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(54) **Title**: COOLING RING FOR PHYSICAL VAPOR DEPOSITION CHAMBER TARGET

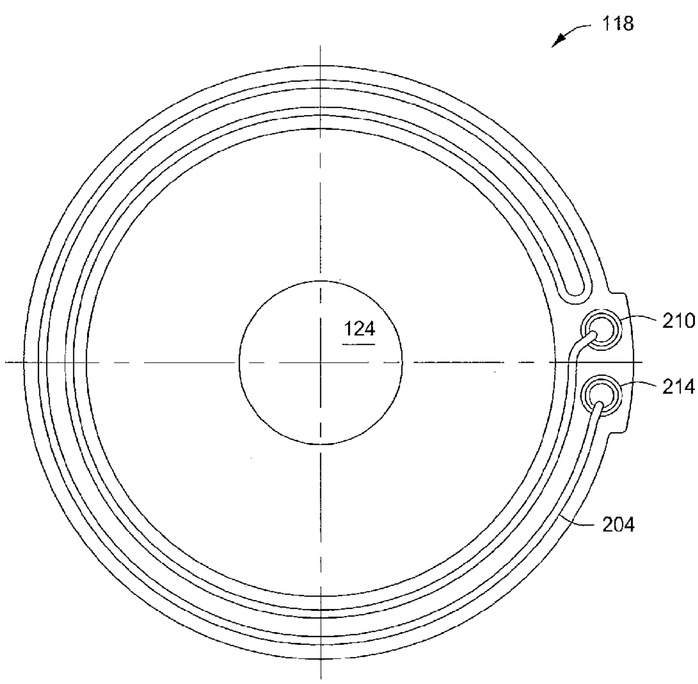

FIG. 2A

(57) **Abstract**: Apparatus and method for physical vapor deposition are provided. In some embodiments, a cooling ring to cool a target in a physical vapor deposition chamber may include an annular body having a central opening; an inlet port coupled to the body; an outlet port coupled to the body; a coolant channel disposed in the body and having a first end coupled to the inlet port and a second end coupled to the outlet port; and a cap coupled to the body and substantially spanning the central opening, wherein the cap includes a center hole.

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COOLING RING FOR PHYSICAL VAPOR DEPOSITION CHAMBER TARGET

FIELD

[0001] Embodiments of the present invention generally relate to physical vapor deposition processing equipment.

BACKGROUND

[0002] Physical vapor deposition (PVD) is a conventionally used process for deposition of materials atop a substrate. A conventional PVD process illustratively includes bombarding a target comprising a source material with ions from a plasma, causing the source material to be sputtered from the target. The ejected source material may be accelerated towards the substrate via a negative voltage or bias formed on the substrate, resulting in a deposition of the source material atop the substrate. During the PVD process a magnetron may be rotated within a water filled cavity, near a backside of the target, to promote uniformity of the plasma. The water-filled cavity is used to remove heat generated during processing. However, the water filled cavity hinders the serviceability of the magnetron and interferes with the feed of RF energy through the surrounding structure to the target.

[0003] Accordingly, the inventors have provided an improved apparatus to perform physical vapor deposition processing.

SUMMARY

[0004] Apparatus and methods for physical vapor deposition are provided. In some embodiments, a cooling ring to cool a target in a physical vapor deposition chamber may include an annular body having a central opening; an inlet port coupled to the body; an outlet port coupled to the body; a coolant channel disposed in the body and having a first end coupled to the inlet port and a second end coupled to the outlet port; and a cap coupled to the body and substantially spanning the central opening, wherein the cap includes a center hole.

[0005] In some embodiments, a target assembly for use in a physical vapor deposition system may include a target including a source material to be deposited on a substrate; a cooling ring coupled to the target and having one or more coolant

channels disposed in the cooling ring to flow a coolant through the coolant ring; a central cavity adjacent a backside of the target at least partially defined by inner walls of the cooling ring; and a rotatable magnet assembly disposed within the cavity.

[0006] In some embodiments, a method of processing a substrate in a physical vapor deposition chamber may include sputtering material from a target disposed in the physical vapor deposition chamber to deposit the material on the substrate supported within the physical vapor deposition chamber; and flowing a coolant through a coolant channel disposed in a body of a cooling ring coupled to a side of the target opposite the substrate.

[0007] Other and further embodiments of the present invention are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] 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.

[0009] Figure 1 depicts a schematic cross sectional view of a process chamber in accordance with some embodiments of the present invention.

[0010] Figure 2A depicts a schematic top view of a cooling ring in accordance with some embodiments of the present invention.

[0011] Figures 2B depicts a side cross-sectional view of a cooling ring in accordance with some embodiments of the present invention.

[0012] 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

[0013] Methods and apparatus for physical vapor deposition (PVD) processing of substrates are provided herein. In some embodiments, the improved apparatus may eliminate the need for a water cavity in a PVD chamber resulting in improved RF efficiency and in simplifying removal of a target and magnetron assembly for example, during maintenance or when installing and/or replacing a target.

[0014] Figure 1 depicts a schematic, cross-sectional view of a physical vapor deposition (PVD) chamber 100 in accordance with some embodiments of the present invention. Examples of suitable PVD chambers include the ALPS® Plus and SIP ENCORE® PVD processing chambers, both commercially available from Applied Materials, Inc., of Santa Clara, California. Other processing chambers from Applied Materials, Inc. or other manufactures may also benefit from the inventive apparatus disclosed herein.

[0015] In some embodiments of the present invention, as depicted in Figure 1, the PVD chamber 100 includes a target assembly 102 disposed atop a process chamber 104. The process chamber 104 contains a movable substrate support 146 for supporting a substrate 148 in a position opposing the target assembly 102.

[0016] The target assembly 102 may be incorporated into a lid of the process chamber 104 and generally includes a target 106 and a cooling ring 118 coupled to the target 106. The cooling ring 118 partially defines a cavity 134 adjacent to a backside of the target 106. The target assembly may further include a rotatable magnetron assembly 136 having a rotatable magnet assembly 168 disposed in the cavity 134. The target assembly 102 may further comprise an RF power source 108 to provide RF energy to the target 106 during processing. In some embodiments, an electrode 112 (*e.g.*, an RF applicator rod) may be provided to couple the RF power source 108 to the target 106 via the cooling ring 118. For example, in some embodiments, the electrode 112 may pass through an opening 150 in an outer ground shield 140 that surrounds the target assembly 102 and may be coupled to the cooling ring 118. The RF power source 108 may include an RF generator and a matching circuit, for example, to minimize reflected RF energy reflected back to the RF generator during operation.

[0017] During operation, heat generated by the process is removed by the cooling ring 118. Although described herein in terms of a ring, the cooling ring 118 need not be circular and may have other geometries, such as rectangular or other polygonal shapes, as desired for a particular process chamber configuration. By removing heat from the process via the cooling ring, as compared to a water filled cavity, this design advantageously removes undesirable consequences of having a water filled cavity. For example, use of the cooling ring makes changing the target and magnet of the source significantly simpler by eliminating the need to drain the coolant from the closed cavity behind the target for maintenance. Also, In the case of target burn through, there is no danger of flooding the chamber with the coolant. Moreover, RF efficiency is improved as RF energy is not wasted through absorption by the water-filled cavity behind the target.

[0018] In some embodiments, the cooling ring 118 includes a body 125 having one or more coolant channels 116, 117 disposed therein. In some embodiments, the body 125 may be annular. In some embodiments, the coolant channels 116, 117 are disposed proximate a circumference of the body 125. The number of coolant channels and their geometry may be determined as desired for a particular process, taking into consideration the structural requirements of the cooling ring to support any other components.

[0019] A coolant source 110 may be coupled to the cooling ring 118 via one or more conduits 114 disposed through an opening in the ground shield 140 to provide a coolant to the coolant channels 116,117. The coolant may be any process compatible coolant, such as ethylene glycol, deionized water, a perfluorinated polyether (such as Galden®, available from Solvay S. A.), or the like, or combinations thereof. In some embodiments, the flow of coolant through the coolant channels 116, 117 may be about 1 to about 7 gallons per minute, although the exact flows will depend upon the process being performed, the configuration of the coolant channels, available coolant pressure, or the like.

[0020] In some embodiments, a cap 122 may be coupled to the body 125 to cover the coolant channels 116, 117. The cap 122 may be coupled to the body 125 in any suitable manner to prevent leakage of the coolant. In some embodiments the cap

122 may be coupled to the body 125 by vacuum or non-vacuum brazing, electron beam welding, adhesives or other bonding agents, or the like. In some embodiments, the cap 122 may be a plate or disc having a central opening 124 to facilitate receiving a shaft 170 of the magnetron assembly 136. Alternatively, an insert (not shown) may be provided to seal the one or more coolant channels 116, 117. In some embodiments, the insert may be welded into the one or more coolant channels 116, 117 beneath the cap 122 by any suitable method, such as e-beam welding, tig welding, laser welding, brazing, or the like.

[0021] In some embodiments, the body 125 and the cap 122 may be fabricated from at least one of copper, aluminum, bronze, brass, stainless steel, alloys thereof (such as a copper chrome alloy), or the like. The body 125 and the cap 122 may be made from the same materials or from different materials. In embodiments where the body 125 and/or cap is made of aluminum, a corrosion prevention coating may be applied to the coolant channels 116, 117, and optionally to the surface of the cap 122 exposed to the coolant channels 116, 117, to prevent corrosion from the coolant. An example of one such coating is Alodine®, a registered trademark of Henkel Technologies. In some embodiments, exterior surfaces of the body 125 and the cap 122 may be silver plated, for example, to enhance RF conductivity of the body 125 and the cap 122.

[0022] Figure 2A depicts a schematic bottom view of a cooling ring 118 including a coolant channel 116 in accordance with some embodiments of the present invention. Figure 2B depicts a cross-sectional side view of the cooling ring 118 including the coolant channel 116 in accordance with some embodiments of the present invention.

[0023] Referring to Figures 2A-B, in some embodiments, one or more coolant inlet ports (one inlet port 210 shown in Figure 2A) and one or more coolant outlet ports (one outlet port 214 shown in Figure 2A) may be provided through the cap 122 and/or the body 125 to facilitate circulating the coolant through the coolant channel 116. In some embodiments, the coolant channel 116 may include a conduit 204 in close thermal contact with the body 125 to contain the coolant. In some embodiments, the conduit 204 may be made of stainless steel, copper, brass, bronze, or the like. In some embodiments, the conduit 204 may be disposed within an outer cladding or body (not shown) that may be press fit into the coolant channel 116 to ensure superior thermal contact between the conduit 204 and the sidewalls of the coolant channel 116. For example, in some embodiments, stainless steel tubing may be embedding into castings and press fit into the coolant channel 116. In some embodiments, the conduit 204 may be swaged or brazed into a part, such as an aluminum body, to enhance thermal connectivity. In some embodiments, the coolant channel 116, or the conduit 204 disposed therein, may be provided in a loop or other similar configuration that provides a counter flow of the coolant in adjacent coolant channel 116 or conduit 204. Such counter flow configuration may advantageously enhance heat removal from the cooling ring 118.

[0024] The body 125 may be coupled to the target 106 in any suitable fashion to provide a robust thermal coupling, such as by bolts or other fasteners, clamps, springs, gravity, or the like. In some embodiments, a plurality of holes 206 may be provided in the body 125 (as shown in Figure 2B) to facilitate bolting the target 106 to the body 125. In some embodiments, thermal connectivity between components may be enhanced using a thermal foil, such as a patterned copper or aluminum foil, grafoil® (available from GrafTech International), or the like, as a thermal conductor. The patterned copper or aluminum foil may be pressed over a screen to form a patterned surface including a plurality of raised surfaces to add a conformal aspect to the foil.

[0025] Returning to Figure 1, the cooling ring 118 may be coupled to the target 106 at a second end 130 of the body 125. In some embodiments, the body 125 may be a tubular member having a first end 126 coupled to a target-facing surface 128 of the cap 122 proximate the peripheral edge of the cap 122. In some embodiments, the body 125 further includes a second end 130 coupled to a cap-facing surface 132 of the target 106 (or to a backing plate of the target 106) proximate the peripheral edge of the target 106. In some embodiments, second end 130 contacting the perimeter of the target has a width in the range of 0.75 inches to 2 inches. In some embodiments, the target 106, when in place in the process chamber, may further be supported on a grounded conductive aluminum adapter 142 through a dielectric isolator 144.

[0026] In some embodiments, an isolator plate 138 may be disposed between the cap 122 and the ground shield 140 to prevent RF energy from being routed directly to ground. The isolator plate 138 may comprise a suitable dielectric material, such as a ceramic, a plastic, or the like. Alternatively, an air gap may be provided in place of the isolator plate 138. In embodiments where an air gap is provided in place of the isolator plate, the ground shield 140 may be structurally sound enough to support any components resting upon the ground shield 140.

[0027] In some embodiments, the cavity 134 may be defined by the inner-facing walls of the body 125, the target-facing surface 128 of the cap 122 and the cap-facing surface 132 of the target 106. The cavity 134 and the central opening 115 may be utilized to at least partially house one or more portions of the rotatable magnetron assembly 136. As used herein, inner-facing walls is stated in plural but include the singular such as when the body 125 is annular.

[0028] For example, the rotatable magnetron assembly 136 may be positioned proximate a back surface (*e.g.,* cap-facing surface 132) of the target 106 (or the backing plate, when present). The rotatable magnetron assembly 136 includes a rotating magnet assembly 168 comprising a plurality of magnets arranged on a base plate. The rotating magnet assembly 168 is coupled to a shaft 170 to provide rotation. In some embodiments, the shaft 170 may be coincident with the central axis of the PVD chamber 100. In some embodiments (not shown), the rotation shaft 170 may be disposed off-center with respect to the central axis of the PVD chamber 100. A motor 172 can be coupled to the upper end of the rotation shaft 170 to drive rotation of the magnetron assembly 136. The ground shield 140 has a central opening 115 to allow the rotation shaft 170 to pass through the hole 124 in the cap 122 and connect to the base plate 168. In some embodiments, the rotation shaft 170 contains an insulator 120 to prevent RF energy from propagating up the shaft 170 to the motor 172. The rotating magnet assembly 168 produces a magnetic field within the PVD chamber 100, generally parallel and close to the surface of the target 106 to trap electrons and increase the local plasma density, which in turn increases the sputtering rate. The rotating magnet assembly 168 produces an electromagnetic field around the top of the PVD chamber 100, and the rotating magnet assembly 168 is rotated to rotate the electromagnetic field which influences the plasma density of the process to more uniformly sputter the target 106.

[0029] In some embodiments, a ground shield 140 is shown covering at least some portions of the PVD chamber 100 above the target 106 in Figure 1. In some embodiments (not shown), the ground shield 140 could be extended below the target 106 to enclose the process chamber 104 as well. The ground shield 140 may comprise any suitable conductive material, such as aluminum, copper, or the like. An insulative gap 139 is provided to prevent RF energy from being routed directly to ground. The insulative gap 139 may be filled with air or some other suitable dielectric material, such as a ceramic, a plastic, or the like.

[0030] 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 cooling ring to cool a target in a physical vapor deposition chamber, comprising:

an annular body having a central opening;

an inlet port coupled to the body;

an outlet port coupled to the body;

a coolant channel disposed in the body to flow a coolant through the coolant ring and having a first end coupled to the inlet port and a second end coupled to the outlet port; and

a cap coupled to the body and substantially spanning the central opening, wherein the cap includes a center hole.

2. The cooling ring of claim 1, wherein the body is made of at least one of copper, aluminum, or bronze.

3. The cooling ring of claim 2, wherein the cap is made of at least one of copper, aluminum, or bronze.

4. The cooling ring of claim 3, wherein the body and the cap are silver plated.

5. The cooling ring of claim 1, wherein the coolant channel is disposed along an outer perimeter of the body.

6. The cooling ring of claim 1, further comprising:

a plurality of coolant channels disposed in the body.

7. The cooling ring of claim 1, wherein the cap is coupled to the body sufficiently to seal the coolant channel.

8. A target assembly for use in a physical vapor deposition system, comprising:

a target comprising a source material to be deposited on a substrate;

a cooling ring as described in any of claims 1 to 7 coupled to the target; and

a central cavity adjacent a backside of the target and at least partially defined by inner walls of the cooling ring, wherein the central cavity is sized to accommodate a rotatable magnet assembly.

9. The target assembly of claim 8, wherein the target comprises a backing plate coupled to and supporting the source material, wherein the cooling ring is coupled to the backing plate of the target.

10. The target assembly of claim 8, wherein the cavity is bounded by a target-facing surface of the cap, a cap-facing surface of the target and the body of the cooling ring.

11. The target assembly of claim 8, further comprising a coolant source coupled to the coolant inlet port.

12. The target assembly of claim 8, further comprising an RF source coupled to the target assembly.

13. The target assembly of claim 8, further comprising:

a rotatable magnet assembly disposed within the cavity; and

a shaft coupled to the rotatable magnet assembly, where the shaft is disposed through the center hole of the cap.

14. A method of processing a substrate in a physical vapor deposition chamber, comprising:

sputtering material from a target disposed in the physical vapor deposition chamber to deposit the material on the substrate supported within the physical vapor deposition chamber; and flowing a coolant through a coolant channel disposed in a body of a cooling ring coupled to a side of the target opposite the substrate.

15. The method of claim 12, wherein the coolant channel circulates the coolant around a perimeter of the body of the cooling ring.

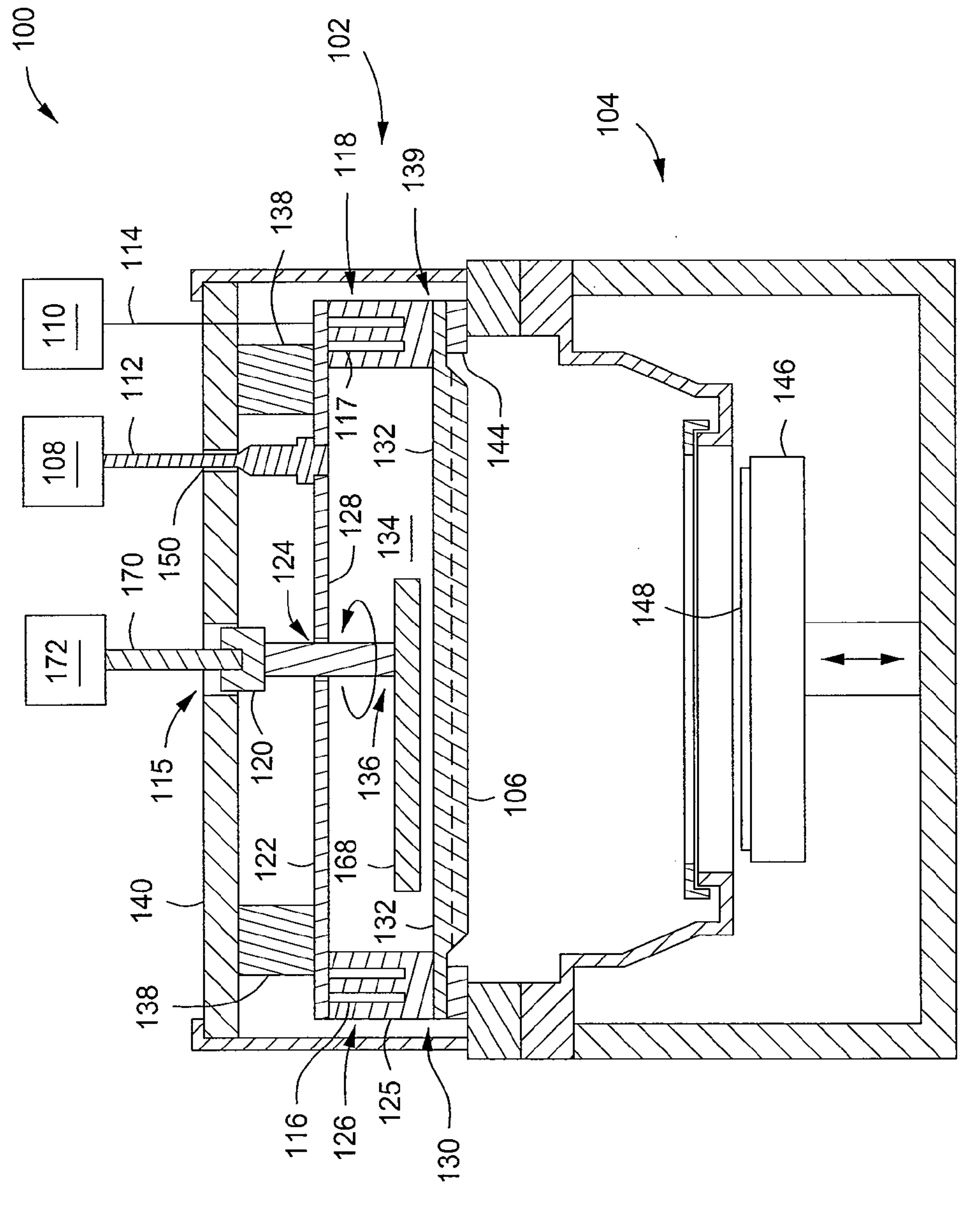
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FIG. 1

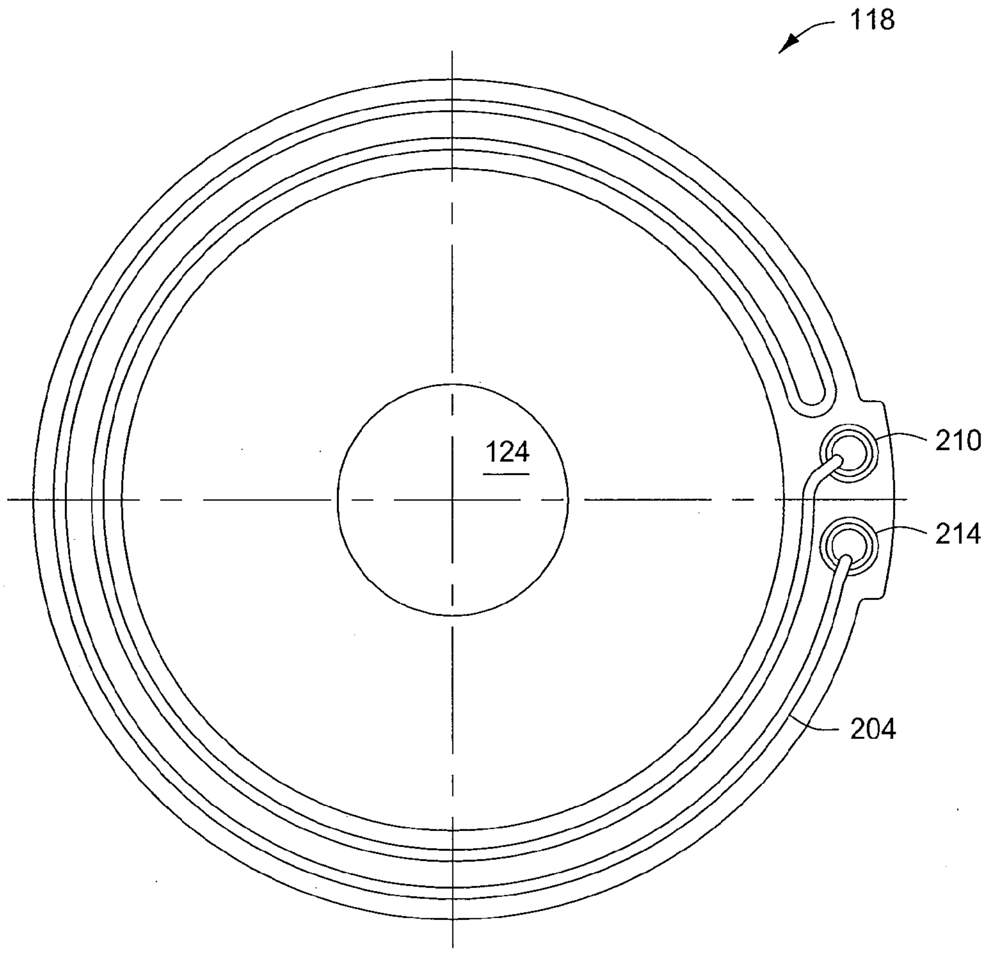
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FIG. 2A

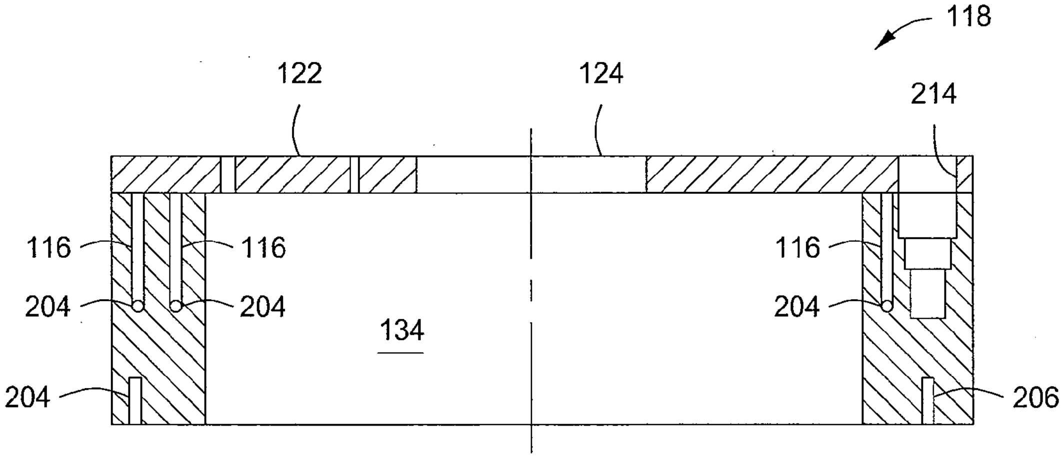
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FIG. 2B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/052680

A. CLASSIFICATION OF SUBJECT MATTER

C23C 14/34(2006.01)i, C23C 14/35(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)
C23C 14/34; C23C 14/35; F26B 17/24

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: sputter, target, deposition, cooling ring, coolant, PVD

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 06039848 A (MOSLEHI, MEHRDAD M. et al.) 21 March 2000 See abstract, column 2 lines 37-51, column 3 lines 53-58, column 5 lines 24-44, column 6 lines 56-67, and figures 1, 2.	1-15
A	US 05953827 A (OR, DAVID T. et al.) 21 September 1999 See abstract, column 4 lines 53-67, column 5 lines 9-16, and figure 2.	1-15
A	US 6228236 B1 (ROSENSTEIN, MICHAEL et al.) 08 May 2001 See abstract, column 2 lines 12-20, column 3 lines 47-53, column 7 lines 15-20, and figure 1.	1-15
A	US 6689254 B1 (HURWITT, STEVEN) 10 February 2004 See abstract, column 6 lines 19-25, 60-67, column 7 lines 1-4, 33-40, and figures 1, 2.	1-15
A	JP 10-287975 A (SONY CORP.) 27 October 1998 See abstract and paragraphs [0021], [0022].	1-15

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of 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	Date of mailing of the international search report
16 JANUARY 2013 (16.01.2013)	**17 JANUARY 2013 (17.01.2013)**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2012/052680

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