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(54) **REMOTE PLASMA APPARATUS FOR GENERATING HIGH-POWER DENSITY MICROWAVE PLASMA**

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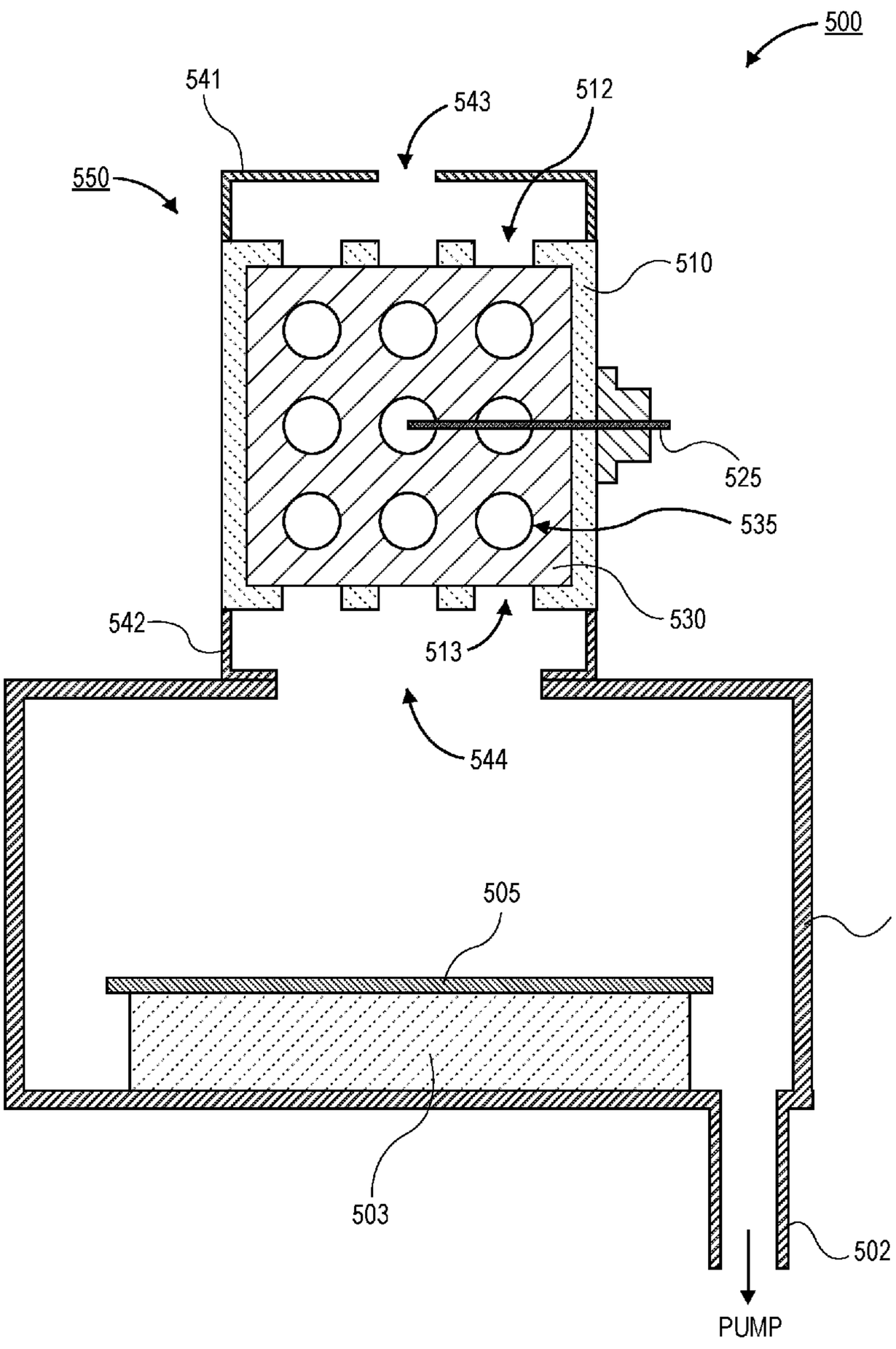
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(57) **ABSTRACT**

Embodiments disclosed herein include a plasma source. In an embodiment, a plasma source comprises a dielectric body with a top surface, a bottom surface, and sidewall surfaces. In an embodiment, a plurality of holes pass through the dielectric body, where a first set of holes pass from the top surface to the bottom surface, and a second set of holes pass between opposite sidewall surfaces. In an embodiment, a housing is around the dielectric body, and a monopole antenna extending into the dielectric body.



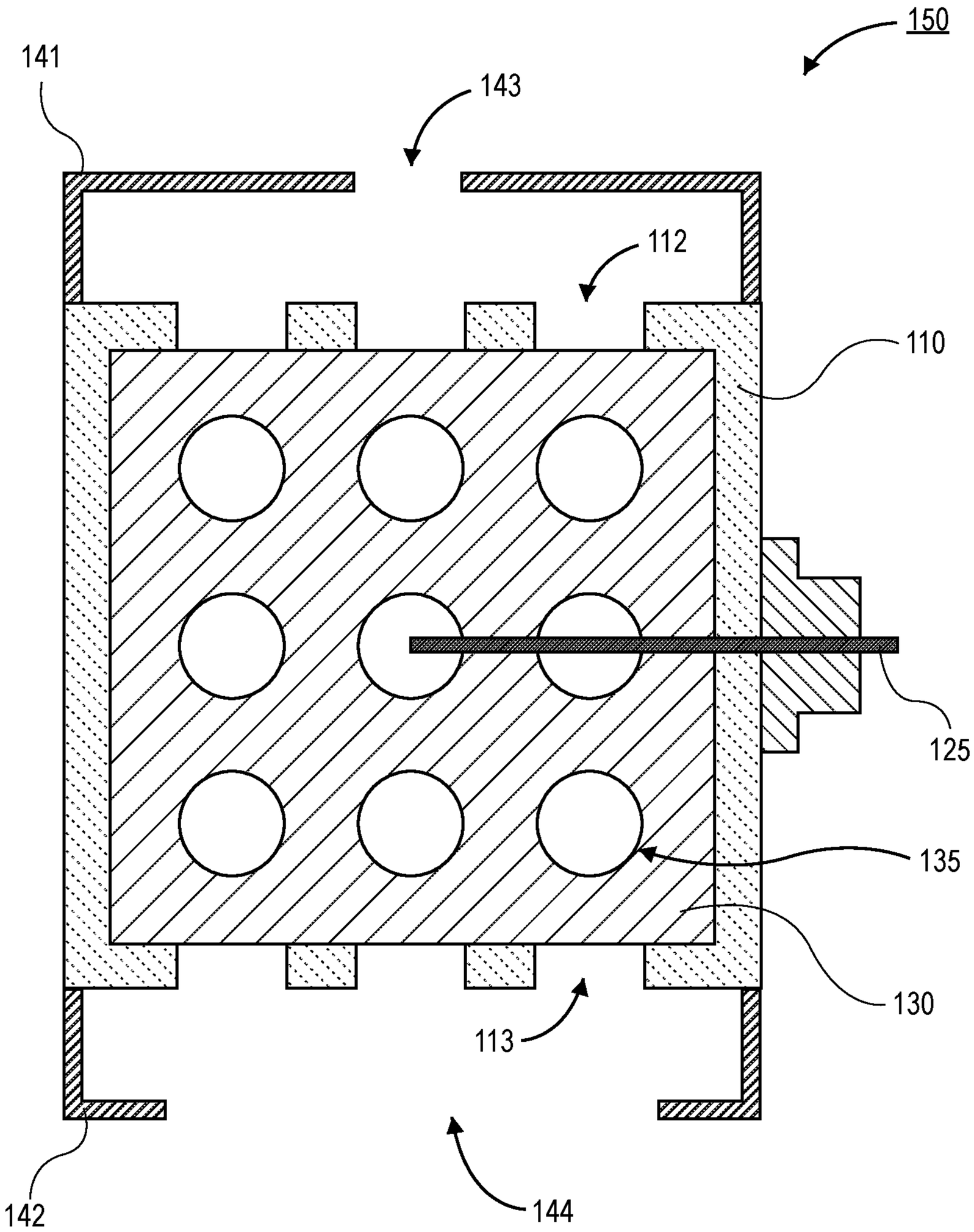


FIG. 1

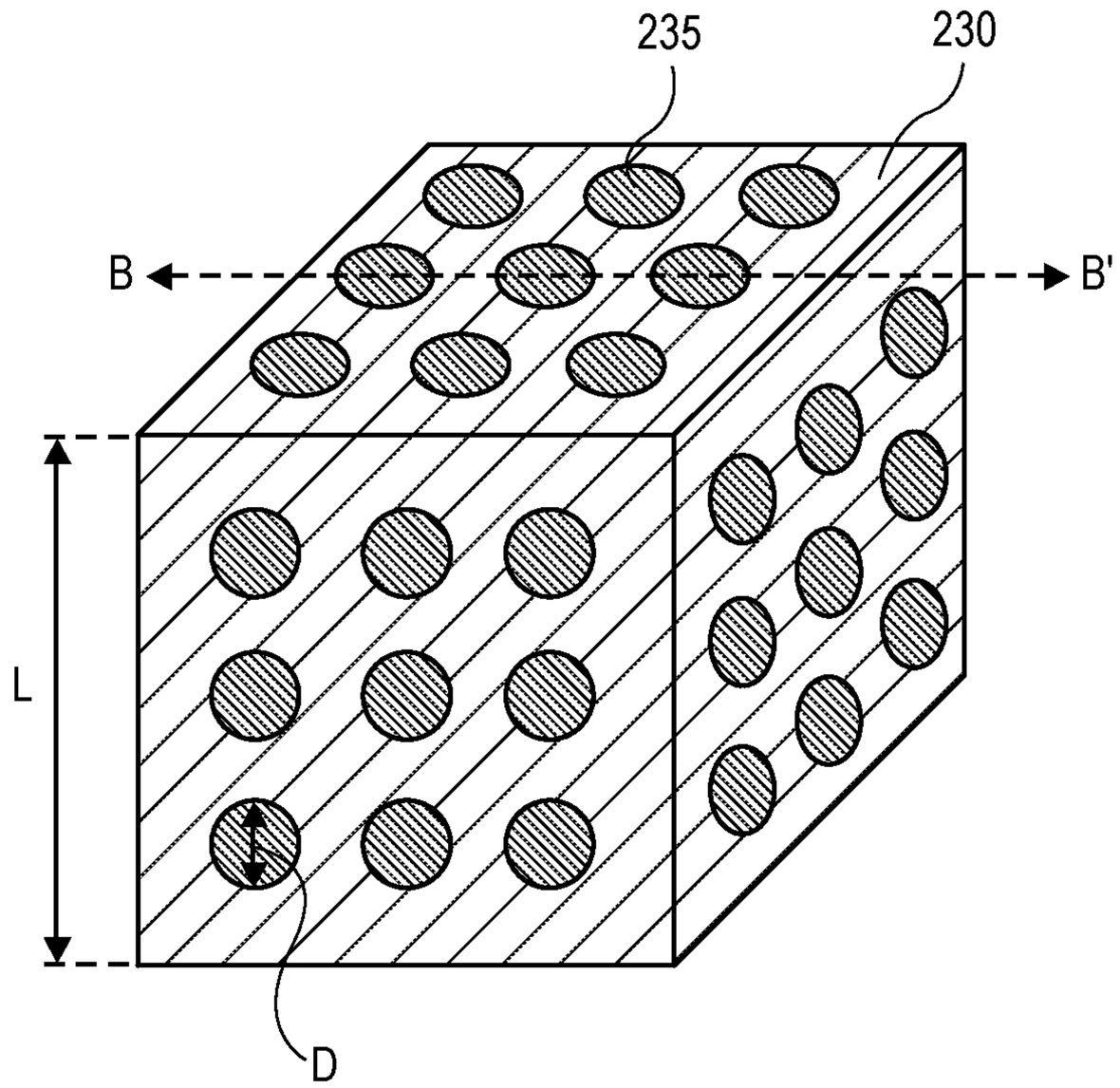


FIG. 2A

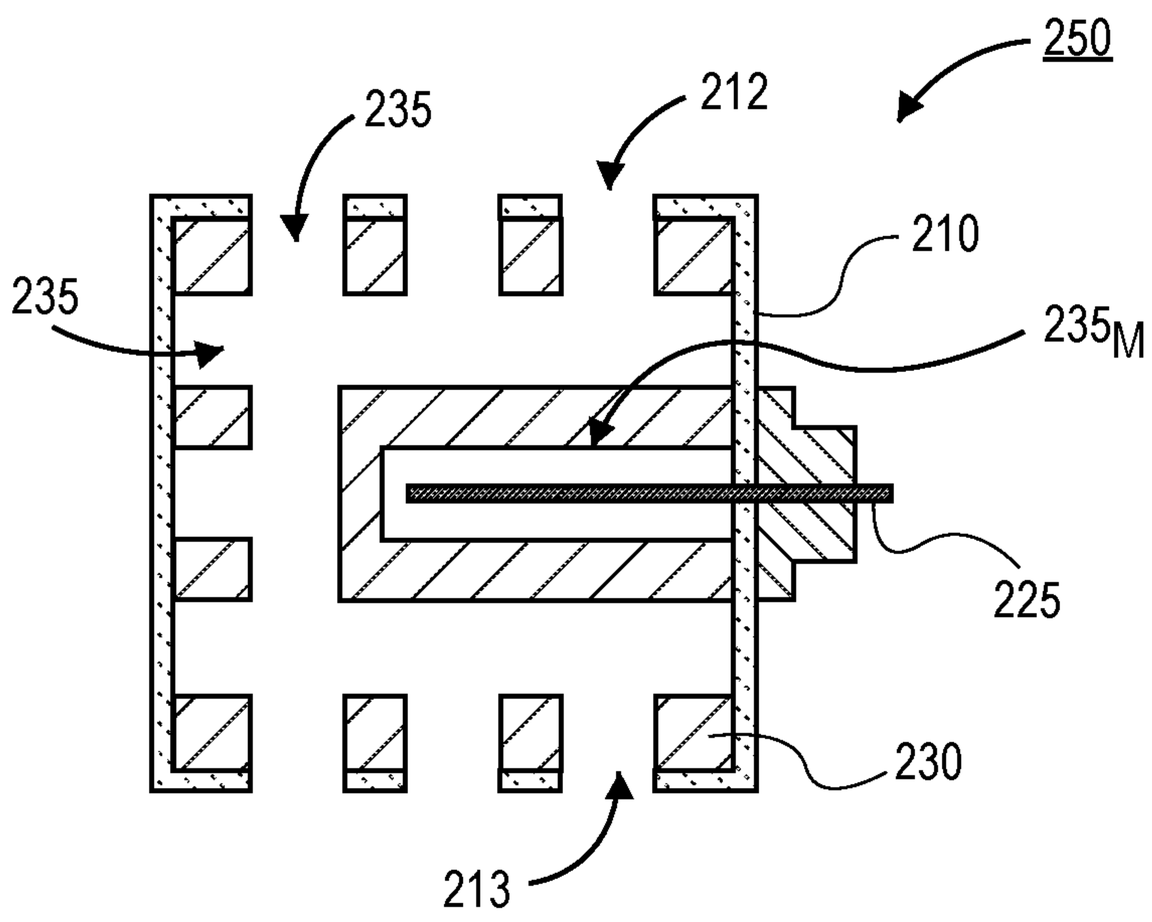


FIG. 2B

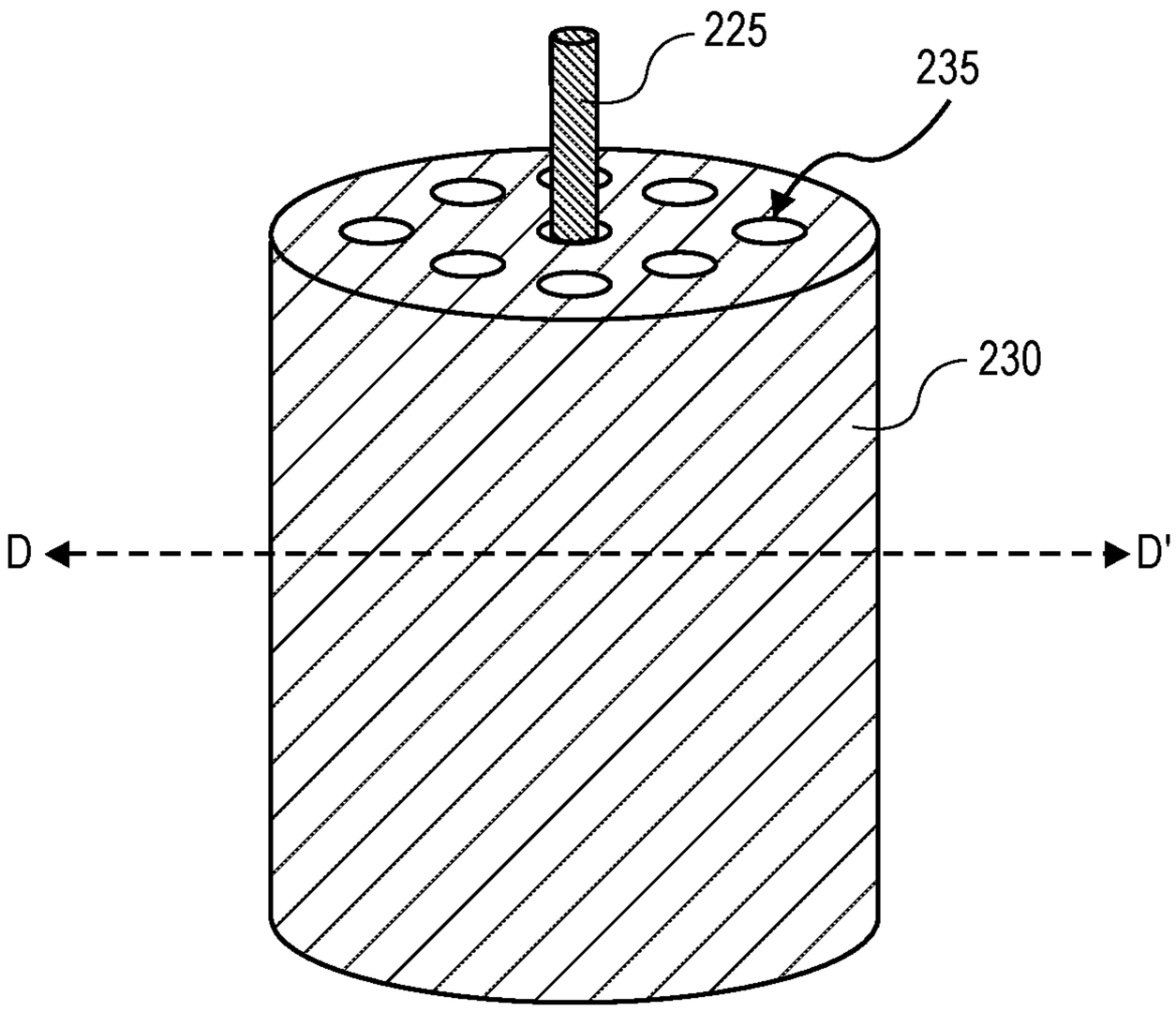


FIG. 2C

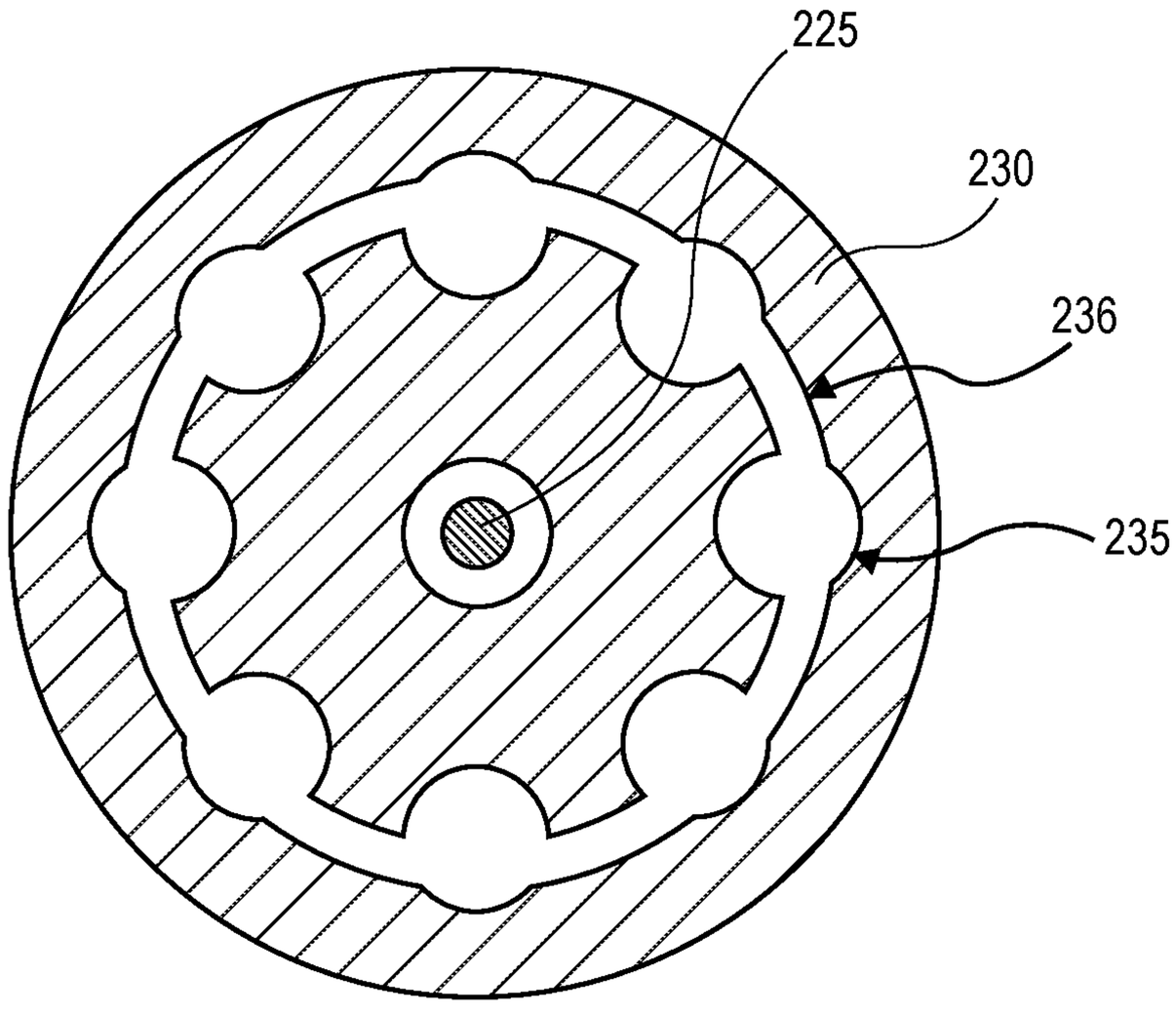


FIG. 2D

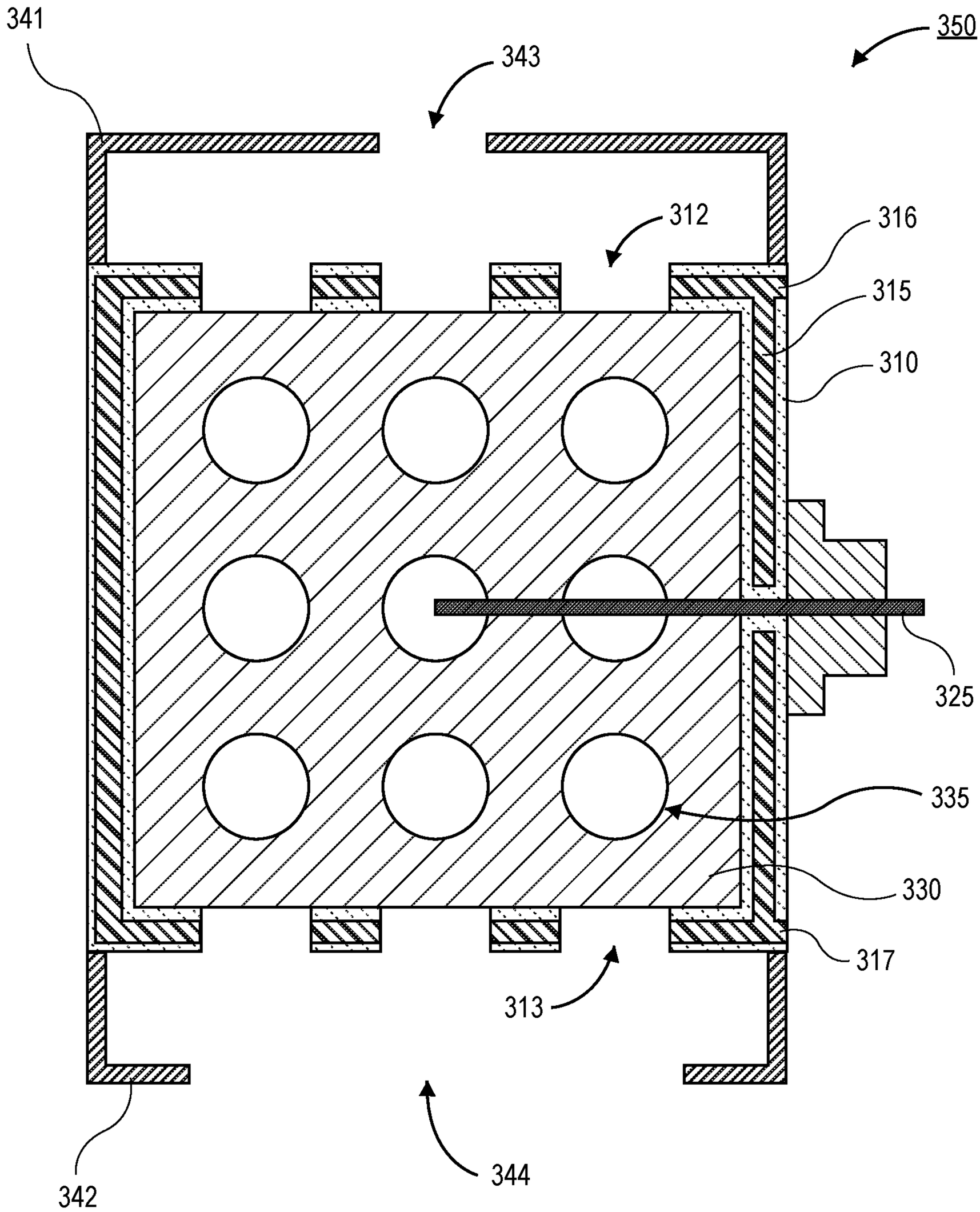


FIG. 3

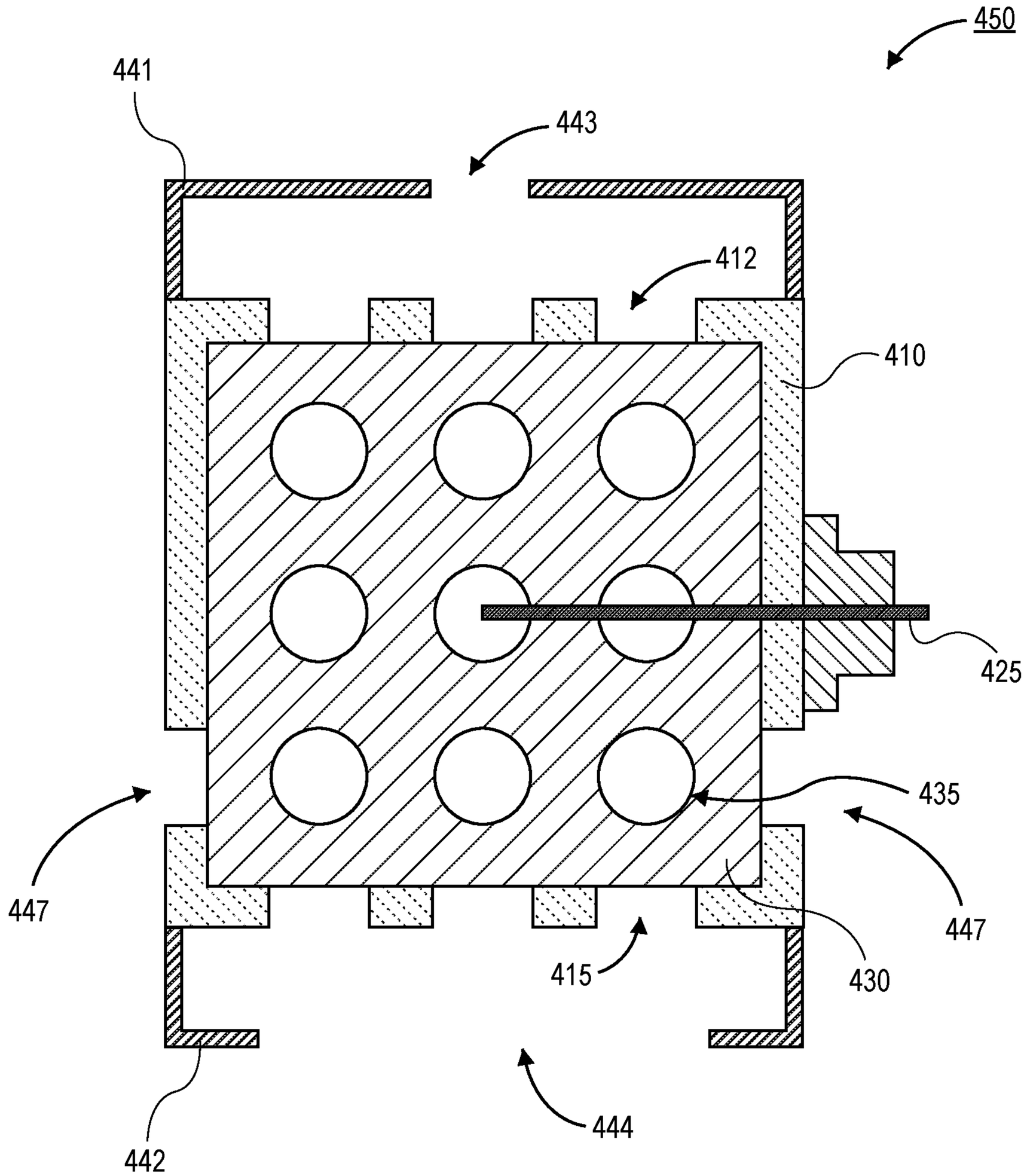


FIG. 4

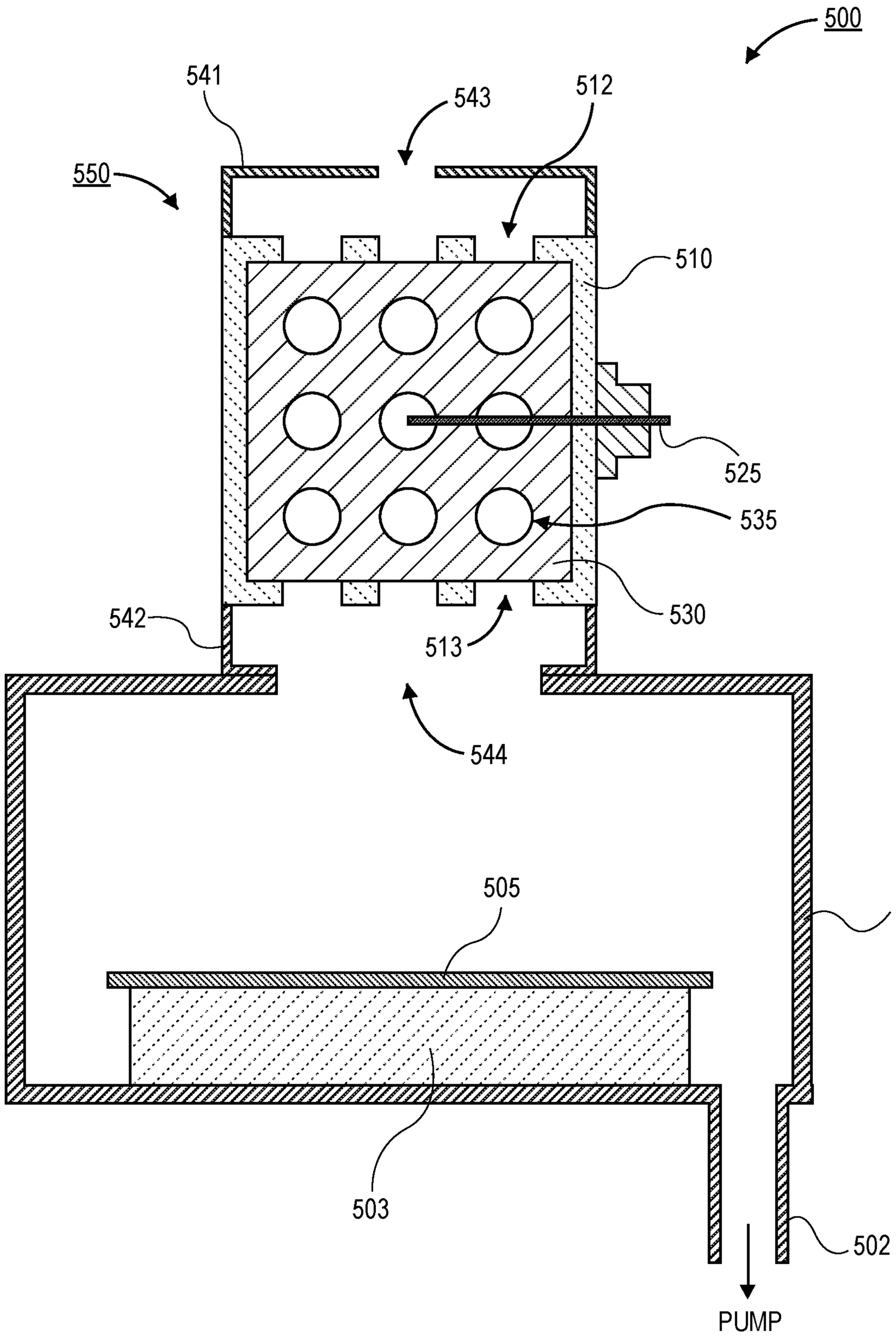


FIG. 5

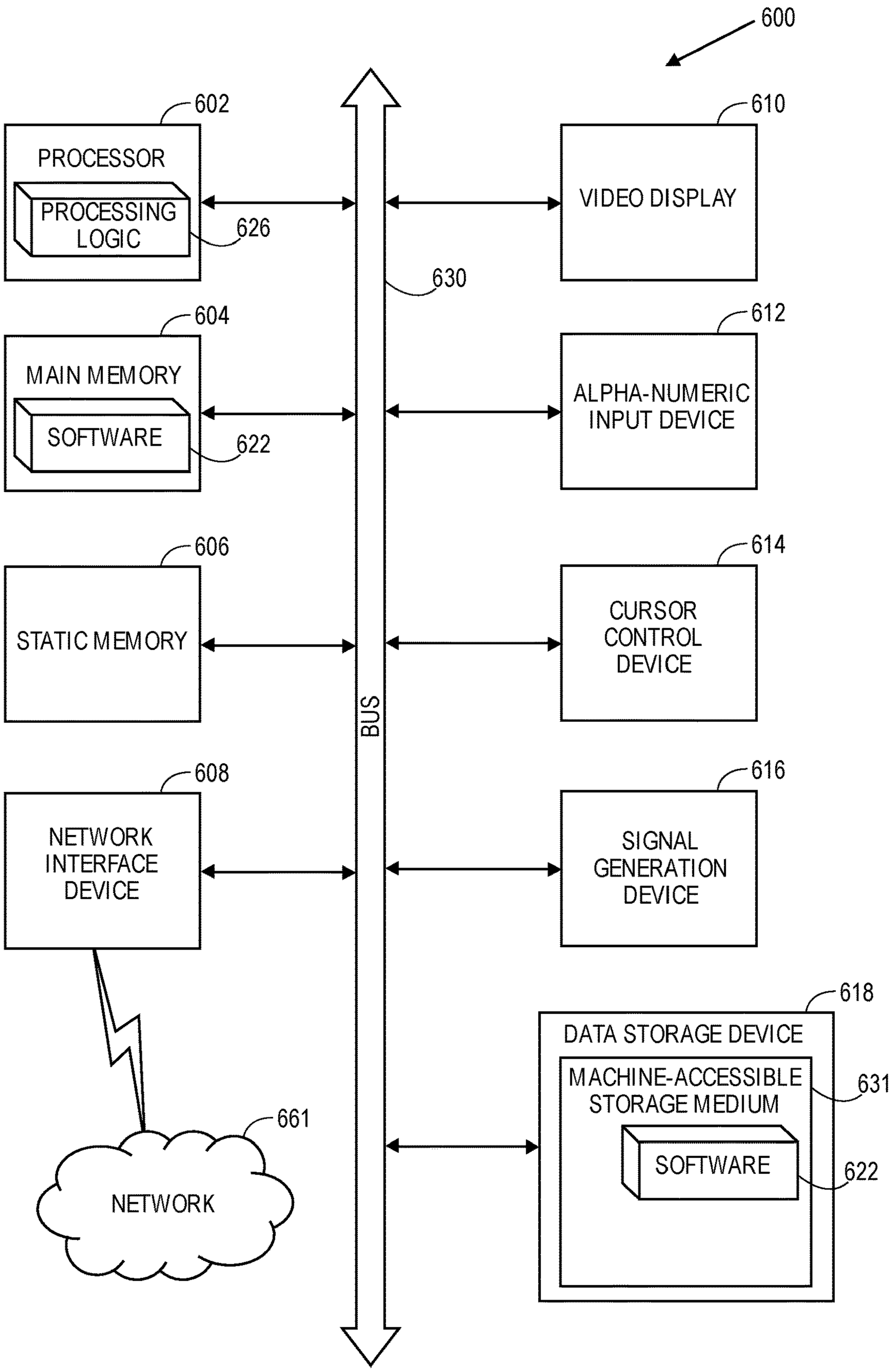

600
602
PROCESSOR
PROCESSING LOGIC
626
604
MAIN MEMORY
SOFTWARE
622
606
STATIC MEMORY
608
NETWORK INTERFACE DEVICE
661
NETWORK
630
BUS
610
VIDEO DISPLAY
612
ALPHA-NUMERIC INPUT DEVICE
614
CURSOR CONTROL DEVICE
616
SIGNAL GENERATION DEVICE
618
DATA STORAGE DEVICE
MACHINE-ACCESSIBLE STORAGE MEDIUM
631
SOFTWARE
622

FIG. 6

REMOTE PLASMA APPARATUS FOR GENERATING HIGH-POWER DENSITY MICROWAVE PLASMA

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/215,370, filed on Jun. 25, 2021, the entire contents of which are hereby incorporated by reference herein.

BACKGROUND

1) Field

[0002] Embodiments of the present disclosure pertain to the field of semiconductor processing and, in particular, to remote plasma systems for generating high-power and density microwave plasmas.

2) Description of Related Art

[0003] Semiconductor deposition systems require frequent chamber cleaning to clear buildup of material on the chamber walls. The most efficient process typically used includes an NF_3 remote plasma clean. In such cleaning processes, the NF_3 is broken down in the plasma to generate atomic fluorine. The atomic fluorine flows from the remote plasma source to the chamber. Atomic fluorine is highly reactive and reacts with the material deposited on the chamber walls to form a volatile product that can be removed through a vacuum exhaust system.

[0004] Typically, such remote plasma cleaning processes require high power and high flow rates of the NF_3 due to low utilization rates. Accordingly, the process can be expensive and wasteful. Additionally, microwave plasma sources are typically bulky and result in the remote chamber being more physically distant from the processing chamber.

[0005] Remote plasma sources are also used for deposition and etch applications where radicals generated by the remote plasma source are used in processing semiconductor wafers. Again, high efficiency processes will assist in higher utilization of input gas and result in a more efficient and faster process.

SUMMARY

[0006] Embodiments disclosed herein include a plasma source. In an embodiment, a plasma source comprises a dielectric body with a top surface, a bottom surface, and sidewall surfaces. In an embodiment, a plurality of holes pass through the dielectric body, where a first set of holes pass from the top surface to the bottom surface, and a second set of holes pass between opposite sidewall surfaces. In an embodiment, a housing is around the dielectric body, and a monopole antenna extending into the dielectric body.

[0007] In an additional embodiment, a plasma processing tool comprises, a chamber, where the chamber is fluidically coupled to a pump that is configured to provide a sub-atmospheric pressure in the chamber, and a plasma source coupled to the chamber. In an embodiment, the plasma source comprises a dielectric body with a top surface, a bottom surface, and sidewall surfaces, and a plurality of holes through the dielectric body, where a first set of holes pass from the top surface to the bottom surface, and a second set of holes pass between opposite sidewall surfaces. In an embodiment, the plasma source may further comprise a housing around the dielectric body, and a monopole antenna extending into the dielectric body.

[0008] In yet another embodiment, a plasma processing tool comprises a chamber, where the chamber is fluidically coupled to a pump configured to provide a sub-atmospheric pressure in the chamber, and a remote plasma source coupled to the chamber. In an embodiment, the remote plasma source comprises a dielectric body and a plurality of holes passing through the dielectric body. In an embodiment, two or more of the plurality of holes intersect each other at a substantially orthogonal angle. In an embodiment, a monopole antenna extends into the dielectric body through an antenna hole, where the antenna hole does not intersect any of the plurality of holes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a front view illustration of a plasma source with a dielectric body with holes through the dielectric body, in accordance with an embodiment.

[0010] FIG. **2**A is a perspective view of the dielectric body of a plasma source, in accordance with an embodiment.

[0011] FIG. **2**B is a cross-sectional illustration of the plasma source that illustrates the intersecting holes and the isolated hole for the monopole antenna, in accordance with an embodiment.

[0012] FIG. **2**C is a perspective view of a dielectric body of a plasma source, where the dielectric body is cylindrical, in accordance with an embodiment.

[0013] FIG. **2**D is a cross-section of the dielectric body in FIG. **2**C, in accordance with an embodiment.

[0014] FIG. **3** is a front view illustration of a plasma source with a dielectric body and cooling channels through the outer housing, in accordance with an embodiment.

[0015] FIG. **4** is a front view illustration of a plasma source with a dielectric body and windows through the outer housing for observing the plasma, in accordance with an embodiment.

[0016] FIG. **5** is a cross-sectional illustration of a plasma processing tool that includes a remote plasma source with a dielectric body with holes through the dielectric body, in accordance with an embodiment.

[0017] FIG. **6** illustrates a block diagram of an exemplary computer system, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0018] Remote plasma systems for generating high-power and density microwave plasmas are described herein. In the following description, numerous specific details are set forth in order to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to one skilled in the art that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known aspects, such as integrated circuit fabrication, are not described in detail in order to not unnecessarily obscure embodiments of the present disclosure. Furthermore, it is to be understood that the various embodiments shown in the Figures are illustrative representations and are not necessarily drawn to scale.

[0019] As noted above, plasma cleaning processes typically utilize remote plasma systems. However, existing systems are limited in gas utilization efficiency and require

high power to achieve a desired gas breakdown efficiency. Accordingly, embodiments disclosed herein include remote plasma sources that have improved gas utilization efficiency and require lower power for the same breakdown efficiency. Additionally, embodiments disclosed herein require a much smaller footprint, and enables closer and better placement of the plasma source relative to the process chamber.

[0020] Particularly, embodiments disclosed herein combine the resonator and reactor chambers to minimize plasma volume and maximize breakdown efficiency of source gases (e.g., NF_3). For example, a grounded reactor chamber may surround a dielectric body that is used as the resonator. Holes may be provided through the dielectric body to provide space to form the plasma. That is, the plasma may be generated inside the resonator. The holes may be oriented to allow for the flow of gasses from a top surface of the dielectric body to a bottom surface of the dielectric body. A monopole antenna inserted into an isolated hole into the dielectric body may excite the plasma within the dielectric body, and dissociated gasses may flow out the bottom surface of the dielectric body to the main processing chamber.

[0021] Referring now to FIG. **1**, a cross-sectional illustration of a plasma source **150** is shown, in accordance with an embodiment. In an embodiment, the plasma source **150** comprises a housing **110** that surrounds a dielectric body **130**. The housing **110** may be a conductive material such as, but not limited to, aluminum. The housing **110** may be grounded in some embodiments. In an embodiment, the dielectric body **130** may be any suitable dielectric material. In a particular embodiment, the dielectric body **130** is a ceramic, such as, but not limited to alumina. In the illustrated embodiment, the housing **110** is shown as a single monolithic structure. However, in other embodiments, top and bottom sides of the housing **110** may be removable and attached to the vertical walls of the housing **110** by elastomer seals, or the like.

[0022] In an embodiment, holes **135** may be provided through the dielectric body **130**. The holes shown in FIG. **1** are oriented from the front of the dielectric body **130** to the back of the dielectric body **130**. It is to be appreciated that additional holes may be provided between the top surface and the bottom surface of the dielectric body **130**, and between sidewall surfaces of the dielectric body **130**. These additional holes are omitted in the interest of clarity in FIG. **1**. A monopole antenna **125** is also shown as being inserted into a sidewall of the dielectric body **130**. While shown as intersection a pair of holes **135**, it is to be appreciated that the monopole antenna **125** may be inserted into an isolated hole **135**, as will be described in greater detail below.

[0023] In an embodiment, a first chamber **141** is above the housing **110**, and a second chamber **142** is below the housing **110**. The first chamber **141** may have an inlet **143** to receive gasses from a gas source. In the case of a plasma cleaning operation, the gas may comprise NF_3. Though, it is to be appreciated that any gas can be flown into the first chamber **141**. That is, the plasma source **150** is not limited to being a plasma source for a cleaning operation. In an embodiment, the second chamber **142** has an outlet **144** that fluidically couples to a processing chamber (not shown in FIG. **1**). In an embodiment, dissociated gas flows out the bottom of the housing **110**, into the second chamber **141** and, eventually, into the processing chamber. In an embodiment, gasses may flow into the dielectric body **130** through openings **112** in the housing **110**. Dissociated gasses may flow out of the dielectric body **130** through openings **113** in the housing **110**. The openings **112** and **113** may be aligned with vertically oriented holes (not shown in FIG. **1**).

[0024] Referring now to FIG. **2**A, a perspective view illustration of the dielectric body **230** is shown, in accordance with an embodiment. In an embodiment, the dielectric body **230** may be a cube. That is, each edge of the dielectric body **230** may have a substantially uniform length L. In other embodiments, the dielectric body may be a rectangular prism (i.e., not all edges have the same length L). In the case of a 2.45 GHz microwave, the length L may be approximately 3 cm.

[0025] As shown, holes **135** are provided along all surfaces of the dielectric body **230**. The holes **135** may have a diameter that is approximately 2 mm or smaller. In an embodiment, the same number of holes **135** are provided along each surface of the dielectric body **230**. For example, in the illustrated embodiment, nine holes are provided along each of the faces of the dielectric body **230**. In other embodiments, different numbers of holes may be provided on different faces. For example the top and bottom surface may comprise nine holes **235**, and the sidewalls may comprise four holes. As will be described in greater detail below, the holes **235** may intersect each other within the dielectric body **230**.

[0026] Referring now to FIG. **2**B, a cross-sectional illustration of the plasma source **250** is shown, in accordance with an embodiment. As shown, a housing **210** surrounds the dielectric body **230**. Holes **235** may be provided through the dielectric body **230**. As shown, the vertical holes may intersect the horizontal holes at a substantially orthogonal angle. However, it is to be appreciated that a middle hole **235**M is not intersected by other holes **235**. The middle hole **235**M may be used to house the monopole antenna **225**. The monopole antenna **225** may also pass through the housing **210** to a coaxial connector on the outside of the plasma source **250**. Providing a dedicated hole **235**M allows for the monopole antenna **225** to be inserted into the dielectric body **230** without also exposing the monopole antenna **225** to the processing gasses. In an embodiment, the antenna **225** is typically at atmospheric pressure, and there is no plasma in the hole **235**M containing the antenna **225**.

[0027] Referring now to FIG. **2**C, a perspective view illustration of a cylindrical dielectric body **230** is shown, in accordance with an embodiment. In an embodiment, the holes **235** may extend from a top surface of the dielectric body **230** to a bottom surface of the dielectric body **230**. The holes **235** may be arranged in a circular pattern, as shown in FIG. **2**C. Of course, it is to be appreciated that any pattern of the holes may be used. In an embodiment, a central hole may be filled by the monopole antenna **225**. The monopole antenna **225** may extend down a radial center of the dielectric body **230**.

[0028] Referring now to FIG. **2**D, a cross-sectional illustration of the dielectric body **230** is shown, in accordance with an embodiment. As shown, the holes **235** may be fluidically connected by a ring **236**. While a substantially circular ring **236** is shown, it is to be appreciated that any type of channel within the dielectric body **230** may fluidically couple two or more of the holes **235** together. As shown, the central hole **235** for the monopole antenna **225** may not be fluidically coupled to the other holes **235**. As such, the monopole antenna **225** may be isolated from gasses

and plasma in the dielectric body **230**. In an embodiment, there may be multiple circular rings **236** along the vertical axis of the dielectric body **230** at various heights.

[0029] Referring now to FIG. **3**, a cross-sectional illustration of a plasma source **350** is shown, in accordance with an additional embodiment. The plasma source **350** may be substantially similar to the plasma source **150** in FIG. **1**, with the exception of the fabrication of the housing **310**. That is, the plasma source **350** may comprise a dielectric body **330** with holes **335**. A first chamber **341** feeds gas from an opening **343** to openings **312** in the housing **310**, and, ultimately, into the dielectric body **330**. Openings **313** in the housing allow for dissociated gas to travel into the second chamber **342** and, ultimately, to a processing chamber through opening **344**. A monopole antenna **325** may be inserted into the dielectric body **330**. While shown as intersecting holes **335**, it is to be appreciated that the monopole antenna **325** may be substantially isolated from all processing gases, similar to the embodiment shown in FIG. **2**B.

[0030] In an embodiment, the housing **310** in FIG. **3** may further comprise cooling channels **315**. The cooling channels **315** may be coupled to an inlet **316** and an outlet **317**. The inlet **316** and the outlet **317** may be coupled to process cooling water (PCW). As such, a dedicated cooling source may not be needed for the housing **310**. In other embodiments, cooling fluids other than water may be used to cool the housing **310**.

[0031] Referring now to FIG. **4**, a cross-sectional illustration of a plasma source **450** is shown, in accordance with an additional embodiment. The plasma source **450** may be substantially similar to the plasma source **150** in FIG. **1**, with the exception of the addition of plasma windows **447** through the housing **410**. That is, the plasma source **450** may comprise a dielectric body **430** with holes **435**. A first chamber **441** feeds gas from an opening **443** to openings **412** in the housing **410**, and, ultimately, into the dielectric body **430**. Openings **413** in the housing allow for dissociated gas to travel into the second chamber **442** and, ultimately, to a processing chamber through opening **444**. A monopole antenna **425** may be inserted into the dielectric body **430**. While shown as intersecting holes **435**, it is to be appreciated that the monopole antenna **425** may be substantially isolated from all processing gases, similar to the embodiment shown in FIG. **2**B.

[0032] In an embodiment, the plasma windows **447** provide a port through the housing **410** that can be used to observe the plasma within the dielectric body **430**. For example, the plasma windows **447** may be aligned with holes (e.g., side holes in FIG. **4**). While shown as a gap in the housing **410**, an optically clear covering may seal the housing **410** at the plasma windows **447**, in accordance with an embodiment. In the illustrated embodiment, a pair of plasma windows **447** are shown. In other embodiments, a single plasma window **447** is provided. In yet another embodiment, more than two plasma windows **447** may be provided.

[0033] Referring now to FIG. **5**, a cross-sectional illustration of a processing tool **500** is shown, in accordance with an embodiment. In an embodiment, the processing tool **500** may be a material deposition tool, such as a chemical vapor deposition (CVD) tool, and atomic layer deposition (ALD) tool, a physical vapor deposition (PVD) tool, or the like. Though it is to be appreciated that embodiments disclosed herein are not limited to deposition tools. For example, the plasma source described herein may optionally be used in etching chambers (e.g., material removal), plasma treatment chambers, or any other plasma chamber typical of semiconductor manufacturing environments.

[0034] The processing tool **500** may comprise a processing chamber **501**. The processing chamber **501** may comprise a pedestal **503**, chuck, or the like for supporting and securing a substrate **505** during processing. The substrate **505** may be a wafer, such as a silicon wafer or other semiconductor wafer. Though, it is to be appreciated that the substrate **505** may also be other substrates, such as glass substrates, organic substrates, or the like. In an embodiment, the processing chamber **501** may be configured to be operated at a sub-atmospheric pressure. For example, the processing chamber **501** may be fluidically coupled to an exhaust **502** that is controlled by a pump. Over the course of processing substrates **505** in the processing chamber **501**, the interior surfaces of the processing chamber **501** may be coated with deposition material (in the case of a deposition process) or by etching byproducts (in the case of an etching process). In order to maintain proper processing conditions with the processing chamber **501**, the interior surfaces need to be periodically cleaned. In an embodiment, the cleaning process may be implemented through the use of a remote plasma.

[0035] In an embodiment, the processing tool **500** may comprise a remote plasma source **550**. The remote plasma source **550** may be provided above the processing chamber **501**. Due to the compact design of the remote plasma source **550**, integration with existing processing chambers **501** is simplified. In an embodiment, the remote plasma source **550** may be fed processing gasses into an opening **543** from a gas source (not shown). In the particular embodiment of a plasma cleaning operation, the gas may comprise NF_3. Though it is to be appreciated that other gasses may also be used in accordance with various embodiments.

[0036] The plasma source **550** shown in FIG. **5** may be substantially similar to the plasma source **150** in FIG. **1**. That is, the plasma source **550** may comprise a dielectric body **530** with holes **535**. A first chamber **541** feeds gas from an opening **543** to openings **512** in the housing **510**, and, ultimately, into the dielectric body **5330**. Openings **513** in the housing allow for dissociated gas to travel into the second chamber **5342** and, ultimately, to a processing chamber through opening **544**. A monopole antenna **525** may be inserted into the dielectric body **530**. While shown as intersecting holes **535**, it is to be appreciated that the monopole antenna **525** may be substantially isolated from all processing gases, similar to the embodiment shown in FIG. **2**B.

[0037] While shown as being substantially similar to the plasma source in FIG. **1**, it is to be appreciated that the plasma source **550** may be similar to any of the embodiments described herein. For example, the plasma source **550** may further comprise a housing **510** with cooling channels that are coupled to the tool PCW, as shown in FIG. **3**. Additionally, plasma windows may be formed through the housing **510** in order to observe the plasma within the dielectric body **530**.

[0038] FIG. **6** illustrates a diagrammatic representation of a machine in the exemplary form of a computer system **600** within which a set of instructions, for causing the machine to perform any one or more of the methodologies described

herein, may be executed. In alternative embodiments, the machine may be connected (e.g., networked) to other machines in a Local Area Network (LAN), an intranet, an extranet, or the Internet. The machine may operate in the capacity of a server or a client machine in a client-server network environment, or as a peer machine in a peer-to-peer (or distributed) network environment. The machine may be a personal computer (PC), a tablet PC, a set-top box (STB), a Personal Digital Assistant (PDA), a cellular telephone, a web appliance, a server, a network router, switch or bridge, or any machine capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines (e.g., computers) that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies described herein.

[0039] The exemplary computer system **600** includes a processor **602**, a main memory **604** (e.g., read-only memory (ROM), flash memory, dynamic random access memory (DRAM) such as synchronous DRAM (SDRAM) or Rambus DRAM (RDRAM), etc.), a static memory **606** (e.g., flash memory, static random access memory (SRAM), MRAM, etc.), and a secondary memory **618** (e.g., a data storage device), which communicate with each other via a bus **630**.

[0040] Processor **602** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processor **602** may be a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, processor implementing other instruction sets, or processors implementing a combination of instruction sets. Processor **602** may also be one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. Processor **602** is configured to execute the processing logic **626** for performing the operations described herein.

[0041] The computer system **600** may further include a network interface device **608**. The computer system **600** also may include a video display unit **610** (e.g., a liquid crystal display (LCD), a light emitting diode display (LED), or a cathode ray tube (CRT)), an alphanumeric input device **612** (e.g., a keyboard), a cursor control device **614** (e.g., a mouse), and a signal generation device **616** (e.g., a speaker).

[0042] The secondary memory **618** may include a machine-accessible storage medium (or more specifically a computer-readable storage medium) **632** on which is stored one or more sets of instructions (e.g., software **622**) embodying any one or more of the methodologies or functions described herein. The software **622** may also reside, completely or at least partially, within the main memory **604** and/or within the processor **602** during execution thereof by the computer system **600**, the main memory **604** and the processor **602** also constituting machine-readable storage media. The software **622** may further be transmitted or received over a network **620** via the network interface device **608**.

[0043] While the machine-accessible storage medium **632** is shown in an exemplary embodiment to be a single medium, the term "machine-readable storage medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The term "machine-readable storage medium" shall also be taken to include any medium that is capable of storing or encoding a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure. The term "machine-readable storage medium" shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media.

[0044] In accordance with an embodiment of the present disclosure, a machine-accessible storage medium has instructions stored thereon which cause a data processing system to perform a method of cleaning a processing chamber using a remote plasma source with a dielectric body with a plurality of holes and a grounded housing.

[0045] Thus, methods for chamber cleaning with a remote plasma have been disclosed.

What is claimed is:

1. A plasma source, comprising:
a dielectric body with a top surface, a bottom surface, and sidewall surfaces;
a plurality of holes through the dielectric body, wherein a first set of holes pass from the top surface to the bottom surface, and a second set of holes pass between opposite sidewall surfaces;
a housing around the dielectric body; and
a monopole antenna extending into the dielectric body.

2. The plasma source of claim **1**, wherein the first set of holes intersect the second set of holes.

3. The plasma source of claim **1**, wherein the housing is grounded.

4. The plasma source of claim **1**, wherein openings are formed through the housing above and below the dielectric body, wherein the openings are aligned with the first set of holes.

5. The plasma source of claim **1**, wherein diameters of individual ones of the holes is approximately 2 mm or smaller.

6. The plasma source of claim **1**, further comprising:
cooling channels through the housing.

7. The plasma source of claim **1**, wherein the dielectric body is a cube.

8. The plasma source of claim **7**, wherein each edge of the cube has a length of approximately 3 cm.

9. The plasma source of claim **1**, wherein the dielectric body is alumina.

10. The plasma source of claim **1**, wherein the monopole antenna extends into the dielectric body through a hole that does not intersect with any other holes.

11. The plasma source of claim **1**, further comprising:
a window through the housing.

12. The plasma source of claim **1**, further comprising:
a gas inlet above the housing; and
a gas outlet below the housing.

13. A plasma processing tool, comprising:
a chamber, wherein the chamber is fluidically coupled to a pump that is configured to provide a sub-atmospheric pressure in the chamber; and
a plasma source coupled to the chamber, wherein the plasma source comprises:

a dielectric body with a top surface, a bottom surface, and sidewall surfaces;

a plurality of holes through the dielectric body, wherein a first set of holes pass from the top surface to the bottom surface, and a second set of holes pass between opposite sidewall surfaces;

a housing around the dielectric body; and

a monopole antenna extending into the dielectric body.

14. The plasma processing tool of claim **13**, further comprising:

a gas inlet to feed gas into the first set of holes; and

a gas outlet between a bottom of the first set of holes and the chamber.

15. The plasma processing tool of claim **13**, wherein the plasma source is a remote plasma source.

16. The plasma processing tool of claim **13**, wherein diameters of individual ones of the plurality of holes is approximately 2 mm or smaller.

17. The plasma processing tool of claim **13**, wherein the dielectric body is a cube, and wherein edges of the cube have a length that is approximately 3 cm or less.

18. A plasma processing tool, comprising:

a chamber, wherein the chamber is fluidically coupled to a pump configured to provide a sub-atmospheric pressure in the chamber; and

a remote plasma source coupled to the chamber, wherein the remote plasma source comprises:

a dielectric body;

a plurality of holes passing through the dielectric body, wherein two or more of the plurality of holes intersect each other at a substantially orthogonal angle, and

a monopole antenna extending into the dielectric body through an antenna hole, wherein the antenna hole does not intersect any of the plurality of holes.

19. The plasma processing tool of claim **18**, further comprising:

a grounded housing surrounding the dielectric body.

20. The plasma processing tool of claim **18**, wherein individual ones of the plurality of holes have diameters that are approximately 2 mm or smaller.

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