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(54) **HIGH-EFFICIENCY RF REMOTE PLASMA SOURCE APPARATUS**

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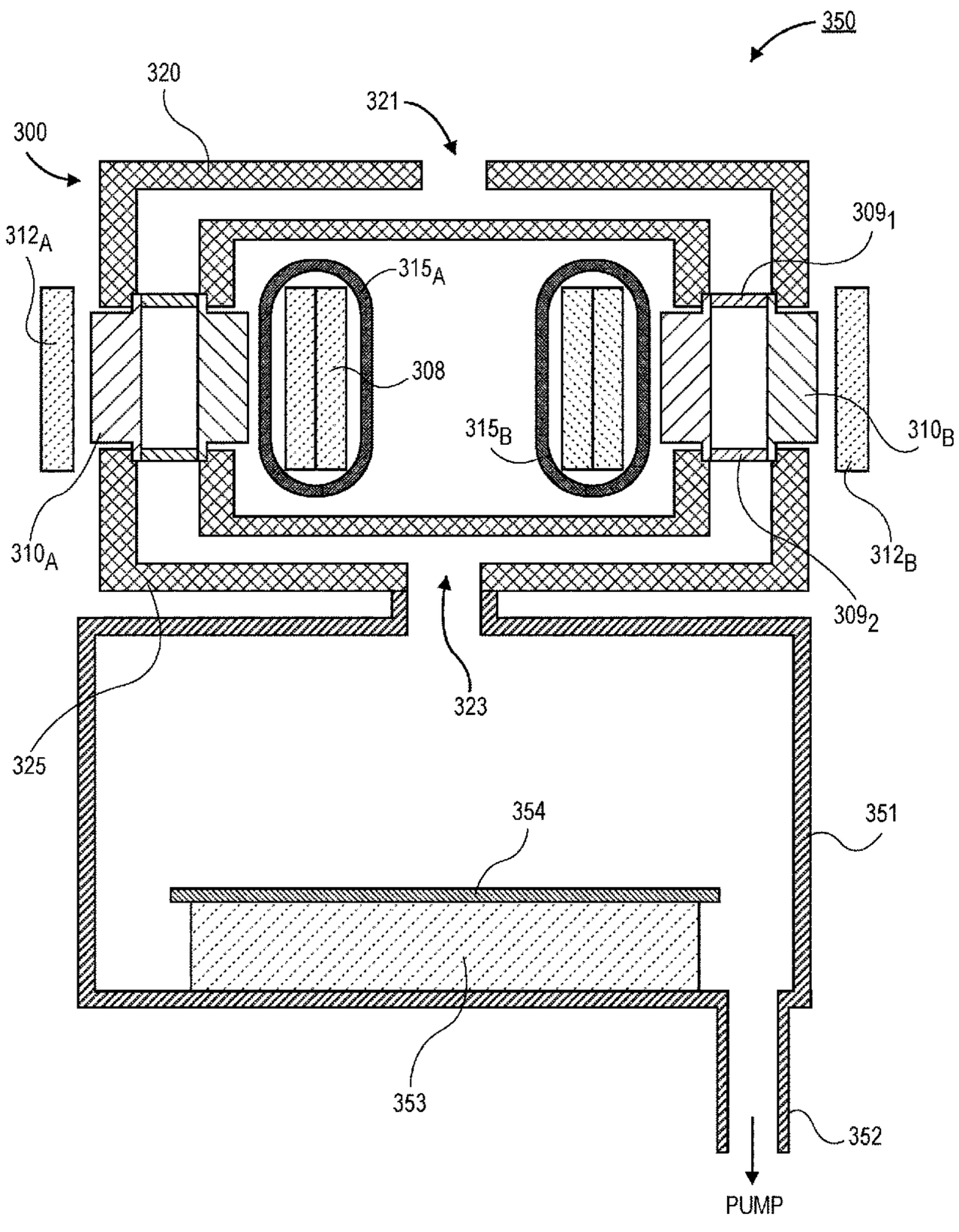
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(57) **ABSTRACT**

Embodiments disclosed herein include plasma sources. In an embodiment, a plasma source comprises an input to a plenum for dividing gas into a plurality of parallel fluidic paths, a plurality of plasma zones, wherein each plasma zone is along one of the plurality of parallel fluidic paths, and a plurality of magnetic cores, wherein each magnetic core surrounds one of the plurality of plasma zones. In an embodiment, an RF coil wraps around the plurality of magnetic cores. In an embodiment, the plasma source further comprises a manifold at a bottom of the plurality of plasma zones, where the manifold merges the plurality of fluidic paths into a single output.



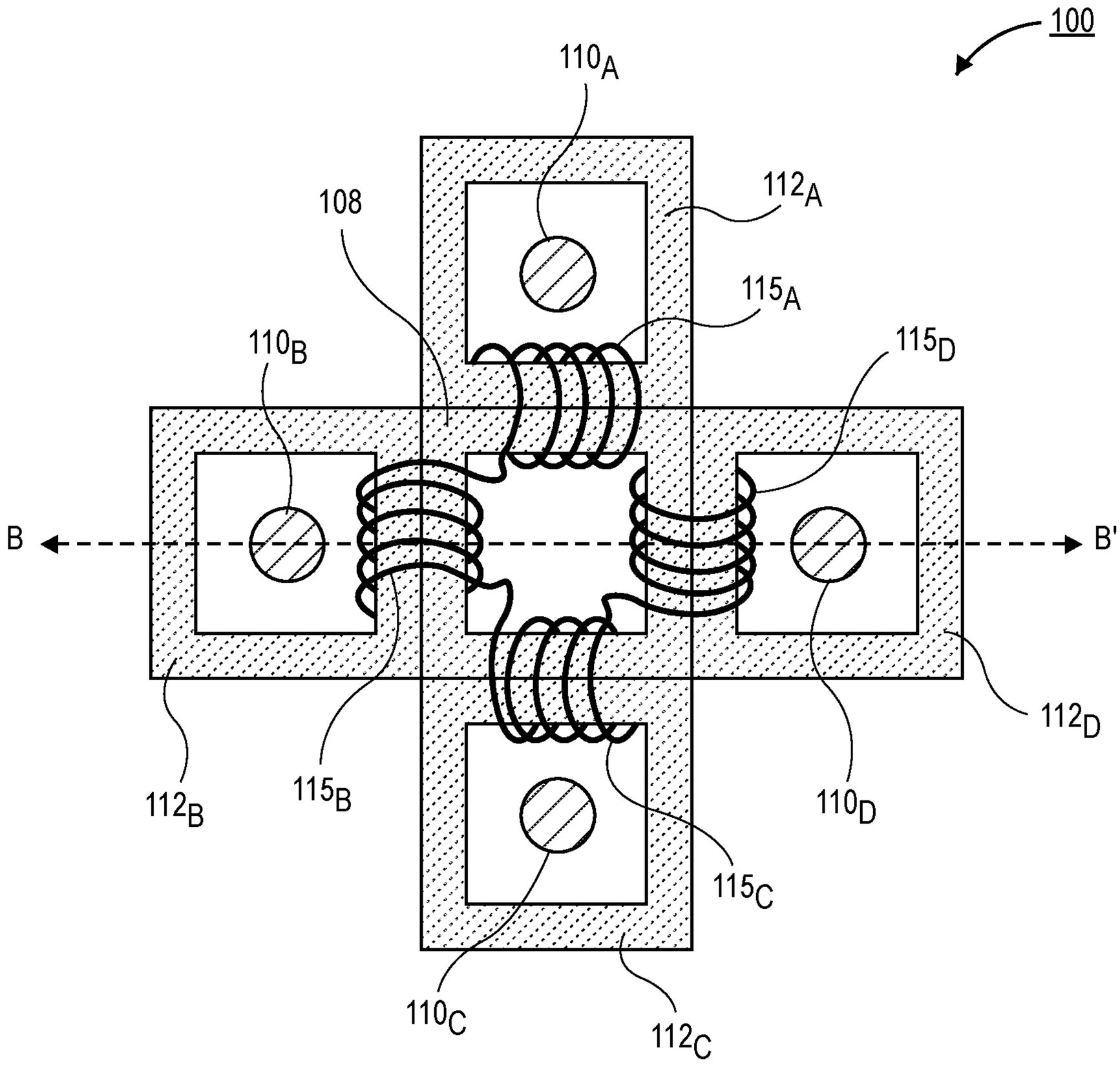

100
110A
108
112A
115A
110B
115D
B
B'
112B
115B
110D
112D
115C
110C
112C

FIG. 1A

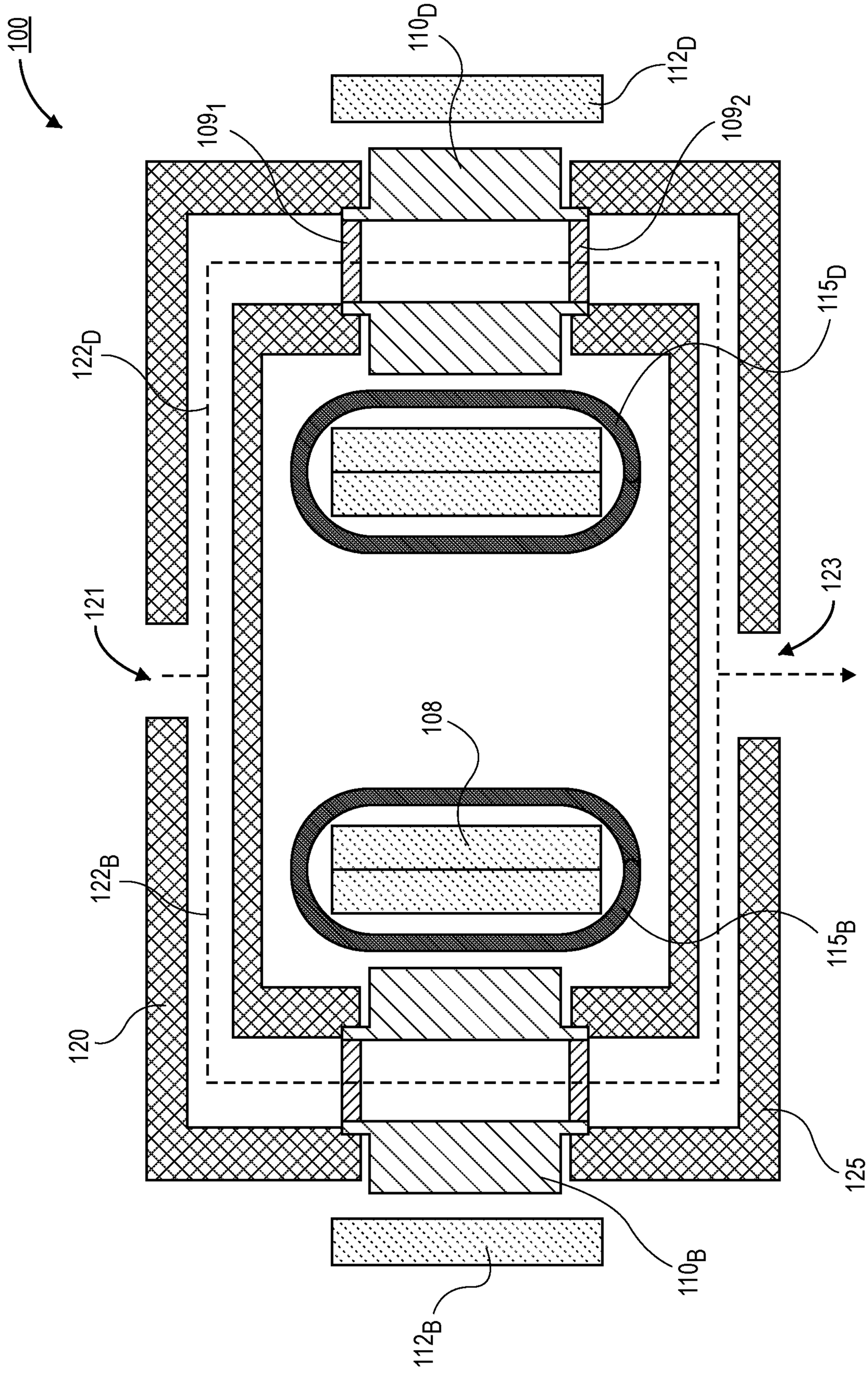

100
110_D
112_D
109_1
109_2
115_D
122_D
121
123
108
122_B
115_B
120
125
110_B
112_B

FIG. 1B

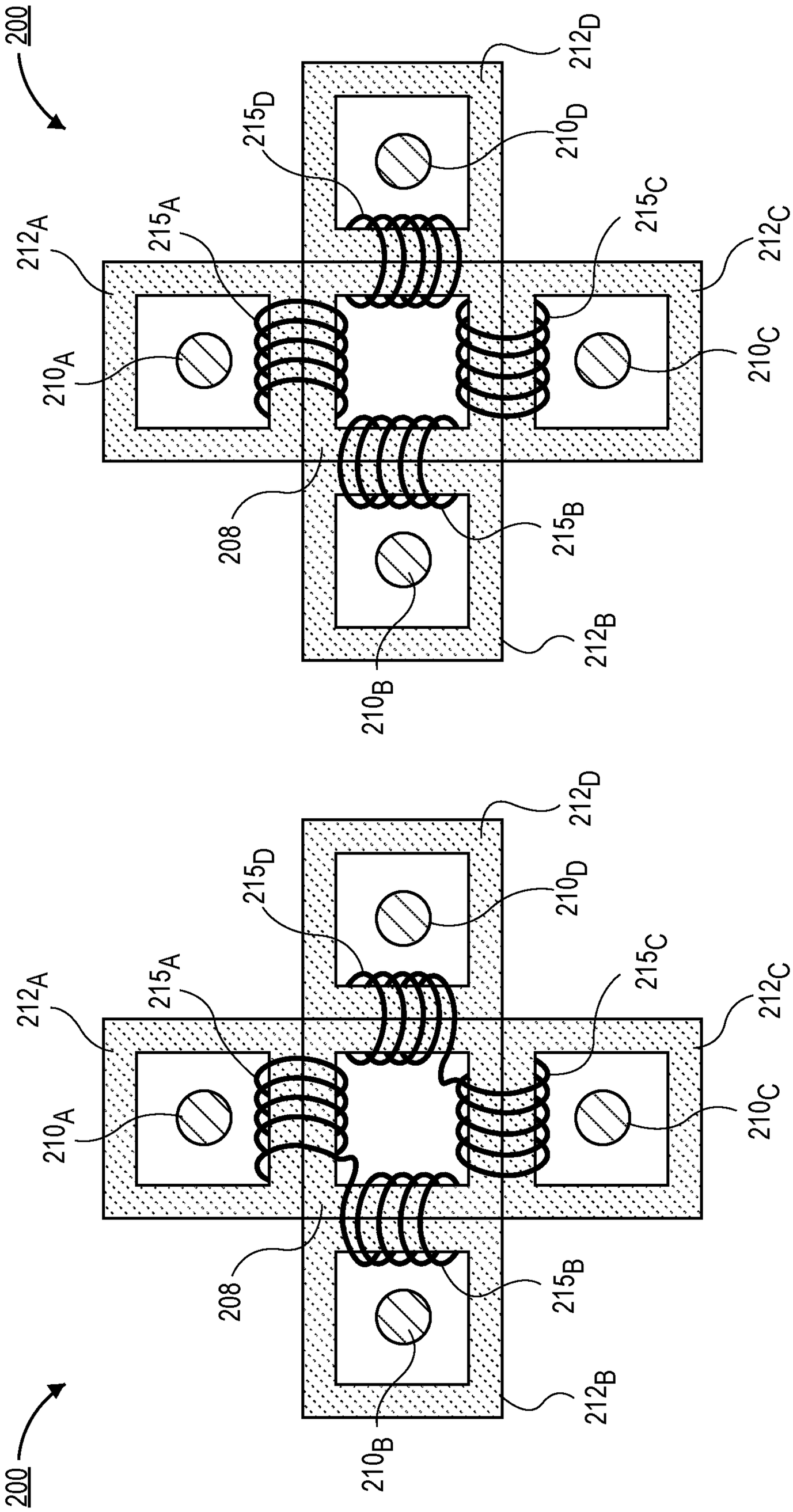

200
212D
215D
210D
212A
215A
215C
212C
210A
210C
208
215B
212B
210B

FIG. 2B

212D
215D
210D
212A
215A
215C
212C
210A
210C
208
215B
212B
210B
200

FIG. 2A

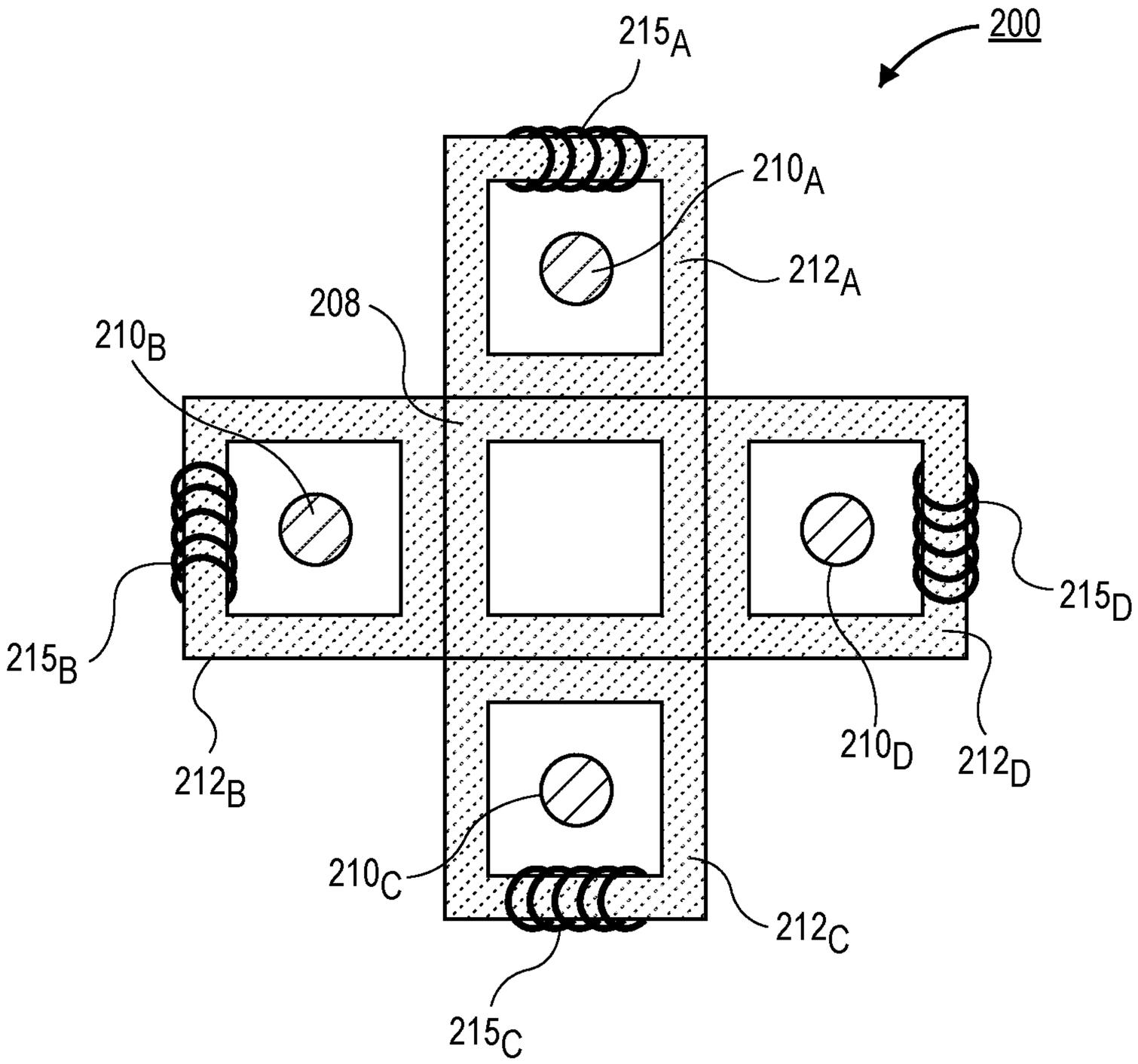

200
215A
210A
212A
208
210B
215B
212B
215D
210D
212D
210C
212C
215C

FIG. 2C

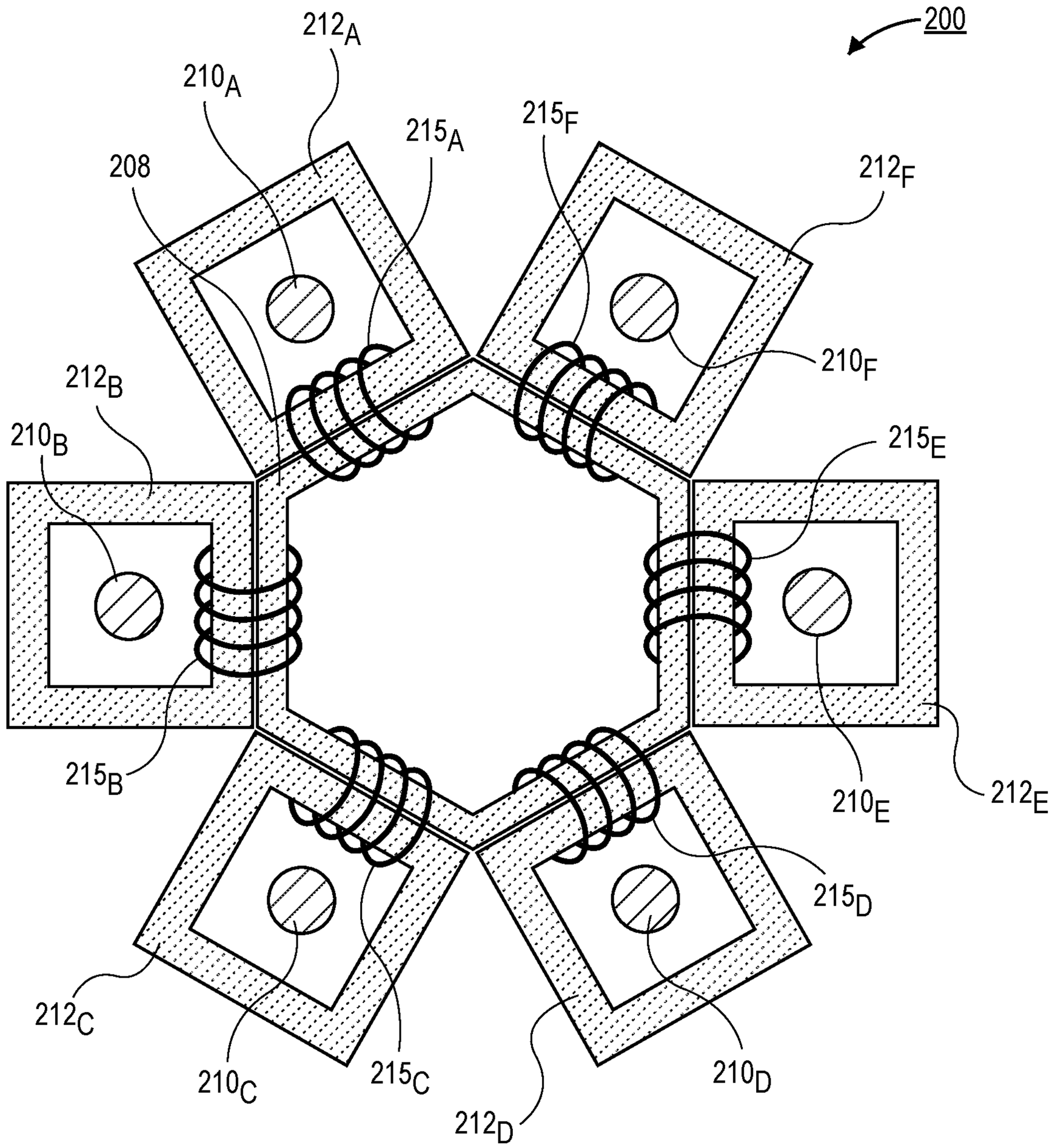

200
212A
210A
215A
208
215F
212F
210F
212B
210B
215E
215B
210E
212E
215D
212C
210C
215C
212D
210D

FIG. 2D

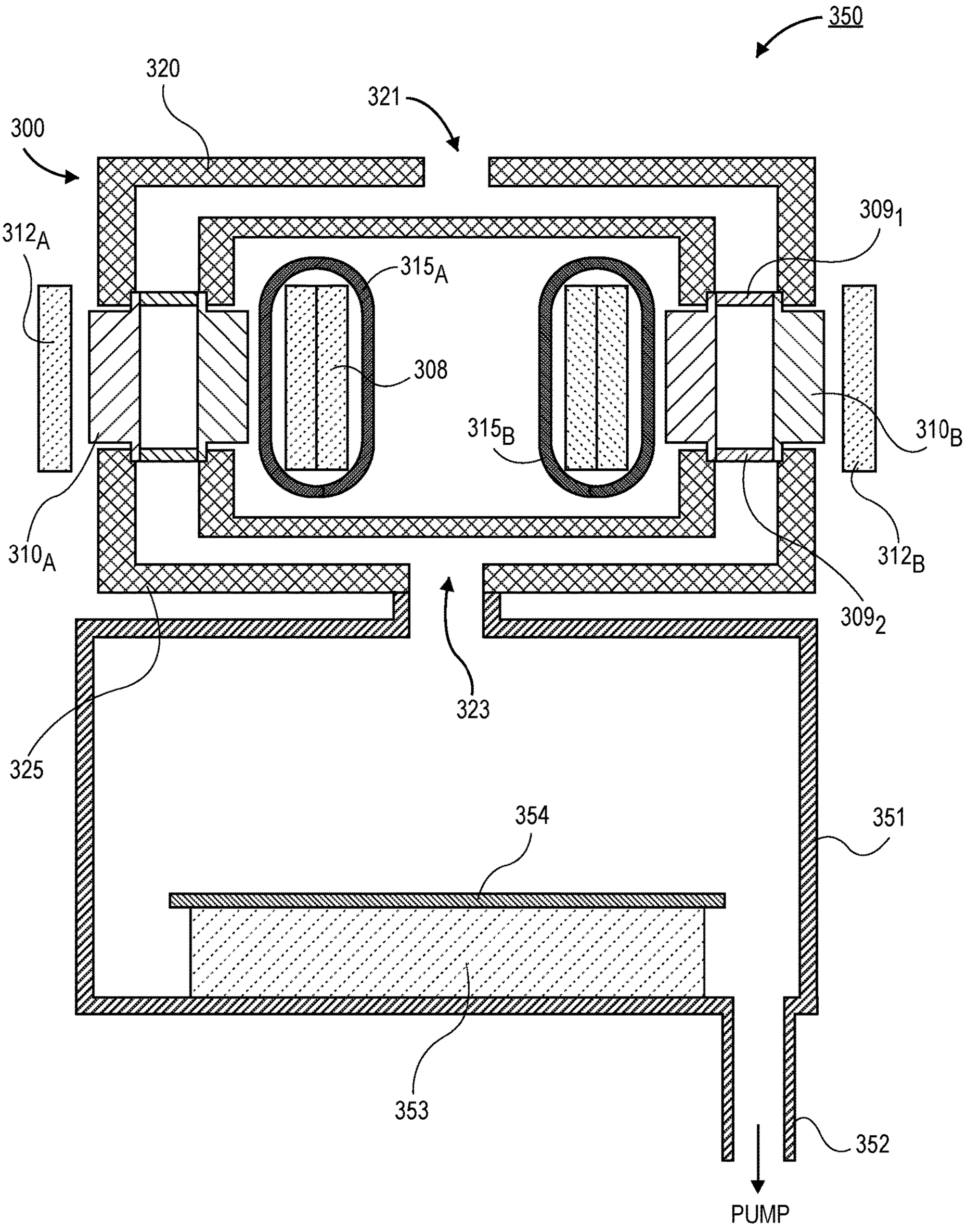

350
320
321
300
309_1
312_A
315_A
308
315_B
310_B
310_A
312_B
309_2
323
325
354
351
353
352
PUMP

FIG. 3

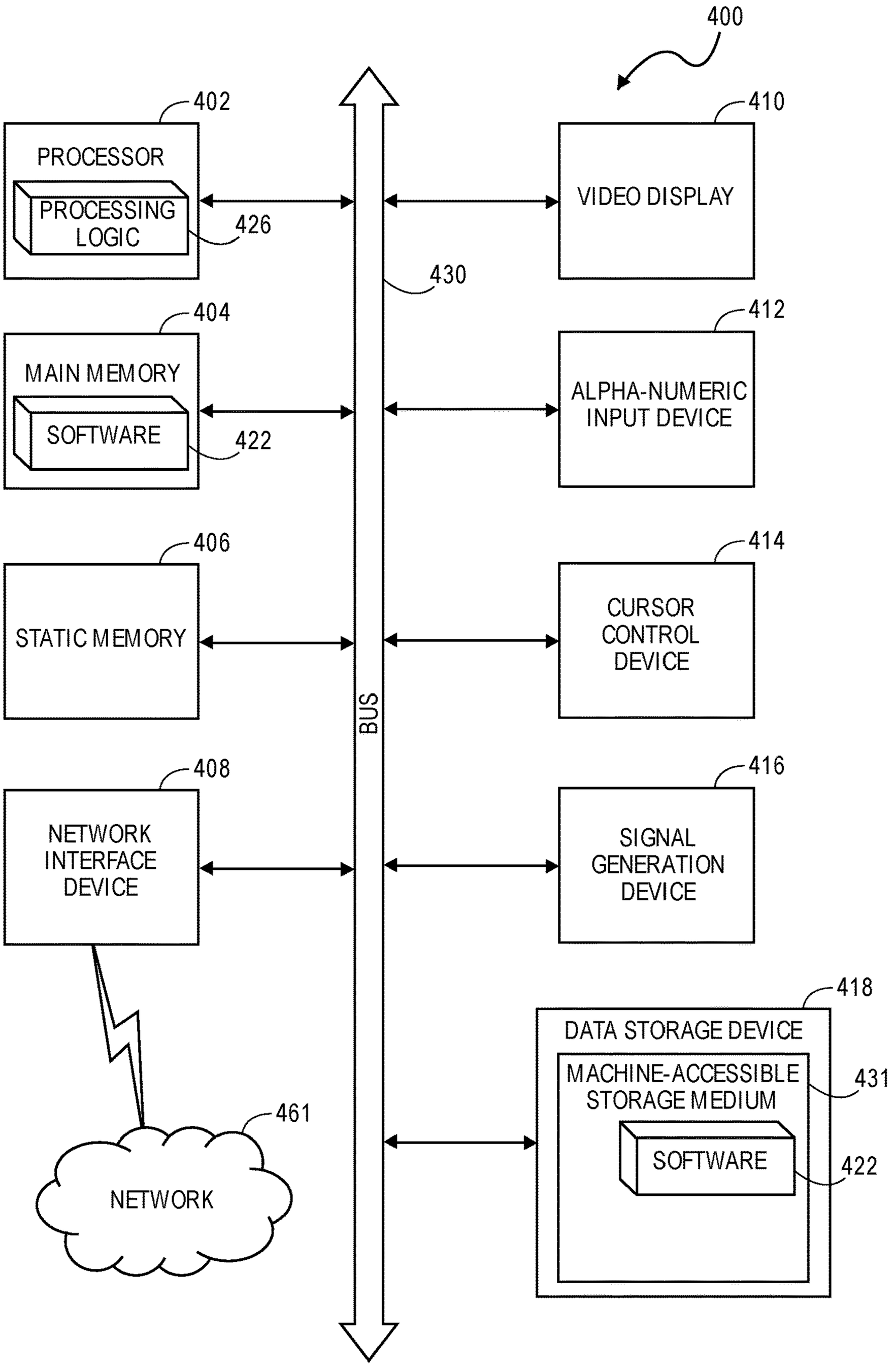

400
402
PROCESSOR
PROCESSING LOGIC
426
410
VIDEO DISPLAY
430
404
MAIN MEMORY
SOFTWARE
422
412
ALPHA-NUMERIC INPUT DEVICE
406
STATIC MEMORY
414
CURSOR CONTROL DEVICE
BUS
408
NETWORK INTERFACE DEVICE
416
SIGNAL GENERATION DEVICE
418
DATA STORAGE DEVICE
MACHINE-ACCESSIBLE STORAGE MEDIUM
431
SOFTWARE
422
461
NETWORK

FIG. 4

HIGH-EFFICIENCY RF REMOTE PLASMA SOURCE APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/215,366, 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 RF remote plasma sources for generating high-efficiency 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.

SUMMARY

[0005] Embodiments disclosed herein include plasma sources. In an embodiment, a plasma source comprises an input to a plenum for dividing gas into a plurality of parallel fluidic paths, a plurality of plasma zones, wherein each plasma zone is along one of the plurality of parallel fluidic paths, and a plurality of magnetic cores, wherein each magnetic core surrounds one of the plurality of plasma zones. In an embodiment, an RF coil wraps around the plurality of magnetic cores. In an embodiment, the plasma source further comprises a manifold at a bottom of the plurality of plasma zones, where the manifold merges the plurality of fluidic paths into a single output.

[0006] In an additional embodiment, a plasma source comprises a fluidic path having an upstream side and a downstream side, where a plurality of fluidic segments are in parallel to each other between the upstream side and the downstream side. In an embodiment, the plasma source further comprises a plurality of plasma zones, where each plasma zone is along one of the fluidic segments. In an embodiment, the plasma source further comprises a plurality of magnetic cores, where each magnetic core surrounds one of the plasma zones.

[0007] Additional embodiments include a semiconductor processing tool. In an embodiment, the semiconductor processing tool comprises a remote plasma source with an upstream end and a downstream end. In an embodiment, the remote plasma source comprises a plenum at the upstream end, where the plenum feeds gas to a plurality of plasma zones, where each plasma zone is surrounded by a magnetic core, and a manifold at the downstream end where the manifold merges gas to an output. In an embodiment, the semiconductor processing tool further comprises a chamber fluidically coupled to the outlet of the remote plasma.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1**A is a plan view illustration of a remote plasma source with a plurality of plasma zones, where each plasma zone is surrounded by a magnetic core, in accordance with an embodiment.

[0009] FIG. **1**B is a cross-sectional illustration of the remote plasma source in FIG. **1**A along line B-B', in accordance with an embodiment.

[0010] FIG. **2**A is a plan view illustration of a remote plasma source with a plurality of plasma zones, where the RF coils around the magnetic cores are connected in pairs, in accordance with an embodiment.

[0011] FIG. **2**B is a plan view illustration of a remote plasma source with a plurality of plasma zones, where the RF coils around the magnetic cores are electrically isolated from each other, in accordance with an embodiment.

[0012] FIG. **2**C is a plan view illustration of a remote plasma source with a plurality of plasma zones, where the RF coils warp around an exterior edge of each magnetic core, in accordance with an embodiment.

[0013] FIG. **2**D is a plan view illustration of a remote plasma source with six plasma zones in a hexagonal pattern, in accordance with an embodiment.

[0014] FIG. **3** is a cross-sectional illustration of a plasma processing tool with a remote plasma source with a plurality of plasma zones, in accordance with an embodiment.

[0015] FIG. **4** illustrates a block diagram of an exemplary computer system, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0016] RF remote plasma sources for generating high-efficiency 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.

[0017] As noted above, plasma cleaning operations that use an NF_3 source gas suffer from significant efficiency limitations. Particularly, high energies are needed in order to breakdown the NF_3 sufficiently. Additionally, a high feed rate of the NF_3 gas is needed due to low utilization of the gas. Due to the need for high power and high flowrates, the cleaning process can become expensive to implement. Additionally, durability of equipment is reduced due to the higher energies needed for the process.

[0018] Accordingly, embodiments disclosed herein include a remote plasma source that allows for a reduction in the power and gas feed rates while still enabling high gas utilization. Particularly, embodiments disclosed herein

include the use of a plenum at an upstream end of the remote plasma source and a manifold at the downstream end of the remote plasma source. The plenum separates the gas into a plurality of parallel fluidic paths, with each fluidic path passing through a plasma zone. Each plasma zone may comprise a conductive shell surrounded by a magnetic core. The conductive shell may have a dielectric coating and be electrically insulated from the plasma and be protected from chemical and physical erosion by the chemicals and ions present. In an embodiment, RF coils wrap around the magnetic cores in order to induce a plasma in the conductive shell. After dissociating the source gas with the plasma, the radical species from each plasma zone can be routed to a single outlet to processing chamber by a manifold.

[0019] The use of parallel fluidic paths allows for the velocity of the gas through the plasma zones to be reduced. The reduced velocity allows for longer residence times within the plasma region and enables a more efficient process and better dissociation efficiency for breaking feed gases to radical species. Such a setup allows for higher flow rates at the input while keeping the same power requirements compared to existing processes and chambers. Alternatively, higher efficiencies can be obtained when the flow rates are kept similar to existing processes and chambers while reducing power input.

[0020] Referring now to FIG. **1**A, a plan view schematic of a portion of a remote plasma source **100** is shown, in accordance with an embodiment. The illustrated portion is through a plane that includes the plasma zones **110**. That is, a plenum (not shown) may be provided above the plane shown in FIG. **1**A, and a manifold (not shown) may be provided below the plane shown in FIG. **1**A. Each of the plasma zones $\mathbf{110}_A$-$\mathbf{110}_D$ may be parallel fluidic paths between the plenum and the manifold. The plasma zones $\mathbf{110}_A$-$\mathbf{110}_D$ are illustrated as cylinders in FIG. **1**A in order to not obscure embodiments disclosed herein. However, it is to be appreciated that the plasma zones $\mathbf{110}_A$— $\mathbf{110}_D$ have a more complex structure, as will be described in greater detail below.

[0021] In an embodiment, each of the plasma zones $\mathbf{110}_A$-$\mathbf{110}_D$ may be surrounded by a magnetic core **112**A-$\mathbf{112}_D$. In an embodiment, each of the magnetic cores **112** may be a ring of magnetic material that completely surrounds a perimeter of the plasma zones **110**. In the illustrated embodiment, the magnetic cores **112** are square shaped rings, though it is to be appreciated that other shapes may also be used in other embodiments (e.g., circular rings, or the like). In an embodiment, the magnetic material of the magnetic cores **112** may be ferrite or other magnetic materials.

[0022] In an embodiment, the magnetic cores **112** may each be oriented on a face of a central magnetic core **108**. In an embodiment, the central magnetic core **108** may be a square shaped ring. That is, there are four faces that can be adjacent to the magnetic cores **112**. Since each plasma zone **110** is surrounded by a magnetic core **112**, there can be a total of up to four plasma zones **110** when a square shaped ring is used for the central magnetic core **108**. It is to be appreciated that other shapes may be used for the central magnetic core **108** to provide remote plasma source **100** with a different number of plasma zones **110**. An example of a different shaped central magnetic core **108** is provided in greater detail below. Additionally, not all sidewalls of the central magnetic core **108** may be populated by a plasma zone **110**. For example, a remote plasma source **100** with a square shaped central magnetic core **108** may include two plasma zones **110** or three plasma zones **110**. Additionally, a plasma zone **110** may also be provided in the central magnetic core **108**.

[0023] In an embodiment, RF coils **115** may wrap around each of the magnetic cores **112**. The RF coils **115** may also wrap around the adjacent surface of the central magnetic core **108**. As shown, each of the RF coils $\mathbf{115}_A$-$\mathbf{115}_D$ are electrically connected to each other in series. That is, an end of RF coil $\mathbf{115}_A$ is connected to a start of RF coil $\mathbf{115}_B$, an end of RF coil **115**E is connected to a start of RF coil $\mathbf{115}_C$, and an end of RF coil $\mathbf{115}_C$ is connected to a start of RF coil $\mathbf{115}_D$. As will be described in greater detail below, different connection schemes between the RF coils $\mathbf{115}_A$-$\mathbf{115}_D$ may be used in other embodiments. Due to the radial arrangement of the magnetic cores **112** and the RF coils **115**, a single power supply is able to service each of the plasma zones $\mathbf{110}_A$-$\mathbf{110}_D$.

[0024] Referring now to FIG. **1**B, a cross-sectional illustration of the remote plasma system along line B-B' in FIG. **1**A is shown, in accordance with an embodiment. The illustrated embodiment passes through the second plasma zone **110**E and the fourth plasma zone $\mathbf{110}_D$. However, it is to be appreciated that other plasma zones $\mathbf{110}_A$ and $\mathbf{110}_C$ may have substantially similar architectures. Additionally, it is to be appreciated that fluidic paths through the plasma zones $\mathbf{110}_A$ and $\mathbf{110}_C$ are in parallel with the fluidic paths through the second plasma zone **110**E and the fourth plasma zone $\mathbf{110}_D$.

[0025] As shown, a plenum **120** is provided at an upstream side of the plasma zones **110**. An inlet **121** can be coupled to a gas source. In a particular embodiment, the gas source comprises NF_3. However, it is to be appreciated that the gas source may comprise any gas used in semiconductor processing environments. In an embodiment, the plenum splits that gas flow into a plurality of fluidic paths **122**. For example, a fluidic path $\mathbf{122}_B$ is routed to the second plasma zone $\mathbf{110}_B$, and a fluidic path $\mathbf{122}_D$ is routed to the fourth plasma zone $\mathbf{110}_D$. The plenum **120** also routes gasses to the plasma zones **110** out of the plane of FIG. **1**B.

[0026] In an embodiment, the plasma zones **110** are a conductive shell. Gas is allowed to flow into and out of the conductive shell through a first limiter **1091** on the upstream side of the plasma zone **110** and a second limiter **1092** on a downstream side of the plasma zone **110**. The limiters **109** may have holes large enough to allow for adequate gas flows, while still confining a plasma that is struck in the space within the conductive shell. In an embodiment, the plasma is struck in the plasma zones using an RF coil **115**. As shown, the RF coil **115**E wraps around an edge of the magnetic core $\mathbf{112}_E$ and the central magnetic core **108**, and the RF coil $\mathbf{115}_D$ wraps around an edge of the magnetic core $\mathbf{112}_D$ and the central magnetic core **108**.

[0027] In an embodiment, the downstream ends of the plasma zones **110** are fluidically coupled together by a manifold **125**. The manifold **125** routes the fluidic paths $\mathbf{122}_B$ and $\mathbf{122}_D$ to a single outlet **123** that can be coupled to a processing chamber (not shown). In an embodiment, the manifold **125** also routes the downstream ends of the plasma zones **110** not shown in the cross-section of FIG. **1**B.

[0028] Referring now to FIG. **2**A, a plan view illustration of a remote plasma system **200** is shown, in accordance with an additional embodiment. The remote plasma system **200** in FIG. **2**A may be substantially similar to the remote plasma

system **100** in FIG. **1**A, with the exception of the configuration of the RF coils **215**. That is, the remote plasma system **200** may comprise a central magnetic core **208** and a plurality of magnetic cores $\mathbf{212}_A$-$\mathbf{212}_D$ surrounding the central magnetic core **208**. Plasma zones $\mathbf{210}_A$-$\mathbf{210}_D$ are provided within the magnetic cores $\mathbf{212}_A$-$\mathbf{212}_D$.

[0029] The difference in FIG. **2**A is how the RF coils **215** are connected. Instead of connecting all of the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ in series, pairs of RF coils **215** are coupled together or individually driven by the power supply or power supplies. For example, RF coil $\mathbf{215}_A$ is connected to RF coil $\mathbf{215}_B$, and RF coil $\mathbf{215}_C$ is connected to RF coil $\mathbf{215}_D$. In an embodiment, the pairs of RF coils ($\mathbf{215}_A$-$\mathbf{215}_B$ and $\mathbf{215}_C$-$\mathbf{215}_D$) may be connected to a single power supply in parallel. In other embodiments, different power supplies may be used for the different pairs. In some embodiments, the direction of the current within the RF coils **215** may be adjusted to enhance the field in the central magnetic core **208** to increase the overall efficiency of the units in breaking down the feed-gas in the plasma.

[0030] Referring now to FIG. **2**B, a plan view illustration of a remote plasma system **200** is shown, in accordance with an additional embodiment. The remote plasma system **200** in FIG. **2**B may be substantially similar to the remote plasma system **100** in FIG. **1**A, with the exception of the configuration of the RF coils **215**. That is, the remote plasma system **200** may comprise a central magnetic core **208** and a plurality of magnetic cores $\mathbf{212}_A$-$\mathbf{212}_D$ surrounding the central magnetic core **208**. Plasma zones $\mathbf{210}_A$-$\mathbf{210}_D$ are provided within the magnetic cores $\mathbf{212}_A$-$\mathbf{212}_D$.

[0031] The difference in FIG. **2**B is how the RF coils **215** are connected. Instead of connecting all of the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ in series, each of the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ are electrically isolated from each other. In an embodiment, each of the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ may be connected to a single power supply in parallel. In other embodiments, different power supplies may be used for the different RF coils **215**. In some embodiments, the direction of the current within the RF coils **215** may be adjusted to enhance the field in the central magnetic core **208** to increase the overall efficiency of the units in breaking down the feed-gas in the plasma.

[0032] Referring now to FIG. **2**C, a plan view illustration of a remote plasma system **200** is shown, in accordance with an additional embodiment. The structure of the remote plasma system **200** in FIG. **2**C may be substantially similar to the structure in FIG. **2**B, with the exception of the location of the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$. Instead of being on an interior edge and wrapping around the central magnetic core **208**, the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ are provided around outer edges of the magnetic cores $\mathbf{212}_A$-$\mathbf{212}_D$. Such a configuration allows for each plasma zone **210** to operated truly independently. In the illustrated embodiment, each of the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ are electrically isolated from each other. However, in other embodiments, the RF coils $\mathbf{215}_A$-$\mathbf{215}_D$ may be connected in series, or in any other configuration.

[0033] Referring now to FIG. **2**D, a plan view illustration of remote plasma source **200** is shown, in accordance with an additional embodiment. In an embodiment, the remote plasma source **200** in FIG. **2**D is substantially similar to the remote plasma source **200** in FIG. **2**B, with the exception of there being additional magnetic cores **212** and plasma zones **210**. Particularly, the central magnetic core **208** may be a hexagonal ring. As such, there are six sidewalls to couple with plasma zones **210**. As such, six plasma zones $\mathbf{210}_A$-$\mathbf{210}_F$ and six magnetic cores $\mathbf{212}_A$-$\mathbf{212}_F$ are provided in FIG. **2**C. It is to be appreciated that any shaped central magnetic core **208** may be used to provide a desired number of parallel plasma zones **210**. For example, a triangular central magnetic core **208** may be used to provide a three plasma zone **210** embodiment, or an octagon shaped central magnetic core **208** may be used to provide an eight plasma zone **210** embodiment. In the same fashion, the plasma source **200** may contain more sides to the central magnetic core **208** and more than eight plasma zones.

[0034] In FIG. **2**D, each of the RF coils $\mathbf{215}_A$-$\mathbf{215}_F$ are shown as being electrically isolated from each other. In other embodiments, two or more of the RF coils $\mathbf{215}_A$-$\mathbf{215}_F$ may be connected together. For example, the RF coils $\mathbf{215}_A$-$\mathbf{215}_F$ may be connected together in pairs (e.g., $\mathbf{215}_A$ connected to $\mathbf{215}_B$), or the RF coils $\mathbf{215}_A$-$\mathbf{215}_F$ may be connected together in groups of three (e.g., $\mathbf{215}_A$ connected to $\mathbf{215}_B$, and $\mathbf{215}_E$ connected to $\mathbf{215}_C$).

[0035] Referring now to FIG. **3**, a cross-sectional illustration of a semiconductor processing tool **350** is shown, in accordance with an embodiment. In an embodiment, the semiconductor processing tool **350** comprises a remote plasma source **300** that is fluidically coupled to a chamber **351**. The chamber **351** supports sub-atmospheric processing pressures. An exhaust system **352** may lead to a pump. In an embodiment, a substrate **354** is supported and secured by a chuck **353**, pedestal, or the like. The substrate **354** may be a semiconductor substrate, such as a silicon wafer or other semiconductor wafer. The substrate **354** may also include glass substrates, organic substrates, or any other substrate processed in a semiconductor manufacturing environment.

[0036] In an embodiment, the processing of multiple substrates **354** over the course of time may result in the deposition of material onto the interior surfaces of the chamber **351**. In an embodiment, the remote plasma source **300** may be used as part of a cleaning operation to remove unwanted depositions on the interior surfaces of the chamber **351**. However, it is to be appreciated that the remote plasma source **300** may also be used for other processes in the chamber **351** as well. During the cleaning process a wafer **354** may or may not be present.

[0037] In an embodiment, the remote plasma source **300** comprises a plenum **320** that takes an input **321** and splits it into a plurality of fluidic paths to feed a plurality of plasma zones **310**. For example, a pair of plasma zones $\mathbf{310}_A$ and $\mathbf{310}_B$ are shown. However, it is to be appreciated that any number of plasma zones **310** may be provided in parallel with each other, as described in greater detail above. In an embodiment, limiters $\mathbf{309}_1$ and $\mathbf{309}_2$ may confine the plasma within the plasma zones **310**. In an embodiment, magnetic cores $\mathbf{312}_A$ and $\mathbf{312}_E$ surround the plasma zones $\mathbf{310}_A$ and $\mathbf{310}_B$. RF coils wrap around the magnetic cores **312** and the central magnetic core **308**. In an embodiment, the downstream end of the plasma zones **310** are coupled together by a manifold **325**. An outlet **323** in the manifold **325** is fluidically coupled to the chamber **351**.

[0038] FIG. **4** illustrates a diagrammatic representation of a machine in the exemplary form of a computer system **400** 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 **400** includes a processor **402**, a main memory **404** (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 **406** (e.g., flash memory, static random access memory (SRAM), MRAM, etc.), and a secondary memory **418** (e.g., a data storage device), which communicate with each other via a bus **430**.

[0040] Processor **402** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processor **402** 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 **402** 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 **402** is configured to execute the processing logic **426** for performing the operations described herein.

[0041] The computer system **400** may further include a network interface device **408**. The computer system **400** also may include a video display unit **410** (e.g., a liquid crystal display (LCD), a light emitting diode display (LED), or a cathode ray tube (CRT)), an alphanumeric input device **412** (e.g., a keyboard), a cursor control device **414** (e.g., a mouse), and a signal generation device **416** (e.g., a speaker).

[0042] The secondary memory **418** may include a machine-accessible storage medium (or more specifically a computer-readable storage medium) **432** on which is stored one or more sets of instructions (e.g., software **422**) embodying any one or more of the methodologies or functions described herein. The software **422** may also reside, completely or at least partially, within the main memory **404** and/or within the processor **402** during execution thereof by the computer system **400**, the main memory **404** and the processor **402** also constituting machine-readable storage media. The software **422** may further be transmitted or received over a network **420** via the network interface device **408**.

[0043] While the machine-accessible storage medium **432** 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 plurality of plasma zones where each plasma zone includes a top limiter and a bottom limiter.

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

What is claimed is:

1. A plasma source, comprising:
- an input to a plenum for dividing gas into a plurality of parallel fluidic paths;
- a plurality of plasma zones, wherein each plasma zone is along one of the plurality of parallel fluidic paths;
- a plurality of magnetic cores, wherein each magnetic core surrounds one of the plurality of plasma zones;
- an RF coil wrapping around the plurality of magnetic cores; and
- a manifold at a bottom of the plurality of plasma zones, wherein the manifold merges the plurality of fluidic paths into a single output.

2. The plasma source of claim **1**, wherein the RF coil is a single RF coil that wraps around all of the plurality of magnetic cores.

3. The plasma source of claim **1**, wherein the RF coil is a plurality of individual segments that are electrically isolated from each other, and wherein each segment wraps around one of the plurality of magnetic cores.

4. The plasma source of claim **1**, further comprising:
- a central magnetic core, wherein individual ones of the plurality of magnetic cores are adjacent to different sides of the central magnetic core.

5. The plasma source of claim **4**, wherein the central magnetic core is square shaped, and wherein the plurality of magnetic cores comprises four magnetic cores.

6. The plasma source of claim **5**, wherein the central magnetic core is hexagonal, and wherein the plurality of magnetic cores comprises six magnetic cores.

7. The plasma source of claim **5**, wherein the RF coil wraps around the central magnetic core.

8. The plasma source of claim **1**, wherein individual ones of the plurality of plasma zones comprise a conductive shell, a first limiter on an upstream side of the plasma zone, and a second limiter on a downstream side of the plasma zone.

9. The plasma source of claim **1**, wherein the output is fluidically coupled to a plasma processing chamber.

10. The plasma source of claim **1**, wherein the magnetic cores are ferrite.

11. A plasma source, comprising:
- a fluidic path having an upstream side and a downstream side, wherein a plurality of fluidic segments are in parallel to each other between the upstream side and the downstream side;
- a plurality of plasma zones, wherein each plasma zone is along one of the fluidic segments; and

a plurality of magnetic cores, wherein each magnetic core surrounds one of the plasma zones.

12. The plasma source of claim **11**, further comprising:

an RF coil that wraps around the plurality of magnetic cores.

13. The plasma source of claim **11**, further comprising:

a plurality of RF coils, wherein individual ones of the plurality of RF coils wrap around different magnetic cores.

14. The plasma source of claim **13**, wherein at least two of the plurality of RF coils are electrically connected together.

15. The plasma source of claim **11**, wherein the plurality of plasma zones is four plasma zones.

16. The plasma source of claim **11**, wherein the plurality of plasma zones is six plasma zones.

17. The plasma source of claim **11**, wherein the plurality of magnetic cores are ferrite.

18. A semiconductor processing tool, comprising:

a remote plasma source with an upstream end and a downstream end, wherein the remote plasma source comprises:

a plenum at the upstream end, wherein the plenum feeds gas to a plurality of plasma zones, wherein each plasma zone is surrounded by a magnetic core; and

a manifold at the downstream end wherein the manifold merges gas to an output; and

a chamber fluidically coupled to the outlet of the remote plasma.

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

an RF coil wrapping around the magnetic cores.

20. The semiconductor processing tool of claim **18**, wherein the plurality of plasma zones comprises four or more plasma zones.

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