform deposition and uneven wearing of the target. The uneven wearing of the target may reduce the effective life of a target, thus requiring more frequent maintenance of the process chamber and reducing productivity. Furthermore, when using a magnetron behind the target, the target material may shunt some or all of the magnetic field needed to generate and confine the plasma at the target surface.

[0003] In addition, the introduction of new device architectures and new materials imposes ever increasing challenges for deposition processes, especially in combination with increasing wafer sizes. This is particularly evident in novel memory devices such as magnetic RAM (MRAM) that require deposition of complex stacks of very thin magnetic layers with sub-nm film thickness uniformity requirements. Conventional sputtering of these materials is challenging due to the fact that magnetic target materials partially shunt the magnetic field generated by the magnetron. As a result only relatively thin targets can be used, which significantly impacts productivity. Furthermore, the erosion profile on the target surface changes through target life due to localized strengthening of the magnetic field as the target thins (pinching effect), causing wafer-to-wafer (WTW) and within-wafer (WIW) film thickness uniformity drifts. Current approaches to this problem include long-throw sputtering sources. However, these sources suffer from poor target utilization since a very large fraction of the sputtered material is lost to the chamber shields, making them largely impractical for 300/450mm wafer sizes.

[0004] Other challenges arise when depositing binary or ternary compounds due to often encountered preferential sputtering of one of the elements. Extensive conditioning is often needed and limits productivity. Often the required material composition is difficult to manufacture and composition of the deposited film drifts as the target is eroded.

[0005] Therefore, the inventors have provided an improved physical vapor deposition apparatus for depositing materials atop a substrate.

SUMMARY

[0006] Apparatus for processing substrates are provided herein. In some embodiments, a physical vapor deposition chamber may include a chamber body having a first portion to retain a target comprising material to be deposited on a substrate, and a scanning substrate support disposed within the chamber body to support the substrate opposite the target during processing, wherein the scanning substrate support is configured to move the substrate laterally in the chamber body during a deposition process with respect to the target.

[0007] In some embodiments, a physical vapor deposition chamber may include a chamber body having a processing volume defined within the chamber body and a first portion to retain a target comprising material to be deposited on a substrate, wherein the target is comprised of a plurality of target strips, and wherein each target strip in the plurality of target strips is comprised of a different material, a movable aperture disposed between the plurality of target strips and the substrate, wherein the movable aperture has an opening that exposes a first surface of one target strip in the plurality of target strips to a surface of the substrate; and a substrate support disposed within the chamber body to support the substrate opposite the target during processing.

[0008] In some embodiments, a method for forming a stack of multiple layers of different materials on a substrate using a target comprised of a plurality of target strips, wherein each target strip in the plurality of target strips is a different material, includes forming a plasma between the target and the substrate supported by a scanning substrate support, moving an aperture to expose a first surface of a first

target strip of the plurality of target strips to a deposition surface of the substrate, applying a bias power to the first target strip to initiate deposition of a first material of the first target strip onto the deposition surface of the substrate, moving the substrate support laterally with respect to the target to uniformly deposit the first material on the deposition surface of the substrate, moving the aperture to expose a second surface of a second target strip of the plurality of target strips to the deposition surface of the substrate, applying a bias power to the second target strip to initiate deposition of a second material of the second target strip onto the first material deposited on the substrate, and moving the substrate support laterally with respect to the target to uniformly deposit the second material on the first material deposited on the substrate.

[0009] Other and further embodiments of the present invention are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments of the present invention, briefly summarized above and discussed in greater detail below, can be understood by reference to the illustrative embodiments of the invention depicted in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0011] Figure 1 depicts a physical vapor deposition chamber suitable for use with an apparatus for providing a plasma to process chamber having a target disposed therein in accordance with some embodiments of the present invention.

[0012] Figures 2A-2B depicts an apparatus for providing a plasma to a process chamber in accordance with some embodiments of the present invention.

[0013] Figures 3A-3B depicts an apparatus for providing a plasma to process chamber in accordance with some embodiments of the present invention.

[0014] Figure 4 depicts a target suitable for use with an apparatus for providing a plasma to a process chamber in accordance with some embodiments of the present invention.

[0015] Figure 5 depicts a cross section of an exemplary Spin Transfer Torque Magnetic RAM (STT-MRAM) stack that can be processed in accordance with some embodiments of the present invention.

[0016] Figures 6A and 6B respectively depict schematic top perspective and side views of an apparatus including a scanning substrate support for use in a process chamber in accordance with some embodiments of the present invention.

[0017] Figures 7A and 7B respectively depict schematic front and side views of an apparatus including another embodiment of a scanning substrate support for use in a process chamber in accordance with some embodiments of the present invention.

[0018] Figures 8A and 8B respectively depict schematic top perspective and side views of an apparatus including a plurality of target strips and a movable aperture for use in a process chamber in accordance with some embodiments of the present invention.

[0019] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. The figures are not drawn to scale and may be simplified for clarity. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0020] Embodiments of the present invention provide apparatus for depositing materials atop substrates using physical vapor deposition (PVD) processes (*e.g.*, sputtering). Embodiments of the inventive apparatus may advantageously provide a more uniform deposition of target material compared to conventional substrate supports and conventional targets, thereby allowing the target material to be sputtered from the target and deposited atop a substrate uniformly and reducing redeposition of sputtered target material on the target surface, thus improving defect performance of the deposited layers.

[0021] Figure 1 depicts a schematic, cross-sectional view of a physical vapor deposition (PVD) chamber in accordance with some embodiments of the present invention. The PVD chamber may be any type of PVD chamber suitable to facilitate the fabrication of magnetic material deposition RAM (MRAM), for example, from substrates of a desired size, for example such as circular wafers (*e.g.*, 200 or 300 mm semiconductor substrates), square panels (*e.g.*, for display, solar, light emitting diode (LED), and other similar applications), or the like. Examples of suitable PVD chambers include the ALPS® Plus and SIP ENCORE® PVD process chambers, both commercially available from Applied Materials, Inc., of Santa Clara, California. Other process chambers from Applied Materials, Inc. or other manufacturers may also benefit from the inventive apparatus disclosed herein.

[0022] In some embodiments, the process chamber 100 may generally comprise a chamber body 116 defining an inner volume 114 that may include a processing volume 120. The processing volume 120 maybe defined, for example, between a substrate support 118 for receiving a substrate 112 disposed within the process chamber 100 and a sputtering source, such as a target 104 disposed opposite the substrate support 118. A conduit 102 (described more fully below) configured to form a plasma 106 is coupled to the processing volume 120 via an opening 122 in the chamber body 116. Although process chamber 100 is shown in an orientation where the substrate and target are supported and processed in a horizontal position, in some embodiments, the process chamber can be configured to support and process the substrate and target in a vertical position, as shown in Figures 7A and 7B, discussed below.

[0023] In some embodiments, the substrate support 118 may include a mechanism that retains or supports the substrate 112 on the surface of the substrate support 118, such as an electrostatic chuck, a vacuum chuck, a substrate retaining clamp, or the like. In some embodiments, the substrate support 118 may include an electrode 123 coupled to one or more power sources, for example, such as a bias power source 124, as shown in Figure 1. In some embodiments, the bias power source 124 may be coupled to the electrode 123 through one or more matching networks (one matching network 126 shown). The biased substrate is used for controlling the species flux and/or ion energy proximate the substrate surface. Alternatively or in combination, in some embodiments, the one or more power sources may include a DC or pulsed DC source.

[0024] In addition, in some embodiments, the substrate support 118 may include mechanisms for controlling the substrate temperature (such as heating and/or cooling devices, not shown).

[0025] The substrate 112 may enter the process chamber 100 via an opening 128 in a wall of the chamber body 116. The opening 128 may be selectively sealed via a slit valve 130, or other mechanism for selectively providing access to the interior of the chamber through the opening 128. In some embodiments, the substrate support 118 may be coupled to a lift mechanism (not shown) that may control the position of the substrate support 118 between a lower position (as shown) suitable for transferring substrates into and out of the chamber via the opening 118 and a selectable upper position suitable for processing. The process position may be selected to maximize process uniformity for a particular process. When in at least one of the elevated processing positions, the substrate support 118 may be disposed above the opening 128 to provide a symmetrical processing region. In some embodiments, the substrate support 118 may move (*e.g.*, scan) the substrate 112 laterally in the process chamber 116 with respect to the target 104. For example, the substrate support 118 may move the substrate 112 with respect to the target to control the deposition of materials sputtered from the target 104 onto the surface of the substrate 112.

[0026] In some embodiments, the process chamber 100 may include an exhaust system 140 for evacuating gases and/or maintaining a desired pressure within the inner volume 114 of the process chamber 100. The exhaust system 140 may generally comprise a vacuum pump 142 coupled to the process chamber 100 via a conduit 145. In some embodiments, the exhaust system 140 may comprise other components (not shown in Figure 1) to facilitate evacuating or maintaining a desired pressure in the process chamber, for example, such as a pumping plenum, valves, or a foreline.

[0027] In some embodiments, one or more shields 160 may be provided, for example between the target 104 and a substrate 112, and may define an opening 162 that defines the deposition area for the substrate and may reduce unwanted deposition on interior surfaces of the process chamber body 116. The shields 160 generally protect the interior surfaces of the process chamber body 116 from undesirably collecting deposited materials. The shields 116 may be mounted in the desired areas of the process chamber 100 in any suitable manner. In some embodiments, the shield 160 includes openings (not shown) to permit the plasma 106 to be introduced into the deposition area of the process chamber.

[0028] In some embodiments, the shields 160 may be electrically biased, for example, via power source 164. Biasing the shields 160 may advantageously densify deposited materials on the shield 160, thereby reducing particle generation which further advantageously helps reduce substrate defects. These defects are often caused by particles flaking off the chamber shields due to poor adhesion of material deposited at a low angles of incidence. By actively biasing shields 160 above a sputtering threshold the material on the shields 160 can be densified periodically (for example, by Argon ion bombardment or other types of densification methods) to increase adhesion of deposited material and reduce flaking. In addition, biasing above sputter threshold would remove material as well, and could be used to clean off excess material.

[0029] A controller 132 may be provided and coupled to various components of the process chamber 100 to control the operation of the various components. The controller 132 includes a central processing unit (CPU) 134, a memory 136, and support circuits 138. The controller 132 may control the process chamber 100 directly, or via computers (or controllers) associated with particular process chamber and/or support system components. The controller 132 may be one of any form of general-purpose computer processor that can be used in an industrial setting for controlling various chambers and sub-processors. The memory, or computer readable medium, 136 of the controller 132 may be one or more of readily available memory such as random access memory (RAM), read only memory (ROM), floppy disk, hard disk, optical storage media (*e.g.*, compact disc or digital video disc), flash drive, or any other form of digital storage, local or remote. The support circuits 138 are coupled to the CPU 134 for supporting the processor in a conventional manner. These circuits include cache, power supplies, clock circuits, input/output circuitry and subsystems, and the like.

[0030] The target 104 generally comprises one or more materials to be deposited on the substrate 112 during sputtering. For example, in some embodiments, the target 104 may comprise one or more of a dielectric material (*e.g.,* AlO_2, SiO_2, or the like), a metallic material (copper, tungsten, or the like), a ceramic material, magnetic materials (*e.g.,* Co, Ni, or the like), or the like. The target 104 may be coupled to a surface of the process chamber, for example, such as a side wall, or lid 144. In some embodiments, a backing plate (not shown) may be coupled to the target 104, for example, to improve structural stability of the target 104. The backing plate may comprise a conductive material, such as copper-zinc, copper-chrome, or the same material as the target 104, such that RF and/or DC power can be coupled to the target 104 via the backing plate. Alternatively, the backing plate may be non-conductive and may include conductive elements (not shown) such as feed structure, electrical feedthroughs, or the like, for coupling RF and/or DC power to the target 104.

[0031] In some embodiments, the target 104 may comprise a substantially homogenous material. In some embodiments, the target 104 may comprise an array of a plurality of target strips and a movable aperture (as shown in Figures 8A and 8B and described in more detail below). Each target strip may be comprised of a different material that can be sequentially sputtered by appropriately biasing the individual target strips by bias power sources and positioning the movable aperture the expose the desired target (as shown in Figures 8A and 8B and described in more detail below).

[0032] The target 104 may be any shape or size suitable to deposit the target materials on the substrate 112 in a desired process. The inventors have observed that in conventional sputtering processes utilizing a planar target 104, erosion of the target 104 may be non-uniform. Specifically, areas proximate the center 152 of the target 104 may have a higher erosion rate than areas proximate the ends 154 of the target 104. The difference in erosion rates may result in low utilization of target material, increased redeposition of sputtered target material and defects in the resultant deposited layers. Accordingly, in some embodiments the target 104 may comprise a non-planar shape, for example such as a convex shape, as shown in Figure 4. By provided the target 104 having a non-planar shape, the distance between portions of the target 104 and the plasma 106 may be varied, thereby varying the erosion rate across the target 104. In addition, the distance between portions of the target 104 and the substrate 112 may also be varied, thereby varying the deposition rate across the substrate 104.

[0033] For example, in some embodiments, a target 104 to plasma 106 distance 403 and the target 104 to substrate 112 distance 410 proximate the center 408 of the target 104 may be greater than a target 104 to plasma 106 distance 404 and the target 104 to substrate 112 distance 412 proximate the ends 406 of the target 104. In such embodiments, the erosion rate of the target 104 proximate the ends 406 of the target 104 may be greater than the erosion rate proximate the center 408 of the target, thus providing a uniform erosion of the target material during processing. In addition, the deposition rate of the target 104 materials proximate the ends 406 of the target 104 may be greater than the deposition rate proximate the center 408 of the target, thus providing a more uniform deposition of the target 104 materials atop the substrate 112 during processing.

[0034] In some embodiments, the target 104 thickness may be varied to further offset a non-uniform erosion of the target materials as discussed above. For example in some embodiments, the target 104 may comprise a first thickness 402 of proximate the ends 406 of the target 104 and a second thickness 414 proximate the center 408 of the target 104. In such embodiments, the first thickness 402 may be about 1 to about 6 mm and the second thickness 402 may be about 2 to about 10 mm.

[0035] Referring back to Figure 1, in some embodiments, one or more power sources (RF power source 146 and DC power source 148 shown) may be coupled to the process chamber 100 to supply RF and/or DC power to the target 104. For example, the DC power source 148 may be utilized to apply a negative voltage, or bias, to the target 104. In some embodiments, RF energy supplied by the RF power source 146 may range in frequency from about 2MHz to about 60 MHz, or, for example, non-limiting frequencies such as 2 MHz, 13.56 MHz, 27.12 MHz, or 60 MHz can be used. In some embodiments, a plurality of RF power sources may be provided (*i.e.*, two or more) to provide RF energy in a plurality of the above frequencies.

[0036] The inventors have observed that in conventional PVD (*e.g.* sputtering) processes the sputtering rates of some materials (*e.g.*, the target 104 materials described above) may be limited by the thermal conductivity of the target material. The inventors have further observed that while sputtering rates are proportional to the power density (*e.g.* supplied by the RF power source 146 and DC power source 148) applied to the target 104, some target materials may fracture if the temperature of the surface 150 of the target 104 exceed certain limits, resulting in limited achievable deposition rates, decreased throughput and reduced the effective life of a target 104. In addition, in conventional PVD processes using a magnetron the magnetron may create varying power densities across the surface 150 of the target 104, which causes high thermal stresses and/or uneven erosion of the target 104, resulting in non-uniform deposition and uneven wearing of the target 104, which further reduces the effective life of a target 104. Accordingly, the inventors have discovered that by generating a homogeneous plasma across the surface 150 of the target 104 without the presence of a magnetron, a more uniform power density across the surface 150 of the target 104 may be achieved, thereby reducing thermal stresses on the target 104 and creating a more uniform erosion of the target 104 during deposition. For example, in some embodiments, the plasma 106 may be formed in a remote plasma source (such as the conduit 102) coupled to the chamber body 116, and extracted into the inner volume 114 of the process chamber 100 proximate the target 104. Examples of remote plasma sources may be found in U.S. Application Serial No. 13/069,205, entitled “DIELECTRIC DEPOSITION USING A REMOTE PLASMA SOURCE”, filed on March 22, 2011, by inventors Ralf Hofmann, et al.

[0037] In some embodiments, the conduit 102 may be coupled to the processing volume 114 of the process chamber 100 via an opening 122 in the chamber body 116. The conduit 102 may be disposed in any position suitable to create the plasma 106 in a desired location with respect to the target 104. For example, in some embodiments, the conduit 102 may be coupled to a sidewall 117 of the process chamber 100 and disposed between the target 104 and substrate support 118, as shown in Figure 1. In such embodiments, a plane of the major axis 121 of the conduit 102 may be substantially parallel to the target 104. By positioning the conduit 102 in such a manner, the conduit 102 may provide a plasma 106 to the processing volume 120 proximate the target 104, wherein the plasma 106 has a uniform plasma region across the surface 150 of the target 104.

[0038] The conduit 102 may be fabricated from any suitable material. For example, in some embodiments the conduit 102 may be fabricated from quartz, Alumina Al2O3, a glass composite (such as a low-thermal-expansion borosilicate glass, for example, PYREX®), or the like. The conduit 102 may comprise any shape and dimensions suitable to produce the plasma 106 having a desired shape and plasma density distribution. For example, in some embodiments, the conduit 102 may comprise a circular cross or a rectangular cross section.

[0039] In addition, the inventors have observed that by using plasma 106 formed in a remote plasma source (such as the conduit 102) coupled to the chamber body 116, the sputter rate is determined by the number of ions extracted from the conduit 102, while the energy of the sputtered material is related to the applied voltage on the target. Thus, in embodiments consistent with the present invention, sputter rate (*e.g.*, ion generation) and energy of the sputtered material target bias (target bias) are largely independent. This advantageously enables a substantially wider process window for the deposition process.

[0040] In some embodiments, a gas supply 120 may be coupled to the conduit 102 to provide one or more process gases to the interior of the conduit 102. The one or more process gases may comprise any gases suitable for performing a desired process, for example, such as a PVD process, in the process chamber 100. For example, in some embodiments, the process gases may comprise argon (Ar), helium (He), nitrogen (N_2), or the like. In some embodiments, nitrogen (N_2) or oxygen (O_2) may be provided for reactive substrate processes, although alternatively or in combination, such reactive gases may be provided near the substrate.

[0041] In some embodiments, a power supply (*e.g.*, RF power source 110) may be coupled to the conduit 102 to provide a sufficient power to the process gas to form the plasma 106. The power supply may provide any amount or power at any desired frequency to form the plasma 106. For example, in some embodiments, the power supply may be capable of producing up to about 3,000 W, or in some embodiments, up to about 5,000 W at a frequency of about 2 MHz and or about 13.56 MHz or a higher frequency, such as 27 MHz and/or 60 MHz.

[0042] In some embodiments, the power supply may provide power to the process gas via an inductive coil element, for example such as an antenna 202, as shown in Figures 2A-B. In such embodiments, the antenna 202 may be disposed proximate the conduit 102 in any manner suitable to provide sufficient power to form the plasma 106. For example, in some embodiments, the antenna 202 may be wrapped around the conduit 102, for example as shown in Figure 2A. Alternatively, in some embodiments, the antenna 202 may be disposed on one or more sides (*e.g.,* a top surface 204) of the conduit 102 and arranged in a circular or recursive pattern, for example, as shown in Figure 2B.

[0043] Referring back to Figure 1, in some embodiments, one or more magnets (two magnets 108a, 108b shown) may disposed proximate the process chamber 100 to facilitate extracting the plasma 106 from the conduit 102. The one or more magnets may be any type of magnets, for example such as permanent magnets, electromagnets, or the like. In some embodiments, more than one set of magnets may be utilized. For example, in some embodiments, a first pair 322 of magnets 108a,d may be disposed proximate a first side 327 of the process chamber 100 and a second pair 324 of magnets 108b,c may be disposed proximate a second side 325 of the process chamber 100, as shown in Figure 3A. In embodiments where the magnets 108a,b,c,d are electromagnets, a power supply 306, 308, 310, 312 may be coupled to each of the magnets 108a,b,c,d to supply a current to form and control the magnitude of a magnetic field to facilitate extraction of the plasma 106 from the conduit. The power supply 306, 308, 310, 312 may be any type of power supply suitable to provide the current to the magnets 108a,b,c,d, for example such as a DC power supply. In some embodiment, magnets 108 a,b and magnets 108 c,d may each be a single ring magnet surrounding the conduit.

[0044] In some embodiments, one or more additional magnetic components may be disposed about the process chamber 102 to facilitate forming the plasma 106 into a desired shape. For example, in some embodiments, a plurality of additional magnets (first additional magnet 302 and second additional magnet 304 shown) may be disposed about the process chamber 100, as shown in Figure 3A. The plurality of additional magnets may be any type of magnet, for example such as a permanent magnet or electromagnet. In embodiments where the plurality of additional magnets are electromagnets, a power supply 314, 316 may be coupled to each of the additional magnets 302, 304 to supply a current to form and control the magnitude of a magnetic field to facilitate forming the plasma 106 into the desired shape. The power supply 314, 316 may be any type of power supply suitable to provide the current to the magnets 302, 304, for example such as a DC power supply.

[0045] The additional magnets 302, 304 may be positioned about the process chamber 100 in any configuration suitable to form the plasma 106 into the desired shape. For example, in some embodiments, the first additional magnet 302 may be disposed between a first magnet (*e.g.,* magnet 108d) of the first pair 322 of magnets and a first magnet (*e.g.,* magnet 108c) of the second pair 324 of magnets proximate a third side 326 of the process chamber 100 and the second additional magnet 304 may be disposed between a second magnet (*e.g.,* magnet 108a) of the first pair 322 of magnets and a second magnet (*e.g.,* magnet 108b) of the second pair 324 of magnets proximate a fourth side 328 of the process chamber 100. Although only two additional magnets 302, 304 are shown in the figure, any amount of additional magnets may be disposed about the process chamber 102 in any configuration suitable to form the plasma 106 into the desired shape.

[0046] Alternatively, or in combination, in some embodiments, the one or more additional magnetic components may comprise one or more yokes (two yokes 318, 320 shown). The yokes 318, 320 may comprise any material suitable to form a magnetic field within the process chamber 100, for example such as iron and other magnetic alloys such as magnetic steel, or the like. The yokes 318, 320 may be positioned about the process chamber 100 in any configuration suitable to form the plasma 106 into the desired shape. For example, in some embodiments, a first yoke (*e.g.,* yoke 318) may be disposed between the first magnet (*e.g.,* magnet 108d) of the first pair 322 of magnets and the first magnet (*e.g.,* magnet 108c) of the second pair 324 of magnets proximate the third side 326 of the process chamber 100 and the second yoke (*e.g.,* yoke 320) may be disposed between a second magnet (*e.g.,* magnet 108a) of the first pair 322 of magnets and the second magnet (*e.g.,* magnet 108b) of the second pair 324 of magnets proximate the fourth side 328 of the process chamber 100. Although only two yokes 318, 320 are shown in the figure, any amount of yokes may be disposed about the process chamber 102 in any configuration suitable to form the plasma 106 into the desired shape.

[0047] In operation, the plurality of additional magnets 302, 304 or yokes 318, 320 create a magnetic field in a direction perpendicular to the major axis 121 of the conduit 102. The magnetic field formed by the plurality of additional magnets 302, 304 or yokes 318, 320 spreads the plasma 306 in a direction perpendicular to the major axis 121 of the conduit 102 to form a desired shape, thereby providing a more uniform coverage of the target 104 and the substrate 112. The desired shape may be any shape needed to provide uniform coverage of any type of substrate. For example, in some embodiments, the plasma 106 may have a substantially circular cross section to facilitate providing uniform plasma 106 coverage across a circular substrate 112, such as shown in Figures 3A-B.

[0048] Figure 5 shows a cross section of an exemplary Spin Transfer Torque Magnetic RAM (STT-MRAM) stack 500 that can be processed by embodiments consistent with the present invention. Various magnetic materials used (*e.g.*, CoFeB, and the like) have stringent demands on film thickness uniformity on a substrate (*e.g.*, +/- 0.1 nm across 300 mm and 450 mm wafers). In addition, binary and ternary compounds of very specific composition are used to create such an exemplary stack as shown in Figure 5. Embodiments consistent with the present invention presented herein can advantageously process substrates to produce the exemplary STT-MRAM stack shown in Figure 5. Note that the STT-MRAM stack shown in Figure 5 is merely one example of the different types of memory or other types of devices or structures that may be processed by embodiments consistent with the present invention.

[0049] Referring to Figures 6A and 6B, further embodiments consistent with the present invention are shown. The embodiments described with respect to Figures 6A and 6B may be used in process chamber 100 and in conjunction with the components described above with respect to Figure 1. Figures 6A and 6B include a scanning (*i.e.*, moving) substrate support 618 that moves the substrate 612 laterally in direction 672 with respect to the target 604. The scanning substrate support 618 may include a mechanism that retains or supports the substrate 612 on the surface of the scanning substrate support 618 as described above with respect to Figure 1. Scanning substrate support 618 may support substrates having crossections of various geometric shapes including, but not limited to, circular, ovate, square, rectangular, and the like. One or more magnets (two magnets 608a, 608b shown) may be used to facilitate extracting the plasma 606 from the conduit 602 as described above with respect to Figure 1. In the exemplary embodiment depicted in Figures 6A and 6B, a target 604 is comprised of material biased via power source 670. Figure 6B includes an optional shield 660 having an opening 662. Figure 6A includes a conduit 602 configured to form a plasma 606. By moving substrate 612 laterally beneath the generated plasma 606 using scanning substrate support 618, a more uniform deposition of materials from the target 604 onto the substrate 612 can be achieved.

[0050] Figures 7A and 7B depict a scanning substrate support 718 disposed in a vertical process chamber 700 in accordance with some embodiments of the present invention. The scanning substrate support 718 retains or supports the substrate 712 on a support surface of the scanning substrate support 718 as described above with respect to Figure 1. The substrate 712 is held vertically and in a position opposite the target assembly, which is also disposed in a vertical orientation (*e.g.*, having a primary processing surface substantially vertical and parallel to the surface of the substrate. The scanning substrate support 718 may be moved laterally in direction 786 with respect to target 704 of a target assembly 778. In some embodiments the scanning substrate support 718 may be moved laterally via an actuator 784. The scanning substrate support 718 may move along and/or be supported by a plurality of rollers 780 which rotate around roller axis 782. In other embodiments, the scanning substrate support 718 may be movably coupled to a track, robotic arm, or other type of conveyor to assist in moving the scanning substrate support lateral into and within process chamber body 716. Figure 7A includes a conduit 702 configured to form a plasma 706 as described above with respect to Figure 1. One or more magnets (two magnets 708a, 708b shown) may be used to facilitate extracting the plasma 706 from the conduit 702 as described herein in other embodiments.

[0051] Referring to Figures 8A and 8B, further embodiments consistent with the present invention are shown. The embodiments described with respect to Figures 8A and 8B may be used in process chamber 100 and in conjunction with the components described above with respect to Figure 1. Figures 8A and 8B include a target array comprising target strips 804a-c and a movable aperture 866 disposed between the target array and the processing volume of the process chamber. In some embodiments, the target strips 804a-c are comprised of different materials from each other such that the material can be co-sputtered or sequentially sputtered by appropriately biasing the individual target strips by bias power sources 876a-c. In other embodiments, the target strips 804a-c may be coupled to a single power source (not shown) such that each of the target strips 804a-c are biased simultaneously. In some embodiments, sputtering of each of the plurality of target strips 804a-c occurs at a different bias power.

[0052] The movable aperture 866 may advantageously only expose the target materials that are to be sputtered. Covering the adjacent target sections that are not to be sputtered prevents re-deposition on these target materials and thus prevents cross-contamination. In some embodiments, two or more target materials may be exposed and individually powered to be sputtered. This advantageously enables combinatorial sputtering (*e.g.*, sputtering materials simultaneously that combine on the substrate surface) without the limitations of alloy targets such as preferential sputtering, or deposition of multi-layer stacks.

[0053] In some embodiments, the movable aperture 866 includes an opening 868 that is smaller than shield opening 862 of the shield 860. The movable aperture 866 may be coupled to an actuator 870 that moves the movable aperture 866 laterally in direction 874. The position of the opening 868 of the movable aperture 866 may be controlled to selectively expose a surface of at least one, or in some embodiments, just one, of the target strips to a surface of the substrate (*e.g.*, to the processing volume of the process chamber). The opening of the aperture may be sized substantially equal to the width of each of the target strips such that it can expose one target strip surface while shielding the substrate 812 from the other target strips. That is, the movable aperture 866 would only expose the target strip from which material is currently sputtered (i.e., one of 804a, 804b, or 804c, in the embodiments depicted in Figures 8A-B). Covering the adjacent target strips with movable aperture 866 advantageously prevents re-deposition on these target strips and thus cross-contamination.

[0054] Although three exemplary target strips are shown in Figures 8A and 8B, the number of target strips used can be more or less than three. The thickness of each target strips is typically about 1 mm to about 15 mm, although higher thicknesses may be used. Furthermore, in embodiments consistent with the present invention, the materials used for the target strips may be a combination of one or more of a dielectric material (*e.g.,* AlO_2, SiO_2, or the like), a metallic material (copper, tungsten, or the like), a ceramic material, magnetic materials (*e.g.,* Co, Ni, or the like), or the like.

[0055] Figures 8A and 8B include a conduit 802 that configured to form a plasma 806 as described herein in embodiments of the present invention. A substrate support 818 is shown which may optionally be configured to move laterally in direction 872. The substrate support may retain or support a substrate 812 on a support surface of the substrate support 818 as described above with respect to Figure 1. One or more magnets (two magnets 808a, 808b shown) may be used to facilitate extracting the plasma 806 from the conduit 802 as described above with respect to Figure 1.

[0056] Thus, apparatus for depositing materials atop substrates using physical vapor deposition (PVD) processes have been provided herein. The inventive apparatus may advantageously provide a more uniform plasma coverage of a target as compared to conventionally shaped plasma fields and conventional substrate supports, thereby allowing the target material to be sputtered from the target and deposited atop a substrate uniformly and reducing redeposition of sputtered target material on the target surface, thus improving defect performance of the deposited layers.

[0057] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof.

Claims:

1. A physical vapor deposition chamber, comprising:

a chamber body having a processing volume defined within the chamber body and a first portion to retain a target comprising material to be deposited on a substrate; and

a scanning substrate support disposed within the chamber body to support the substrate opposite the target during processing, wherein the scanning substrate support is configured to move the substrate laterally in the chamber body during a deposition process with respect to the target.

2. The physical vapor deposition chamber of claim 1, further comprising:

a conduit coupled to the processing volume of the chamber body, wherein a plane of a major axis of the conduit is substantially parallel to the target, and disposed between the target and the substrate support, when the target is present;

a gas supply coupled to the conduit to supply a process gas to the conduit; and

a power supply coupled to the conduit to couple sufficient power to the process gas to form a plasma.

3. The physical vapor deposition chamber of claim 1, wherein the scanning substrate support is configured to support the substrate horizontally along a bottom surface of the substrate, such that deposition of materials from the target to be deposited on a top surface of the substrate occurs in a substantially vertical direction.

4. The physical vapor deposition chamber of claim 1, wherein the scanning substrate support is configured to support the substrate vertically opposite the target such that deposition of materials from the target to be deposited on the substrate occurs in a substantially horizontal direction.

5. The physical vapor deposition chamber of any of claims 1 to 4, wherein the scanning substrate support is coupled to an actuator configured to move the

scanning substrate support laterally with respect to the target during substrate processing.

6. The physical vapor deposition chamber of any of claims 1 to 4, wherein the scanning substrate support is laterally moved parallel to the target such that materials from the target are deposited uniformly over the substrate without the use of a magnetron.

7. The physical vapor deposition chamber of any of claims 1 to 4, wherein the scanning substrate support is movably supported by at least one of (a) one or more rollers, (b) one or more bearings, or (c) one or more actuator arms.

8. The physical vapor deposition chamber of any of claims 1 to 4, wherein the target is comprised of a plurality of target strips, and wherein each target strip in the plurality of target strips is comprised of a different material.

9. The physical vapor deposition chamber of claim 8, wherein each of the plurality of target strips is electrically coupled to at least one power source such that each target strip can be independently electrically biased.

10. The physical vapor deposition chamber of claim 8, wherein the plurality of target strips are electrically coupled to the same power source such that each target strip is simultaneously electrically biased.

11. The physical vapor deposition chamber of claim 10, wherein sputtering of each of the plurality of target strips occurs at a different bias power.

12. The physical vapor deposition chamber of claim 8, further comprising:

a movable aperture disposed between the plurality of target strips and the substrate, wherein the movable aperture has an opening that exposes a first surface of one target strip in the plurality of target strips to a surface of the substrate.

13. The physical vapor deposition chamber of claim 12, wherein the movable aperture is coupled to an actuator which moves the aperture to a desired position.

14. A physical vapor deposition chamber, comprising:

a chamber body having a processing volume defined within the chamber body and a first portion to retain a target comprising material to be deposited on a substrate, wherein the target is comprised of a plurality of target strips, and wherein each target strip in the plurality of target strips is comprised of a different material;

a movable aperture disposed between the plurality of target strips and the substrate, wherein the movable aperture has an opening that exposes a first surface of one target strip in the plurality of target strips to a surface of the substrate; and

a substrate support disposed within the chamber body to support the substrate opposite the target during processing.

15. The physical vapor deposition chamber of claim 14, wherein the substrate support is a scanning substrate support that moves the substrate laterally in the chamber body during a deposition process with respect to the target.

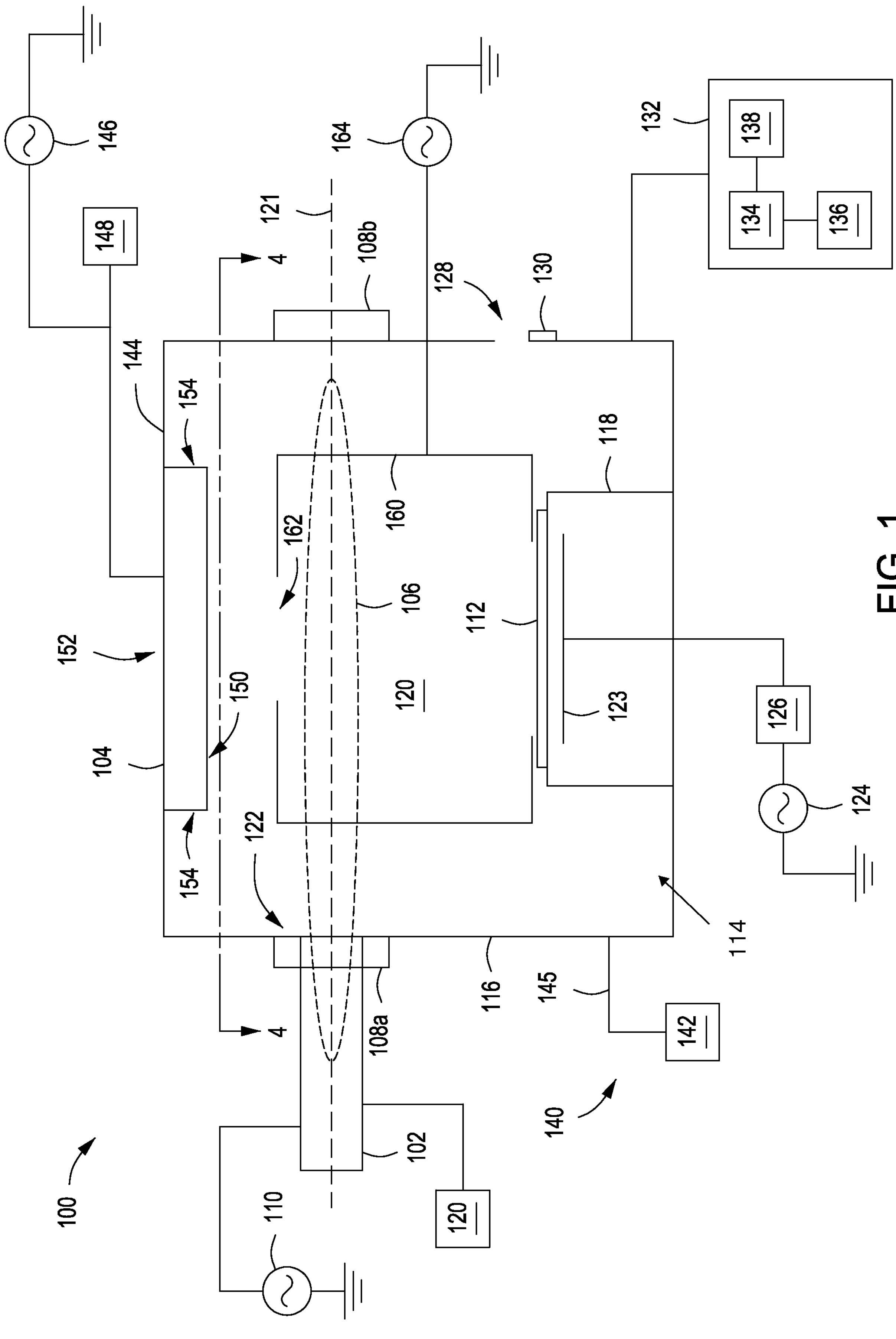
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FIG. 1

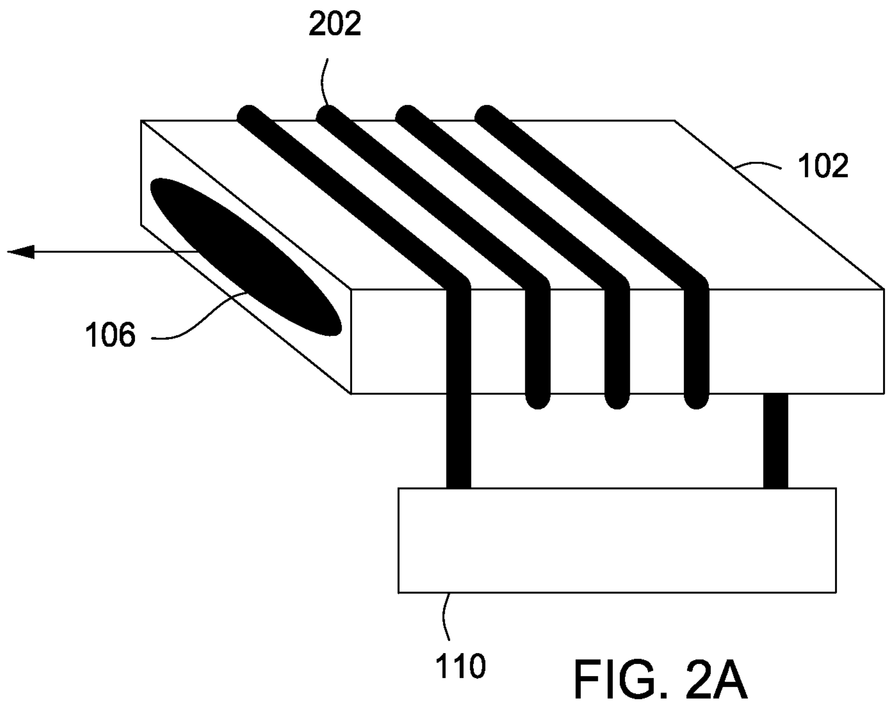

FIG. 2A

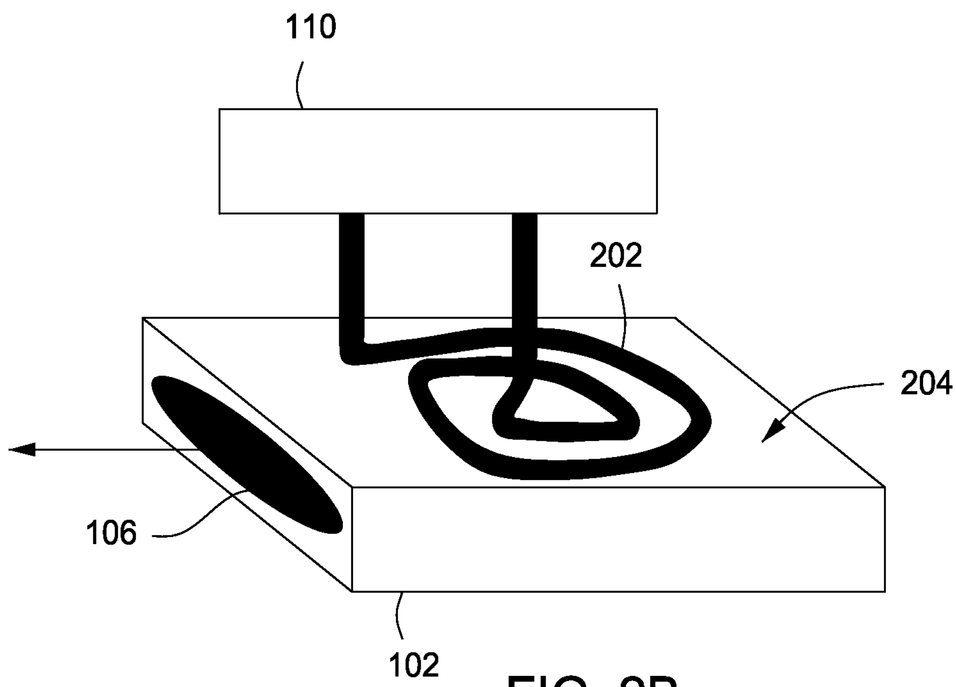

FIG. 2B

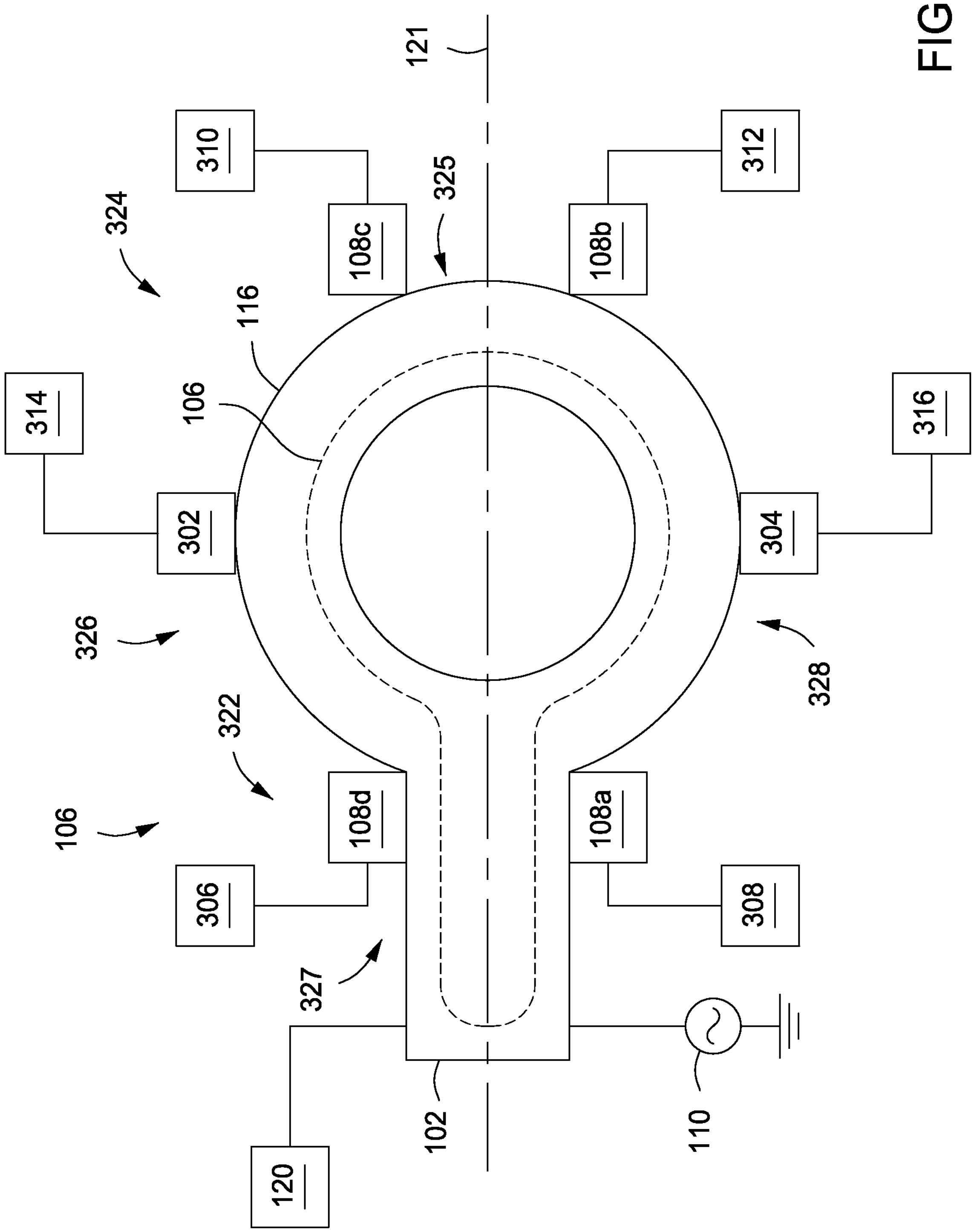
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FIG. 3A

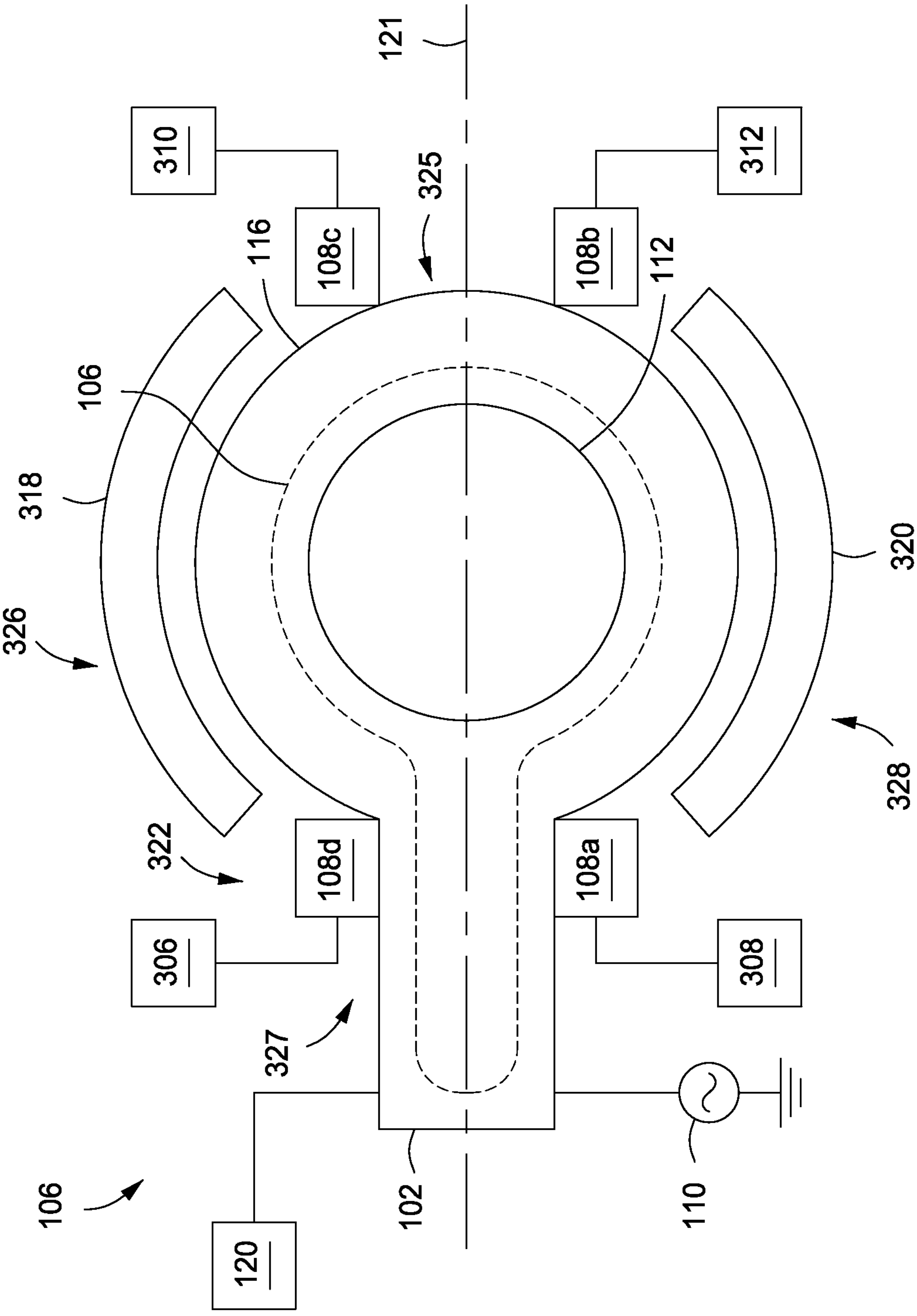
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FIG. 3B

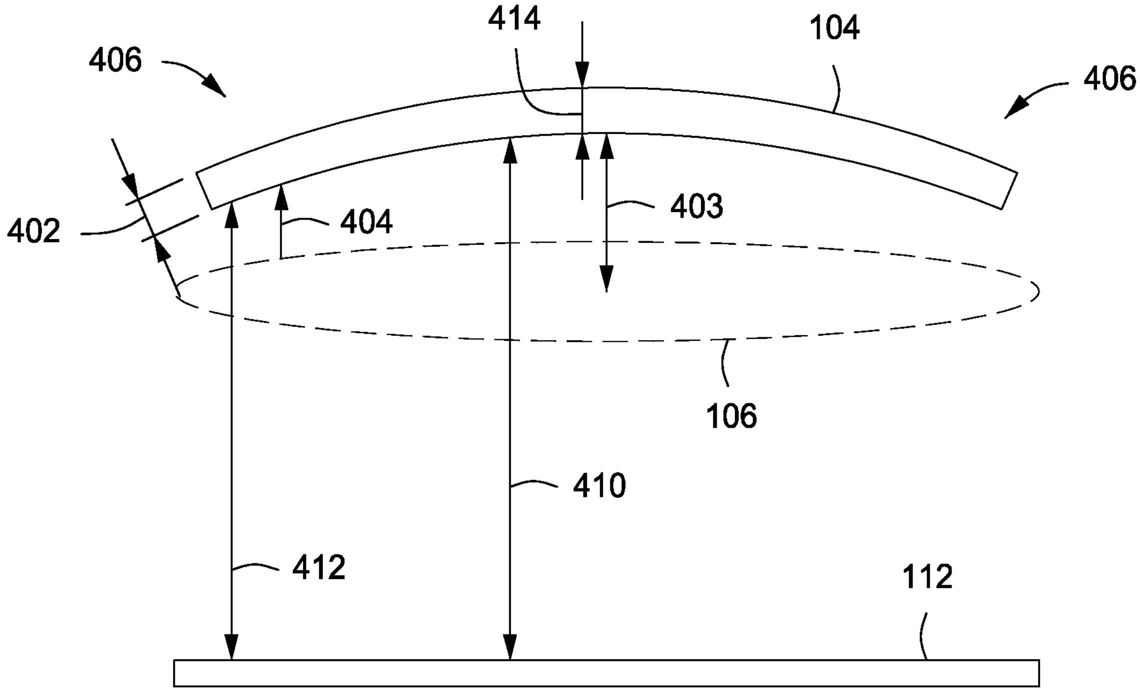
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FIG. 4

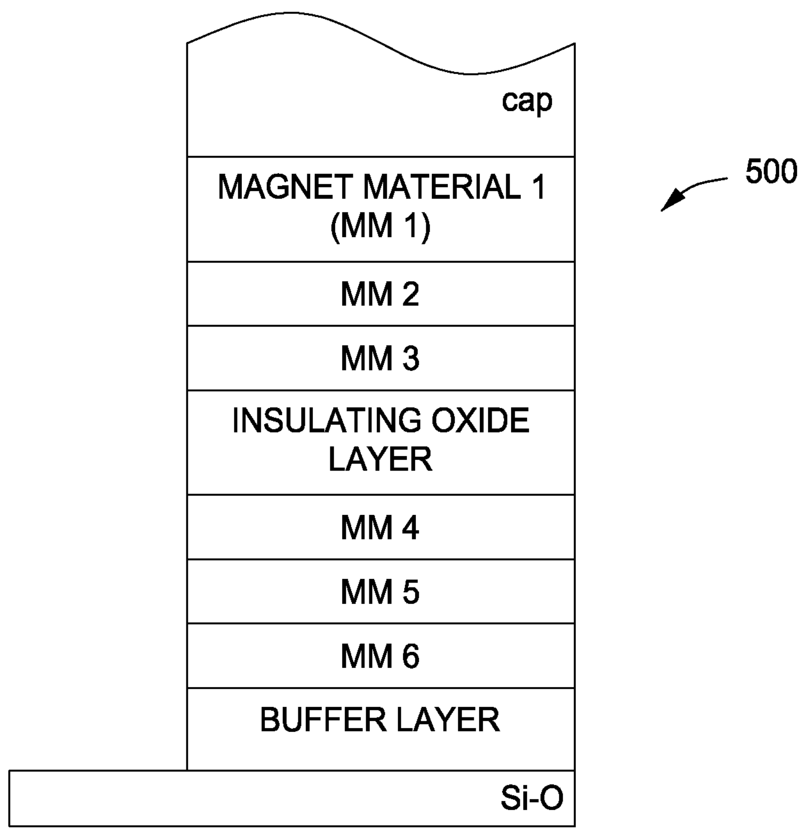
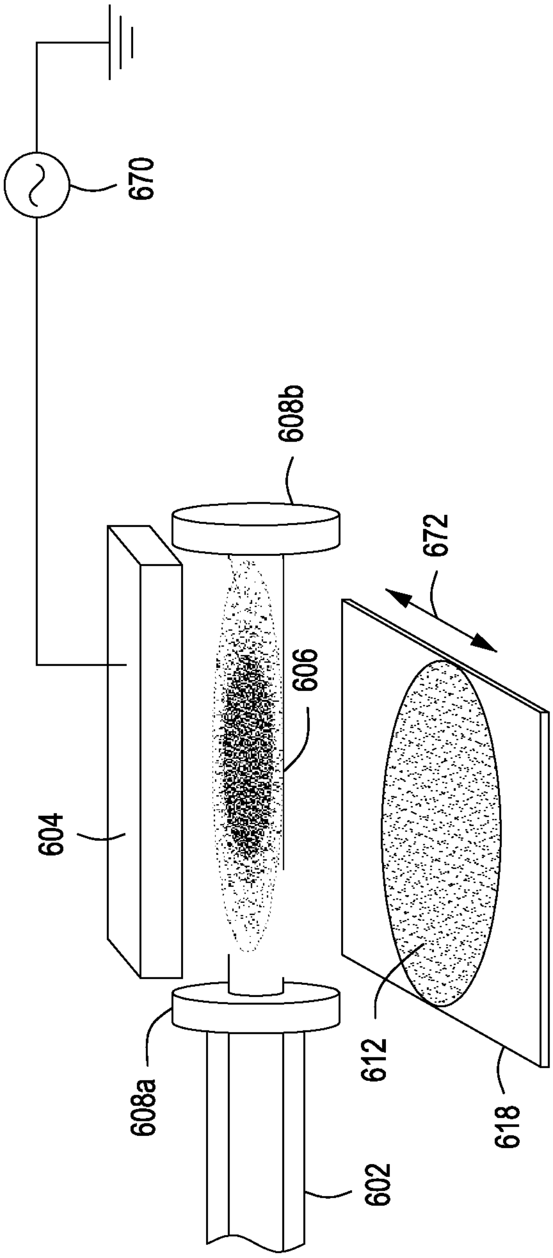

cap
500
MAGNET MATERIAL 1
(MM 1)
MM 2
MM 3
INSULATING OXIDE
LAYER
MM 4
MM 5
MM 6
BUFFER LAYER
Si-O

FIG. 5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608b
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604
612
608a
618
602

FIG. 6A

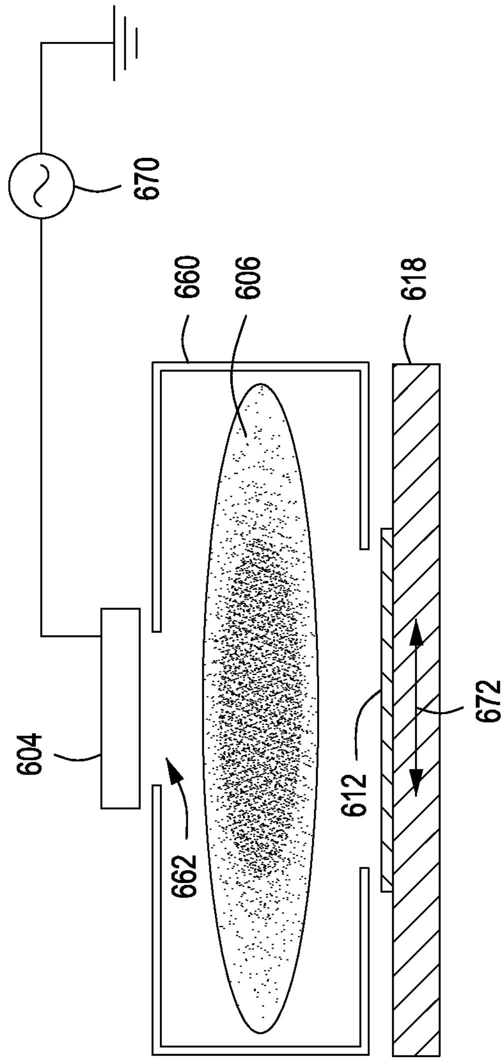
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FIG. 6B

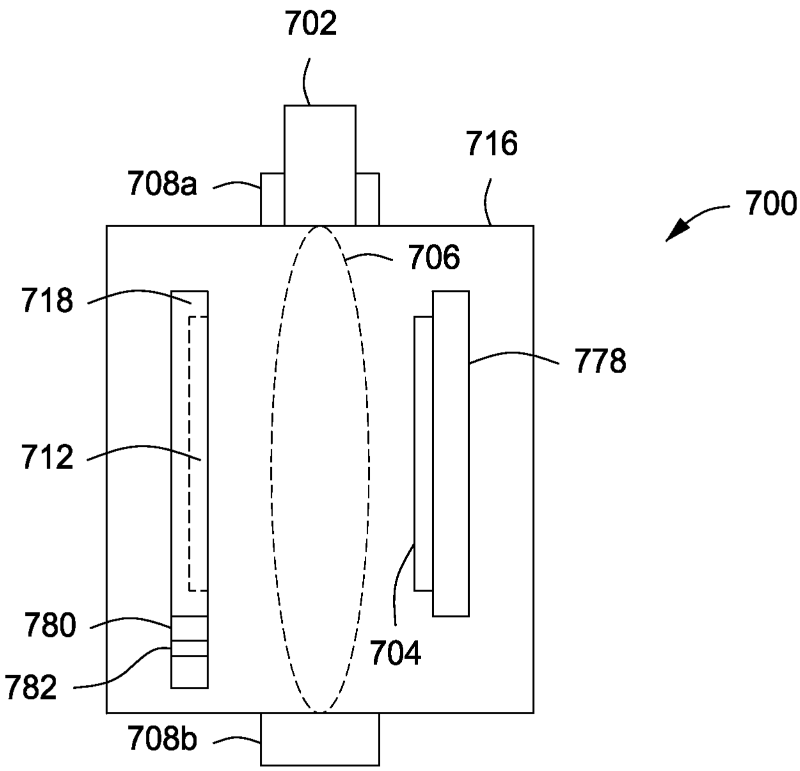
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FIG. 7A

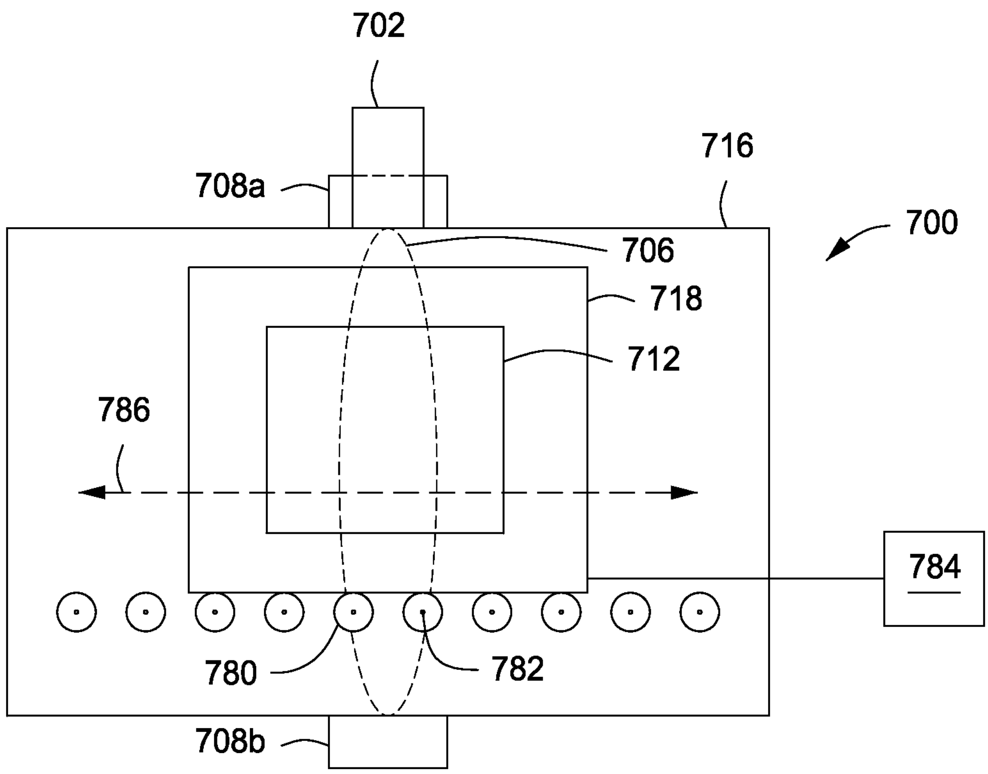
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FIG. 7B

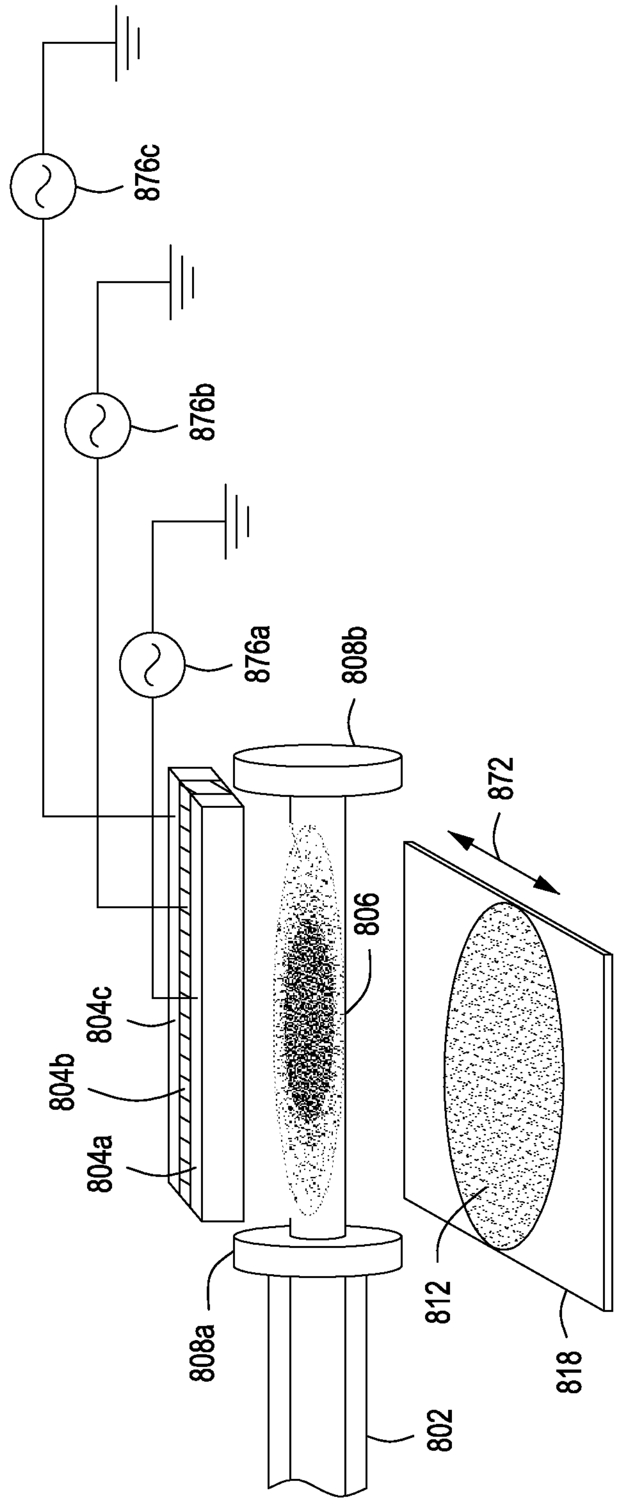
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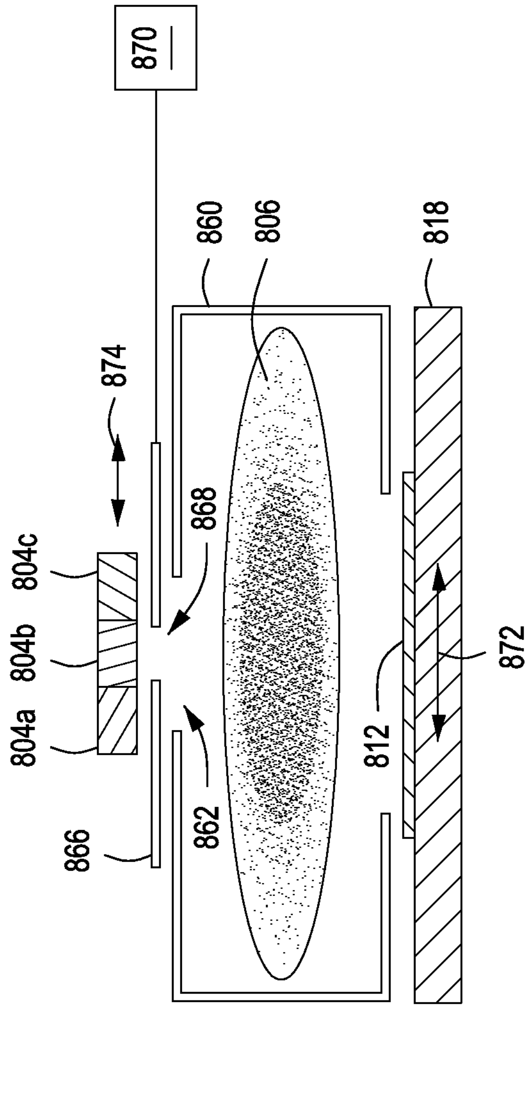
FIG. 8A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804a
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812
872

FIG. 8B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/015773

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/203(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 21/203; C23C 14/35; H05H 1/24; C23C 14/34; C23C 16/513; G11B 5/851; C23C 16/26; C09K 19/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: sputtering, PVD, target, scanning, aperture

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 05-234893 A (TOKYO ELECTRON LTD.) 10 September 1993 See abstract, paragraphs [0016]-[0018], [0021], [0026], [0034] and figures 1, 4-5.	1,3-7
Y		2,8-13,15
Y	US 2009-0258164 A1 (HIROSHI NAKAI et al.) 15 October 2009 See abstract, paragraphs [0053]-[0086], [0102]-[0106] and figures 1, 5A.	2
Y	KR 10-2010-0064400 A (DORCO CO., LTD.) 15 June 2010 See abstract, paragraphs [0017]-[0037], claims 1-2 and figures 1-3.	8-15
Y	US 2007-0110920 A1 (SOON-JOON RHO et al.) 17 May 2007 See paragraph [0039] and figure 2.	9
Y	JP 2011-001597 A (ULVAC JAPAN LTD.) 06 January 2011 See paragraphs [0026]-[0071] and figures 1-11.	12-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
28 May 2014 (28.05.2014)

Date of mailing of the international search report
29 May 2014 (29.05.2014)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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