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(54) **ADAPTABLE ELECTROCHEMICAL PROCESSING CHAMBER**

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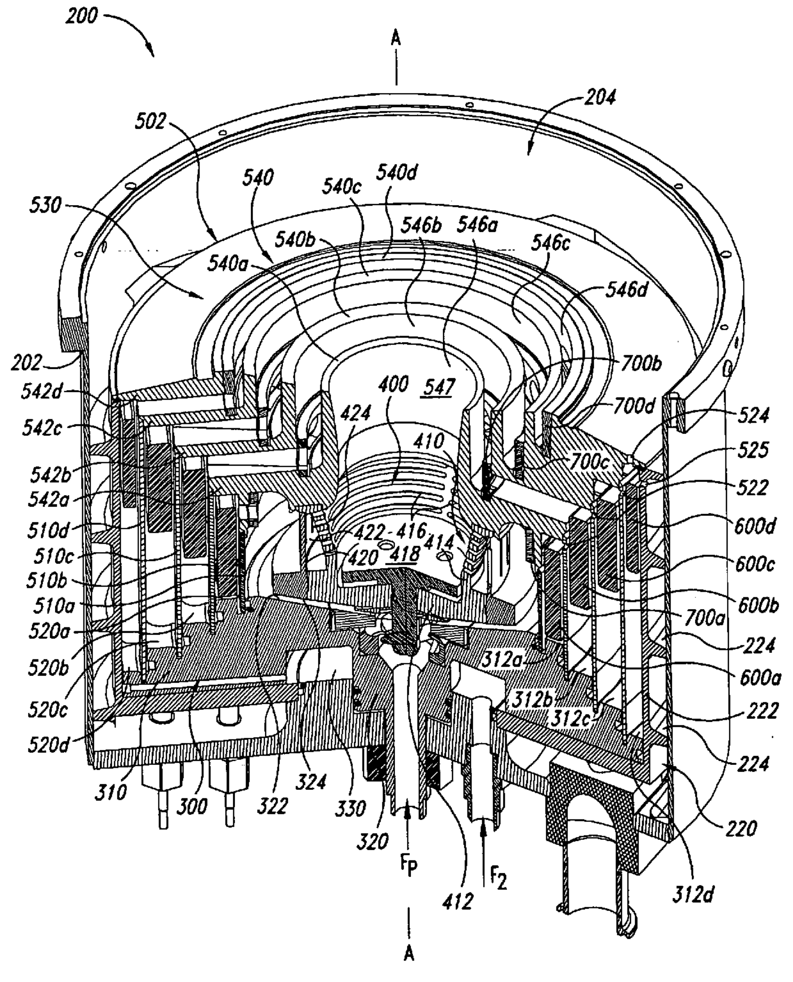
(57) **ABSTRACT**

An electrochemical processing chamber which can be modified for treating different workpieces and methods for so modifying electrochemical processing chambers. In one particular embodiment, an electrochemical processing chamber **200** includes a plurality of walls **510** defining a plurality of electrode compartments **520**, each electrode compartment having at least one electrode **600** therein, and a virtual electrode unit **530** defining a plurality of flow conduits, with at least one of the flow conduits being in fluid communication with each of the electrode compartments. This first virtual electrode unit **530** may be exchanged for a second virtual electrode unit **540**, without modification of any of the electrodes **600**, to adapt the processing chamber **200** for treating a different workpiece.



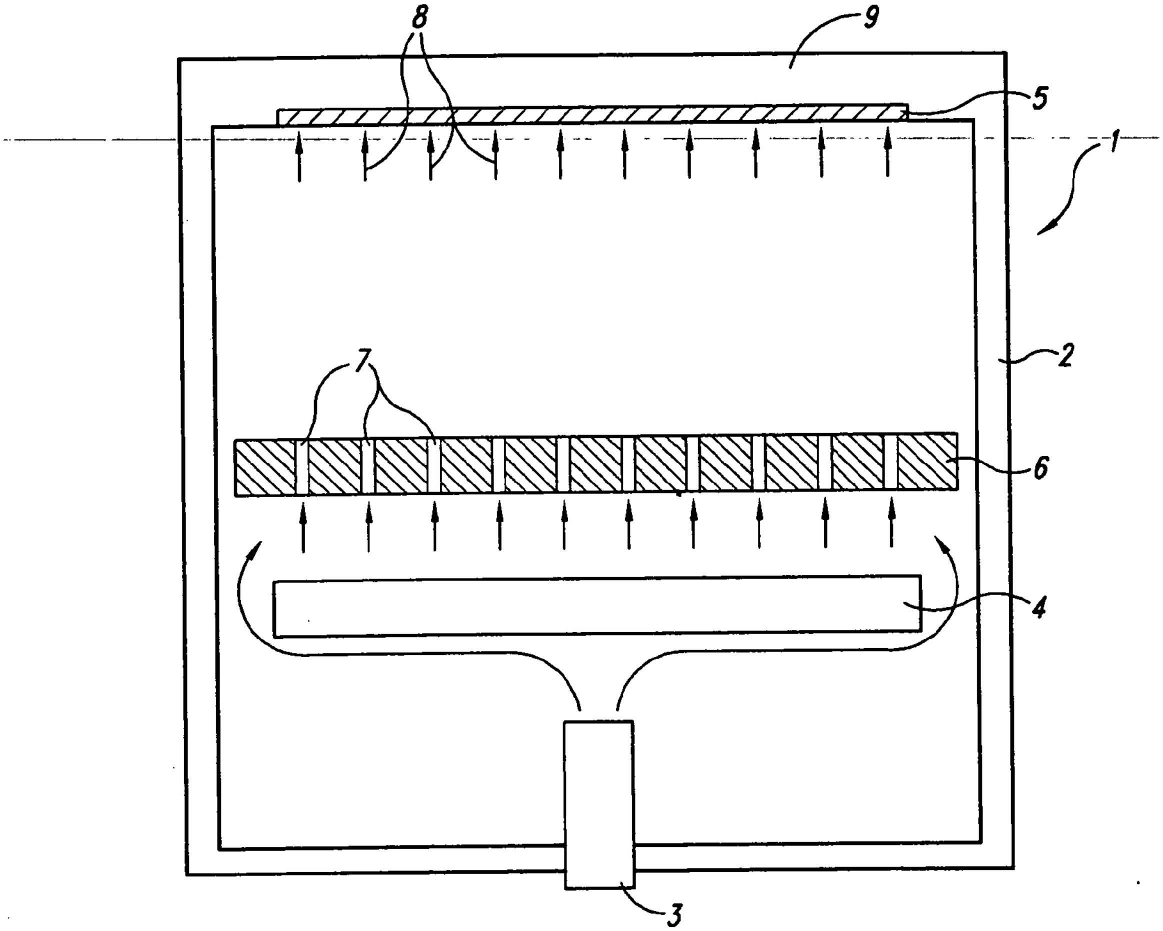
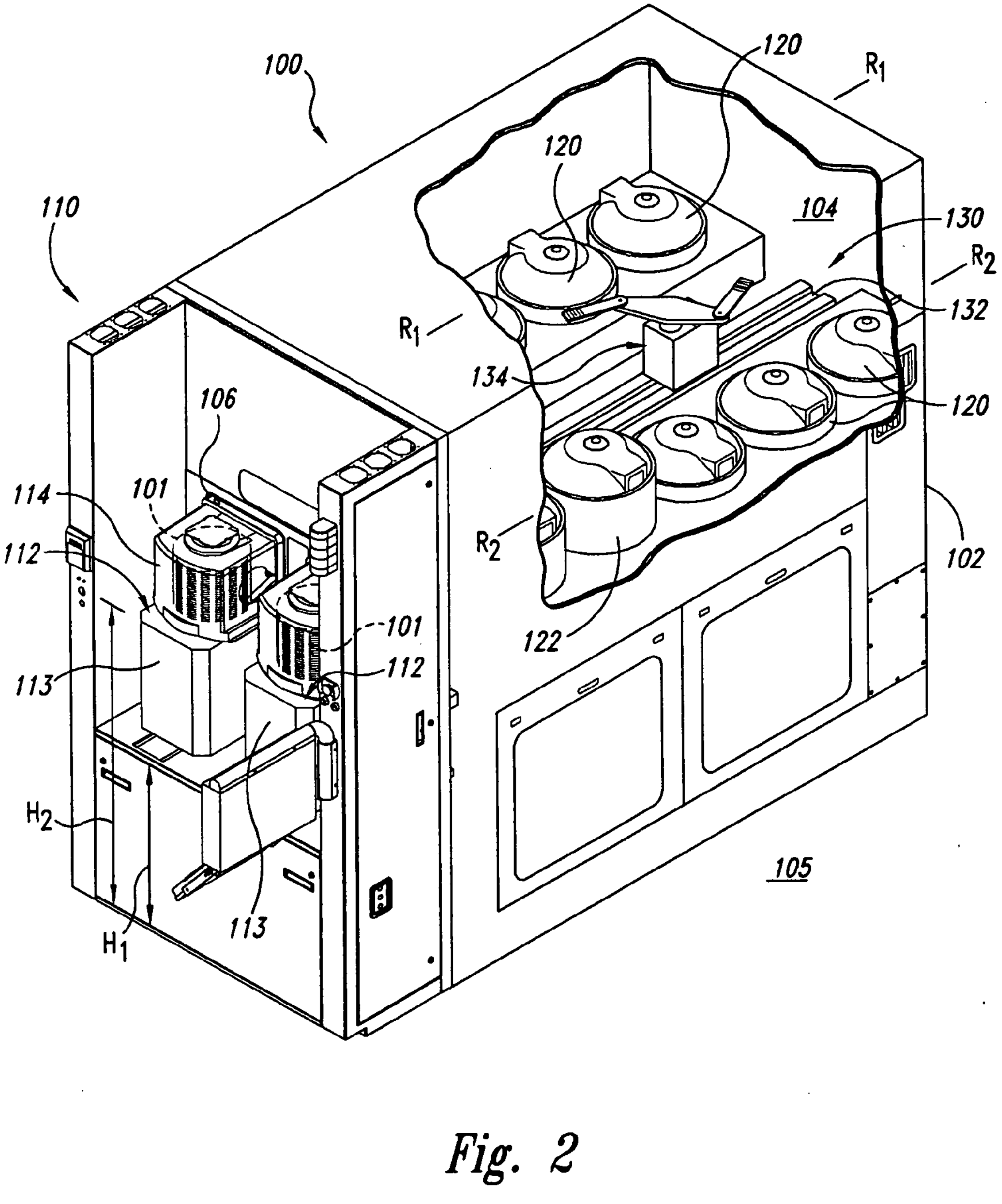


Fig. 1
(Prior Art)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R1
104
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R2
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R1
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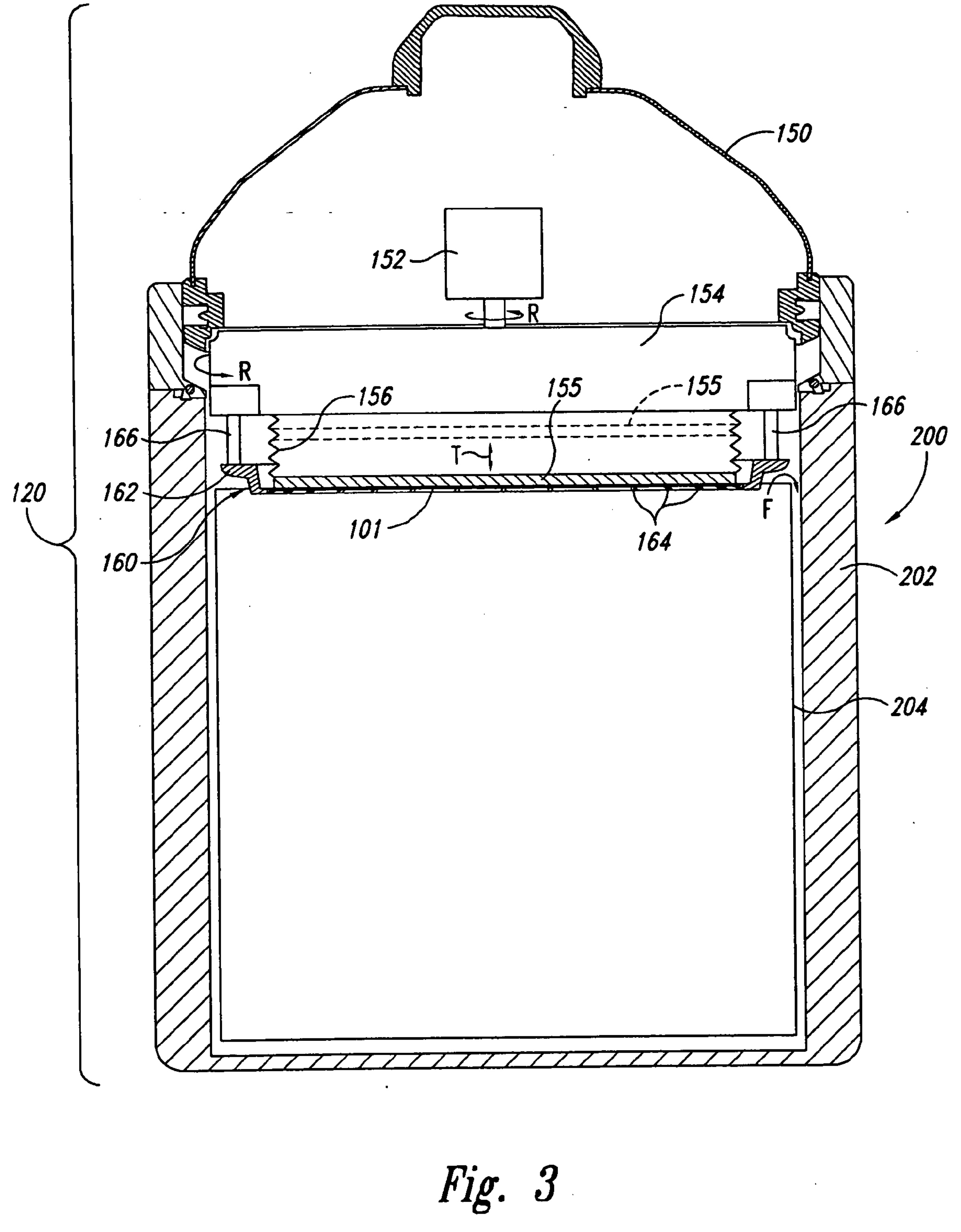
122
113
113
105
H2
H1
113

Fig. 2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200
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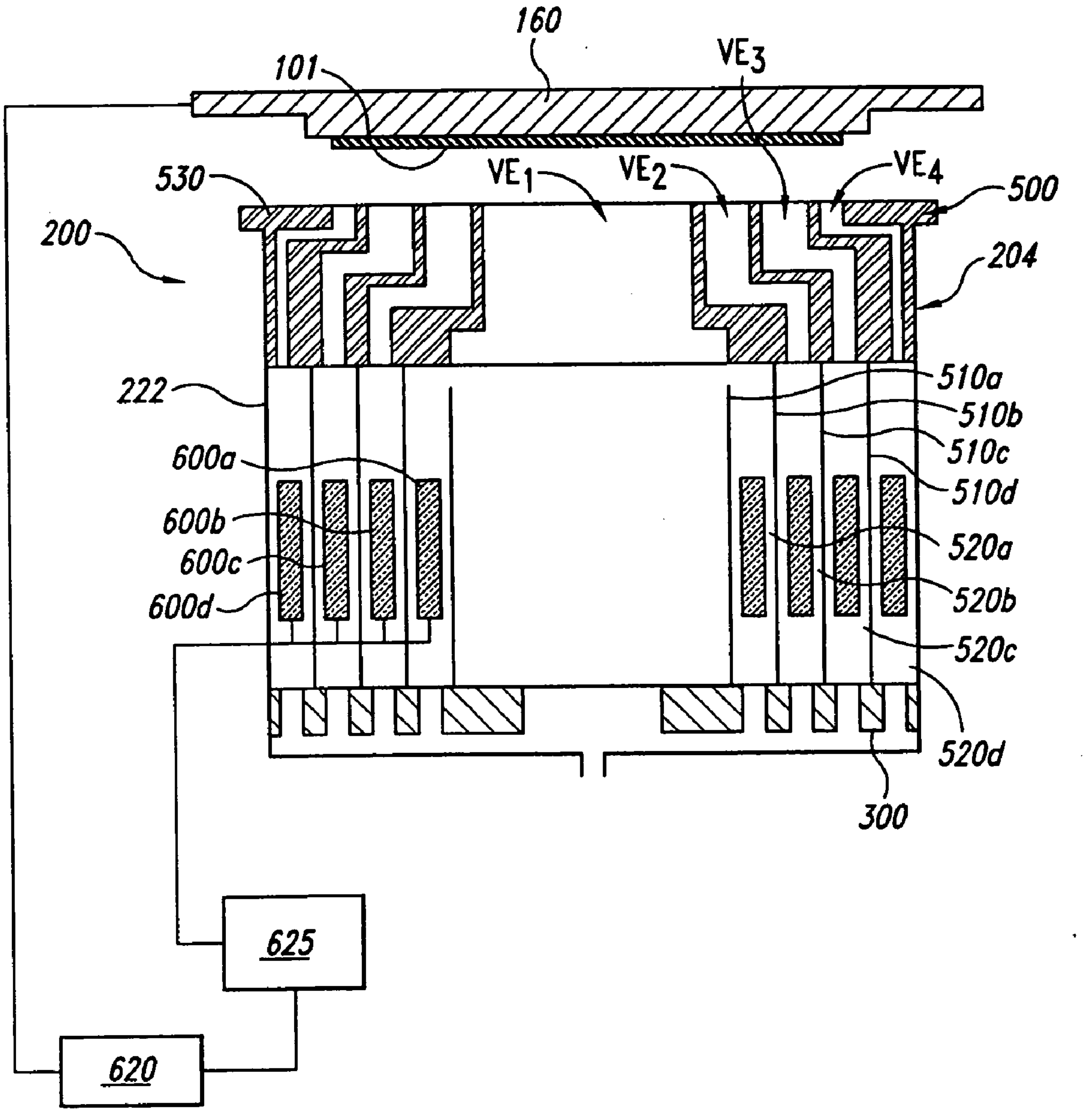
202
204

Fig. 3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VE3
530
VE1
VE2
VE4
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200
204
222
510a
510b
510c
510d
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600c
600d
520a
520b
520c
520d
300
625
620

Fig. 4

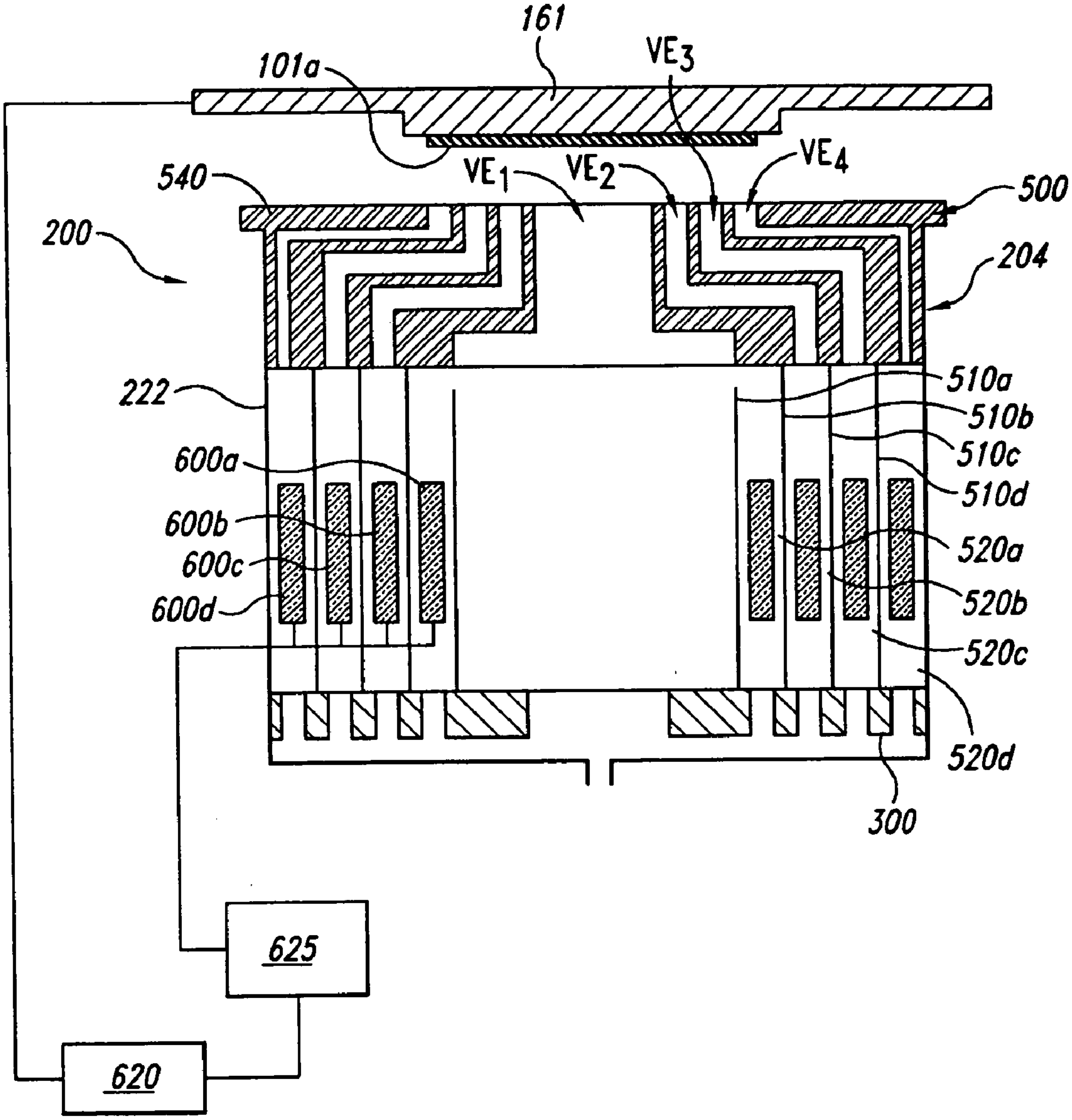
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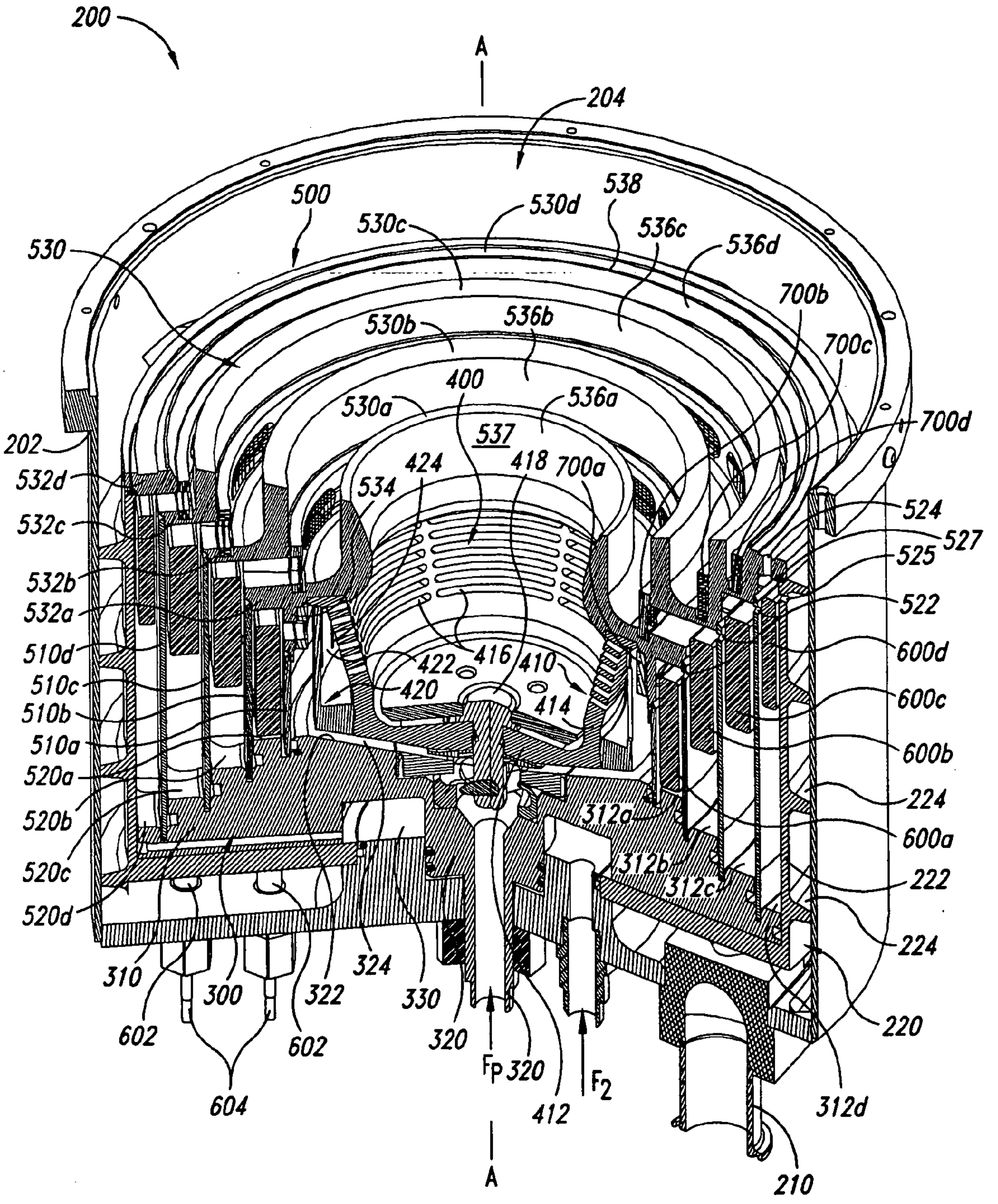
Fig. 5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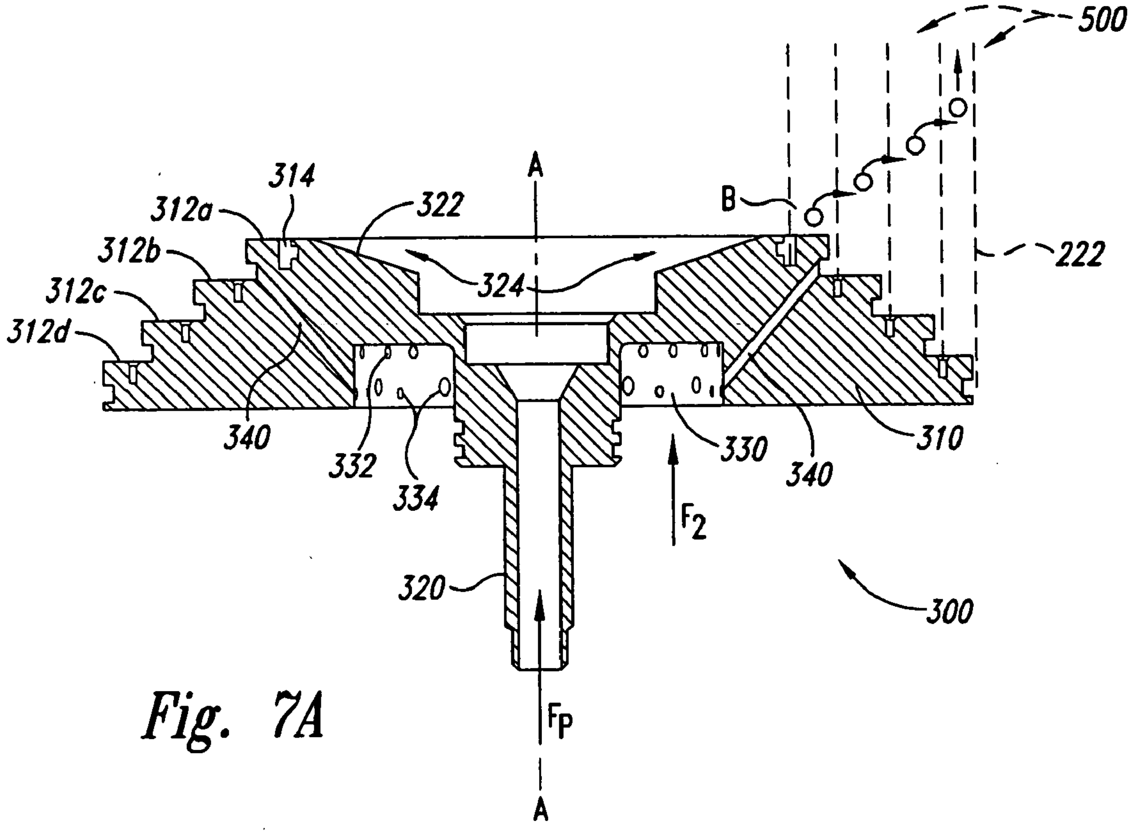
700a
532d
534
524
527
532c
525
532b
522
532a
510d
416
410
600d
422
510c
420
414
600c
510b
600b
510a
520a
224
312a
520b
600a
312b
312c
520c
222
520d
224
310
324
330
300
322
220
602
602
320
Fp
320
F2
604
412
312d
210
A

Fig. 6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FP
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Fig. 7A

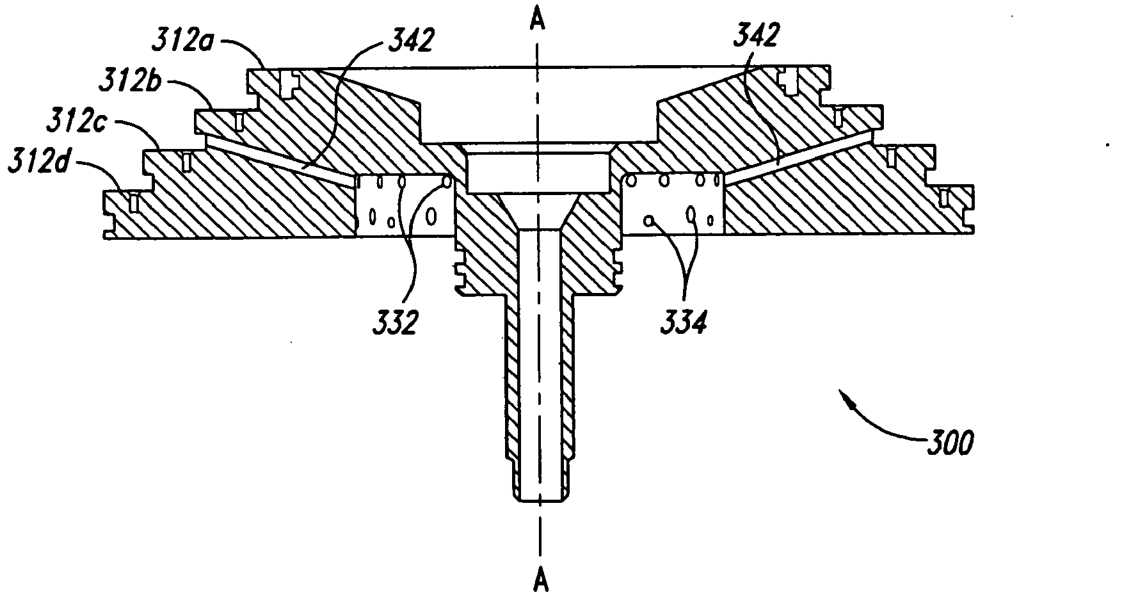
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Fig. 7B

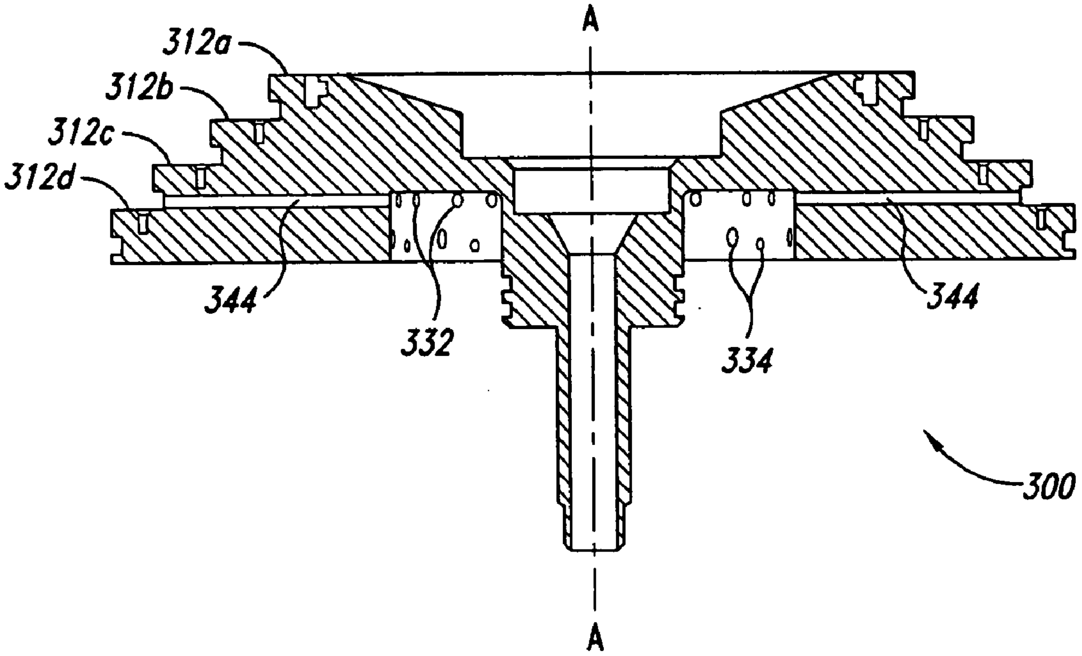
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Fig. 7C

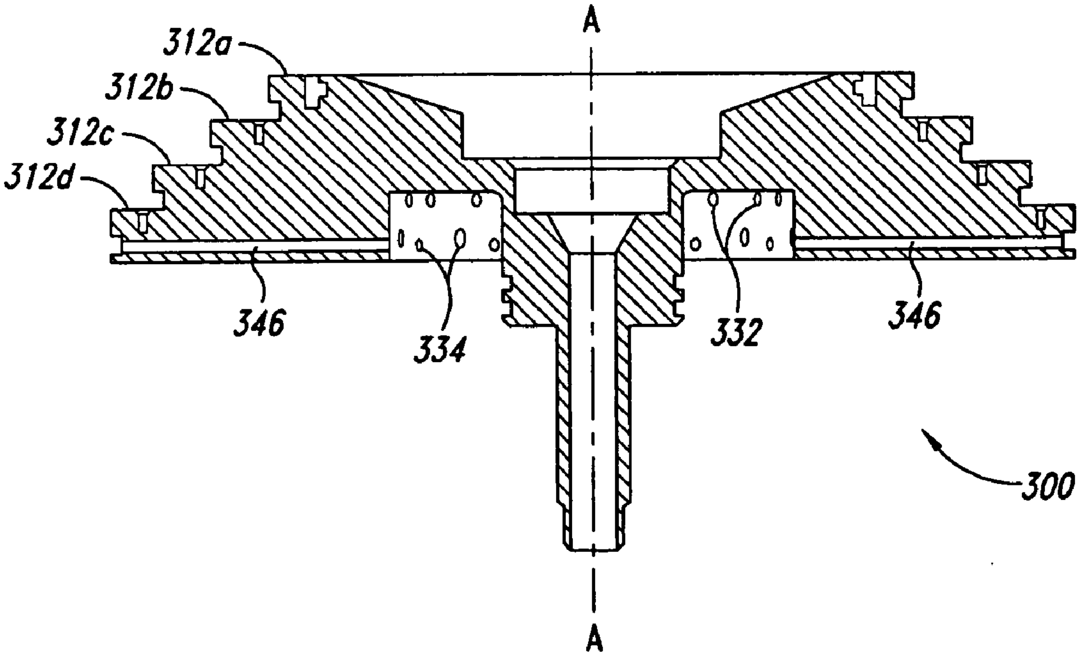
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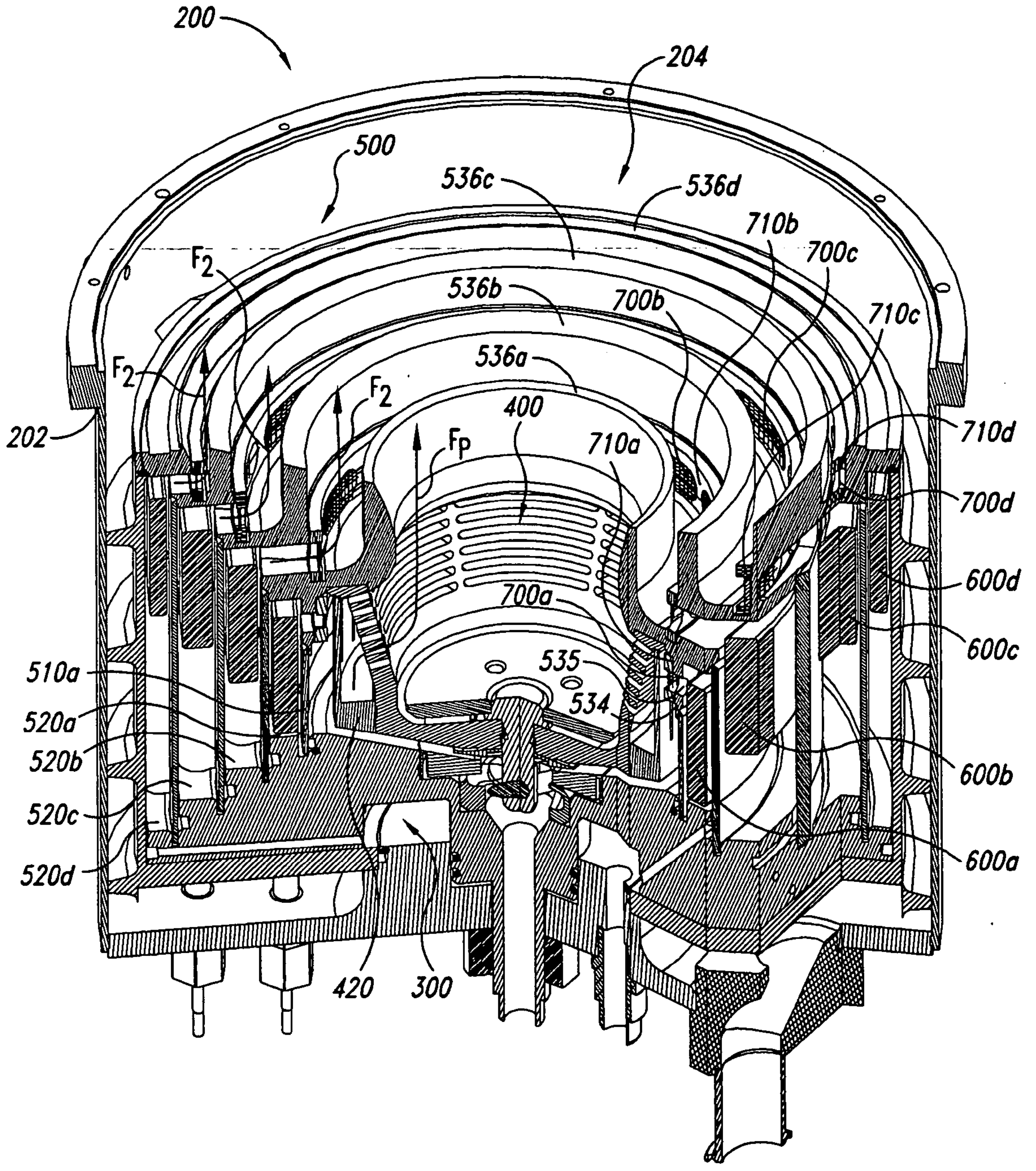
Fig. 7D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700c
F2
536b
700b
710c
F2
536a
F2
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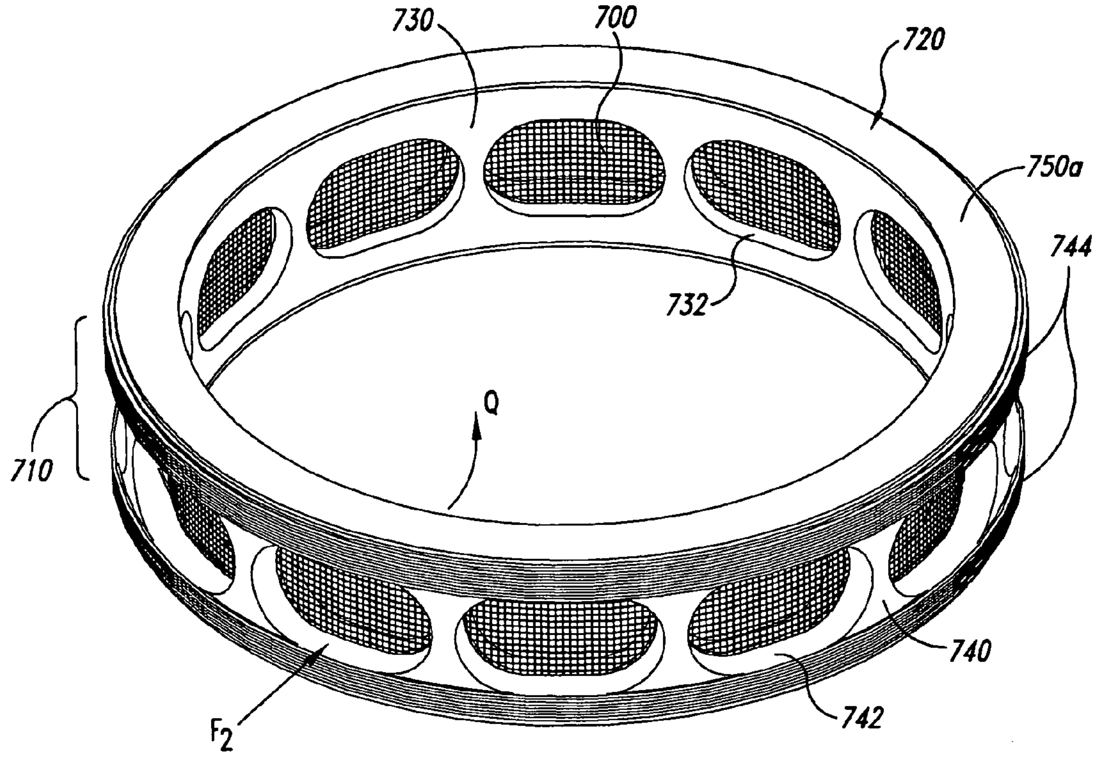
710d
202
700d
600d
700a
600c
510a
535
534
520a
520b
600b
520c
600a
520d
420
300

Fig. 8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732
710
Q
740
742
F2

Fig. 9A

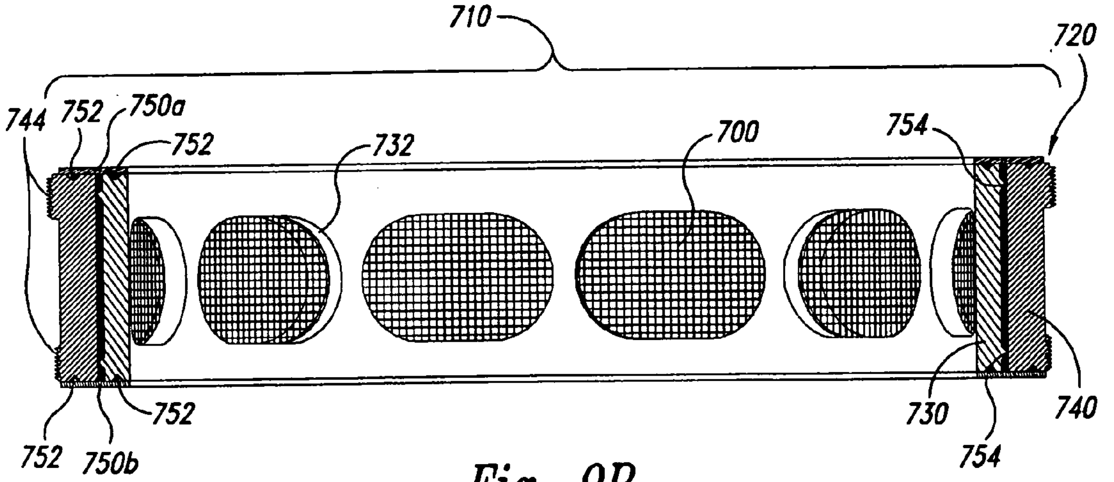
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Fig. 9B

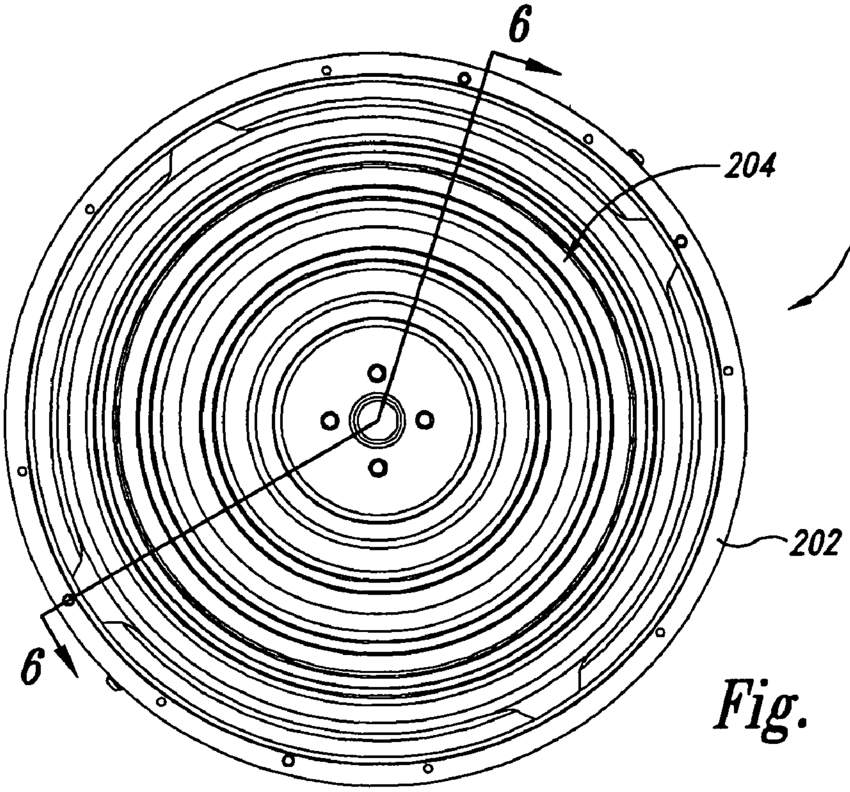

Fig. 10A

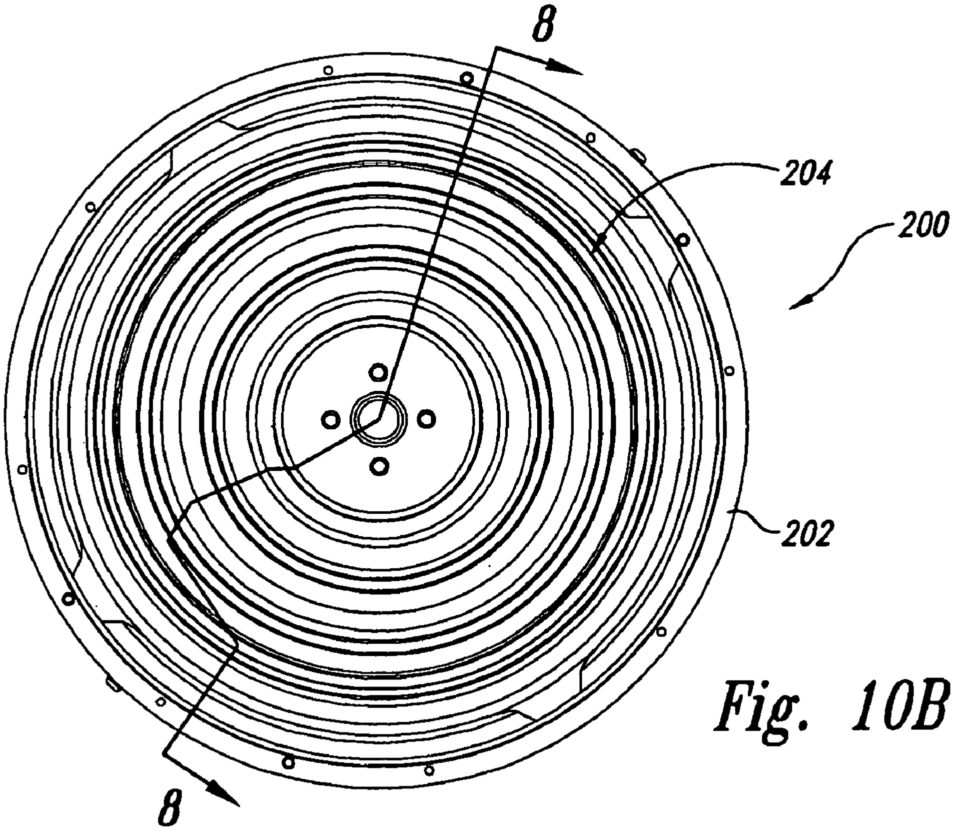

Fig. 10B

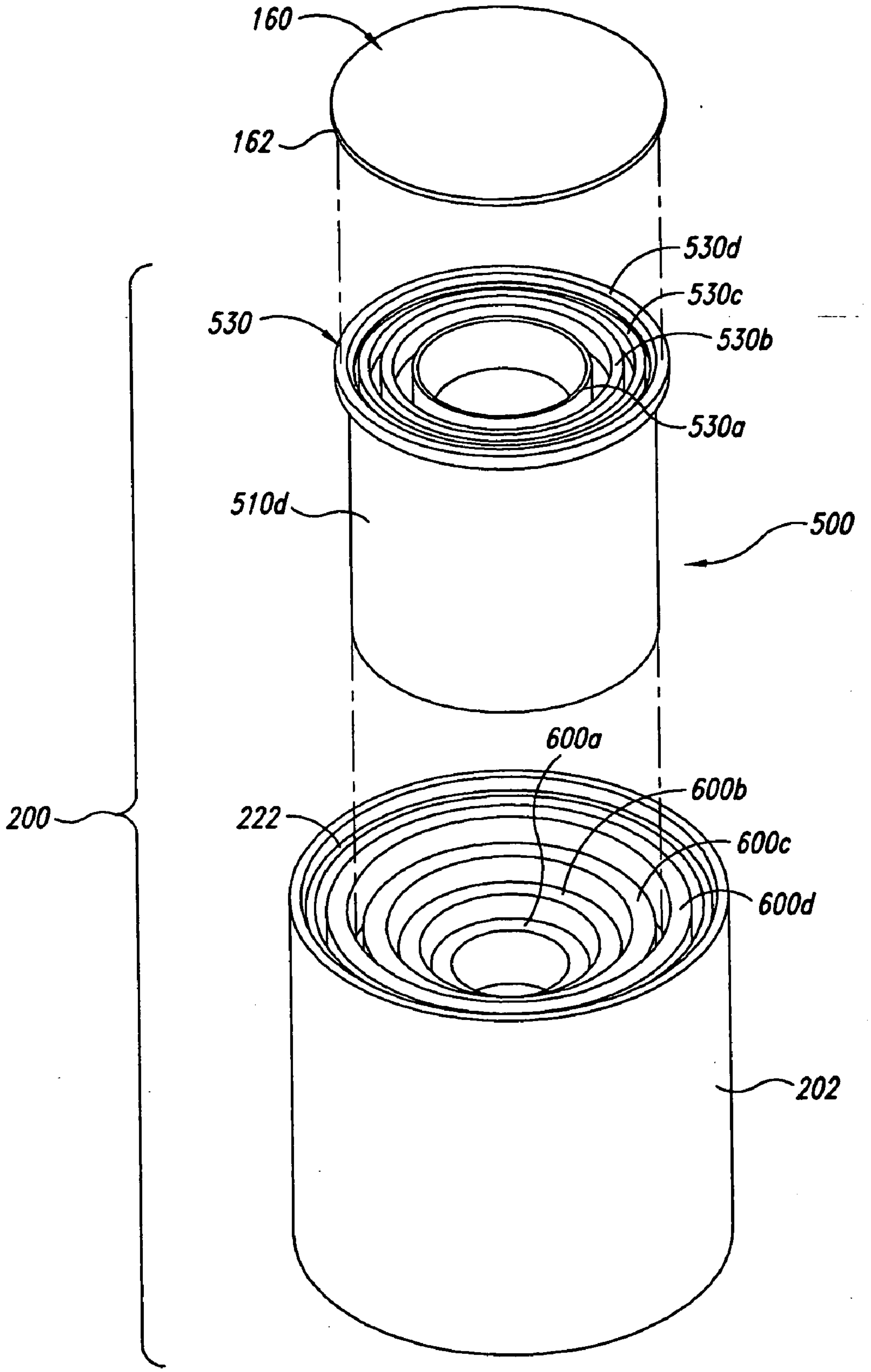
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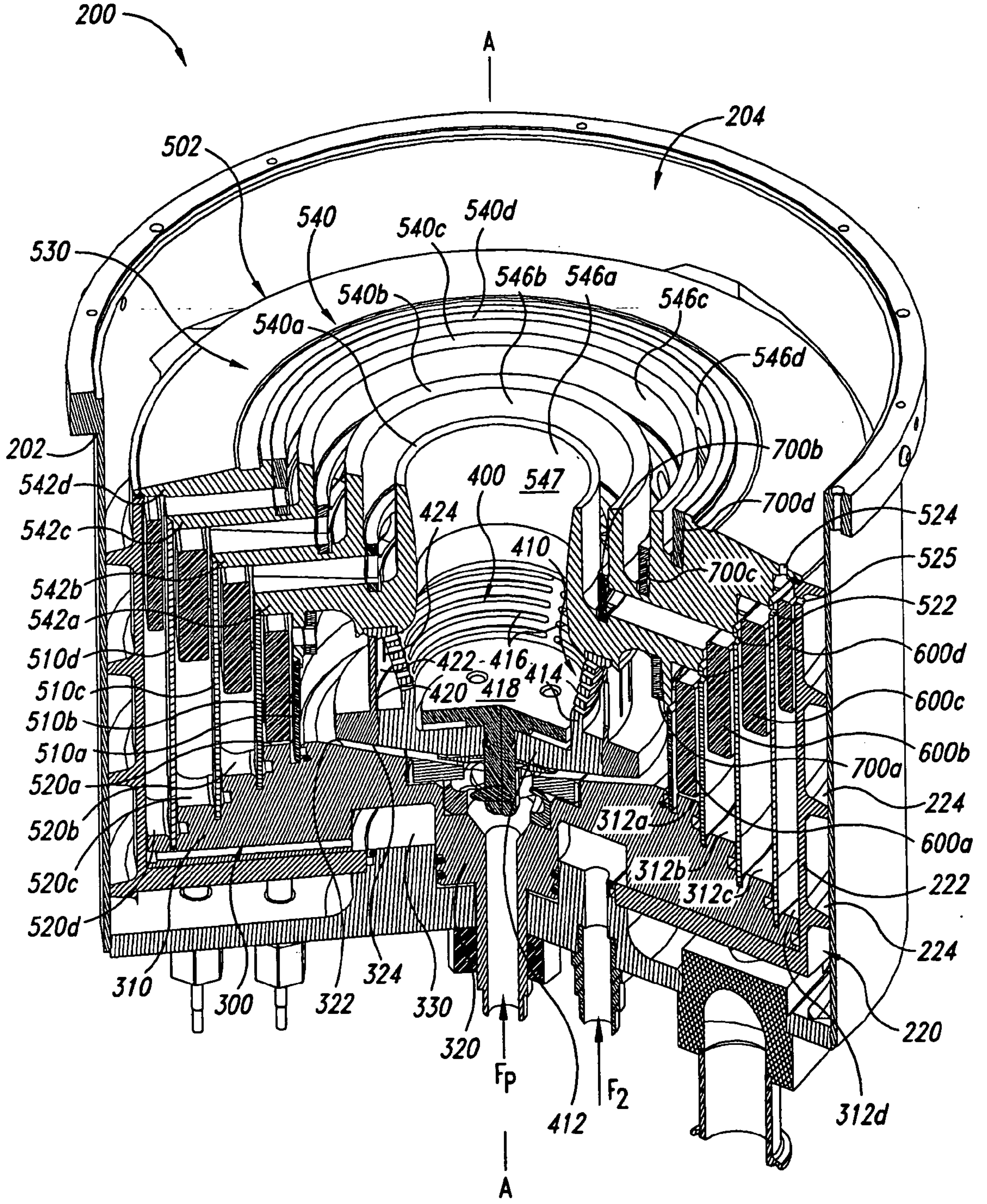
Fig. 11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542c
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542a
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600a
312b
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312d
A

Fig. 12

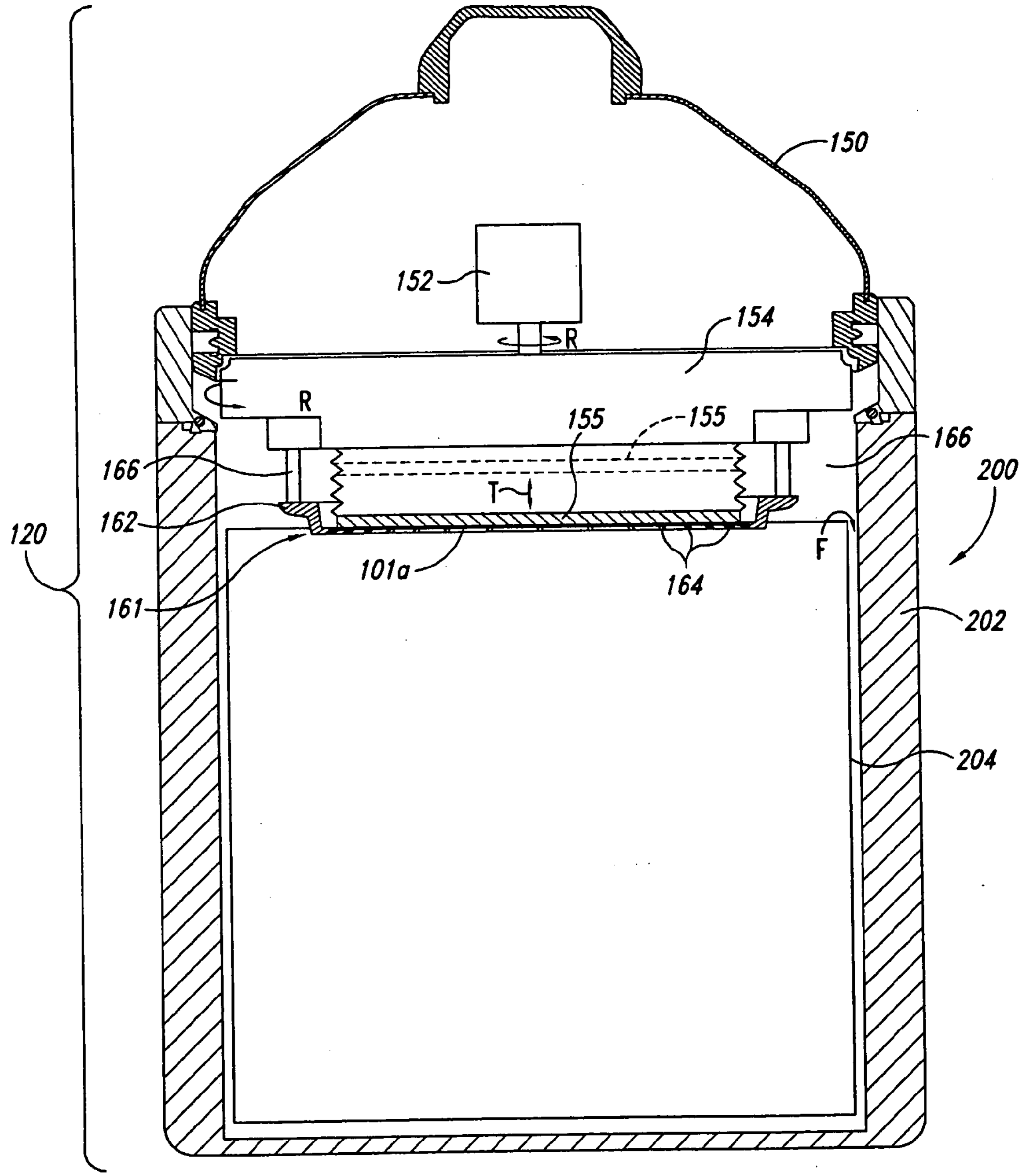
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Fig. 13

ADAPTABLE ELECTROCHEMICAL PROCESSING CHAMBER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of U.S. application Ser. No. 09/804,697, entitled "SYSTEM FOR ELECTROCHEMICALLY PROCESSING A WORKPIECE," filed on Mar. 12, 2001; which is a continuation of International Application No. PCT/US00/10120, filed on Apr. 13, 2000, in the English language and published in the English language as International Publication No. WO00/61498, which claims the benefit of Provisional Application No. 60/129,055, filed on Apr. 13, 1999, all of which are herein incorporated by reference. Additionally, this application is related to the following:

> **[0002]** (a) U.S. patent application entitled "TRANSFER DEVICES FOR HANDLING MICROELECTRONIC WORKPIECES WITHIN AN ENVIRONMENT OF A PROCESSING MACHINE AND METHODS OF MANUFACTURING AND USING SUCH DEVICES IN THE PROCESSING OF MICROELECTRONIC WORKPIECES," filed concurrently, and identified by Perkins Coie LLP Docket No. 29195.8153US00;
>
> **[0003]** (b) U.S. patent application entitled "INTEGRATED TOOLS WITH TRANSFER DEVICES FOR HANDLING MICROELECTRONIC WORKPIECES," filed concurrently, and identified by Perkins Coie Docket No. 29195.8153US01;
>
> **[0004]** (c) U.S. patent application entitled "DISTRIBUTED POWER SUPPLIES FOR MICROELECTRONIC WORKPIECE PROCESSING TOOLS," filed concurrently, and identified by Perkins Coie Docket No. 29195.8155US00;
>
> **[0005]** (d) U.S. patent application entitled "APPARATUS AND METHODS FOR ELECTROCHEMICAL PROCESSING OF MICROELECTRONIC WORKPIECES," filed concurrently, and identified by Perkins Coie LLP Docket No. 29195.8158US00;
>
> **[0006]** (e) U.S. patent application entitled "LIFT AND ROTATE ASSEMBLY FOR USE IN A WORKPIECE PROCESSING STATION AND A METHOD OF ATTACHING THE SAME," filed concurrently, and identified by Perkins Coie Docket No. 29195.8154US00;
>
> **[0007]** (f) U.S. Patent Applications entitled "TUNING ELECTRODES USED IN A REACTOR FOR ELECTROCHEMICALLY PROCESSING A MICROELECTRONIC WORKPIECE," filed on May 4, 2001, and identified by U.S. application Ser. No. 09/849,505, and two additional applications filed on May 24, 2001, and identified separately by Perkins Coie Docket Nos. 29195.8157US02 and 29195.8157US03.

[0008] All of the foregoing U.S. Patent Applications in paragraphs (a)-(f) above are herein incorporated by reference.

TECHNICAL FIELD

[0009] This application relates to reaction vessels and methods of making and using such vessels in electrochemical processing of microelectronic workpieces.

BACKGROUND

[0010] Microelectronic devices, such as semiconductor devices and field emission displays, are generally fabricated on and/or in microelectronic workpieces using several different types of machines ("tools"). Many such processing machines have a single processing station that performs one or more procedures on the workpieces. Other processing machines have a plurality of processing stations that perform a series of different procedures on individual workpieces or batches of workpieces. In a typical fabrication process, one or more layers of conductive materials are formed on the workpieces during deposition stages. The workpieces are then typically subjected to etching and/or polishing procedures (i.e., planarization) to remove a portion of the deposited conductive layers for forming electrically isolated contacts and/or conductive lines.

[0011] Plating tools that plate metals or other materials on the workpieces are becoming an increasingly useful type of processing machine. Electroplating and electroless plating techniques can be used to deposit copper, solder, permalloy, gold, silver, platinum and other metals onto workpieces for forming blanket layers or patterned layers. A typical copper plating process involves depositing a copper seed layer onto the surface of the workpiece using chemical vapor deposition (CVD), physical vapor deposition (PVD), electroless plating processes, or other suitable methods. After forming the seed layer, a blanket layer or patterned layer of copper is plated onto the workpiece by applying an appropriate electrical potential between the seed layer and an anode in the presence of an electroprocessing solution. The workpiece is then cleaned, etched and/or annealed in subsequent procedures before transferring the workpiece to another processing machine.

[0012] **FIG. 1** illustrates an embodiment of a single-wafer processing station **1** that includes a container **2** for receiving a flow of electroplating solution from a fluid inlet **3** at a lower portion of the container **2**. The processing station **1** can include an anode **4**, a plate type diffuser **6** having a plurality of apertures **7**, and a workpiece holder **9** for carrying a workpiece **5**. The workpiece holder **9** can include a plurality of electrical contacts for providing electrical current to a seed layer on the surface of the workpiece **5**. When the seed layer is biased with a negative potential relative to the anode **4**, it acts as a cathode. In operation the electroplating fluid flows around the anode **4**, through the apertures **7** in the diffuser **6** and against the plating surface of the workpiece **5**. The electroplating solution is an electrolyte that conducts electrical current between the anode **4** and the cathodic seed layer on the surface of the workpiece **5**. Therefore, ions in the electroplating solution plate the surface of the workpiece **5**.

[0013] The plating machines used in fabricating microelectronic devices must meet many specific performance criteria. For example, many processes must be able to form small contacts in vias that are less than 0.5 μm wide, and are desirably less than 0.1 μm wide. The plated metal layers accordingly often need to fill vias or trenches that are on the order of 0.1 μm wide, and the layer of plated material should also be deposited to a desired, uniform thickness across the surface of the workpiece **5**. One factor that influences the uniformity of the plated layer is the mass transfer of electroplating solution at the surface of the workpiece. This parameter is generally influenced by the velocity of the flow of the electroplating solution perpendicular to the surface of the workpiece. Another factor that influences the uniformity of the plated layer is the current density of the electrical field across the surface of the wafer.

[0014] One concern of existing electroplating equipment is providing a uniform mass transfer at the surface of the workpiece. Referring to **FIG. 1**, existing plating tools generally use the diffuser **6** to enhance the uniformity of the fluid flow perpendicular to the face of the workpiece. Although the diffuser **6** improves the uniformity of the fluid flow, it produces a plurality of localized areas of increased flow velocity perpendicular to the surface of the workpiece **5** (indicated by arrows **8**). The localized areas generally correspond to the position of the apertures **7** in the diffuser **6**. The increased velocity of the fluid flow normal to the substrate in the localized areas increases the mass transfer of the electroplating solution in these areas. This typically results in faster plating rates in the localized areas over the apertures **7**. Although many different configurations of apertures have been used in plate-type diffusers, these diffusers may not provide adequate uniformity for the precision required in many current applications.

[0015] Existing plating tools are typically optimized for use with a single size of workpiece. Hence, the anode **4** and the diffuser **6** will have a size and shape which is specific to a particular size of workpiece. Using an anode **4** and diffuser **6** designed for one size of workpiece to process a differently sized workpieces **5** will yield inconsistent results. For example, a semiconductor wafer having a 150 mm diameter is small enough to fit in a processing station **1** designed for a 200 mm diameter wafer. Even if the workpiece holder **9** were modified to hold a 150 mm wafer, however, the flow patterns and electric field characteristics of the anode **4** and diffuser **6** designed for a 200 mm wafer would yield an uneven plating layer on the smaller 150 mm wafer.

[0016] As a result, adapting a processing station **1** to handle a differently sized workpiece **5** typically will require substantial modification. This will usually include replacing at least the anode **4** and diffuser **6**. Replacing these parts is frequently more difficult and time consuming than the simple schematic diagram of **FIG. 1** would imply. This requires stocking separate supplies of differently-sized anodes. If the anodes **4** are consumable, replacing them is complicated by the fact that they require maintenance of a passivated film layer for consistent operation. As a consequence, manufacturers typically optimize the processing station to process a single size workpiece and leave it unchanged. If the manufacturer wishes to produce two different sizes of workpieces, the manufacturer will commonly purchase an entirely separate processing machine so that each machine need only handle one size.

SUMMARY OF THE INVENTION

[0017] Various embodiments of the present invention provide electrochemical processing chambers and methods enabling a single electrochemical processing chamber to be used to treat different workpieces. Many of these embodiments permit a user to process different workpieces (e.g., a 200 mm semiconductor wafer and a 300 mm semiconductor wafer) in the same electrochemical processing chamber. For example, a processing chamber of the invention can include a virtual electrode unit defining virtual electrodes. Simply by replacing one virtual electrode unit for another in such an embodiment, the effective electrical field in the processing chamber can be modified. A further embodiment of the invention incorporates a virtual electrode unit in a field shaping unit which also includes one or more walls defining a separate compartment for each electrode. If so desired, such a field shaping unit may be replaced as a unit, further simplifying modification of the processing chamber. Certain embodiments of the invention provide methods which capitalize on the ease of replacing the virtual electrode units to thereby alter the electrical field in an electrochemical processing chamber to meet the processing needs for different workpieces.

[0018] One embodiment of the invention provides a method of modifying an electrochemical processing chamber from a first configuration for treating a first workpiece to a second configuration for treating a different second workpiece. The processing chamber initially includes a reaction vessel having a plurality of electrodes positioned in electrically separate electrode compartments and a first virtual electrode unit. The first virtual electrode unit defines a first set of virtual electrodes adapted for treating the first workpiece, each of the virtual electrodes being in fluid communication with one of the electrode compartments. The method includes providing a second virtual electrode unit which defines a second set of virtual electrodes adapted for treating the second workpiece. The relative positions of the virtual electrodes in the first set differ from the relative positions of the virtual electrodes in the second set. The first virtual electrode unit is replaced with the second virtual electrode unit, thereby modifying an effective electric field of the electrochemical processing chamber for treatment of the second workpiece without necessitating modification of the electrodes. This can extend the functionality of a processing line, enabling a manufacturer to readily process different types of workpieces in the same processing chamber rather than purchase a separate processing line dedicated to each type of workpiece.

[0019] In more particular aspects of this embodiment, the electrode compartments may be defined by a plurality of walls coupled to the first virtual electrode unit, with the walls and the first virtual electrode unit defining a first field shaping unit. With such a field shaping unit, replacing the first virtual electrode unit may comprise removing the first field shaping unit as a unit. The second virtual electrode unit may also include a plurality of walls coupled thereto to define a second field shaping unit, enabling the second field shaping unit to be installed as a unit. In a further embodiment, the first configuration of the processing chamber includes a first contact assembly adapted to support the first workpiece in a predetermined position with respect to the first set of virtual electrodes. This enables treatment of the first workpiece by defining an electrical potential between the electrodes and the first workpiece. The first contact assembly may also be replaced with a second contact assembly adapted to support the second workpiece and the second workpiece may be treated by defining an electrical potential between the electrodes and the second workpiece.

[0020] Another embodiment of the invention provides a method of effectuating electrochemical treatment of different first and second workpieces. This method includes providing an initial electrochemical processing chamber and a second virtual electrode unit. The initial processing chamber includes a reaction vessel having a plurality of electrodes in electrically separate electrode compartments and a first virtual electrode unit defining a first set of virtual electrodes. The second virtual electrode unit is adapted to define a second set of virtual electrodes, with relative positions of the virtual electrodes of the second virtual electrode unit being different from relative positions of the virtual electrodes of the first virtual electrode unit. A user is instructed to treat the first workpiece with the initial processing chamber; to replace the first virtual electrode unit with the second virtual electrode unit, thereby modifying the initial electrochemical processing chamber by repositioning the virtual electrodes; and to treat the second workpiece with the modified electrochemical processing chamber.

[0021] An alternative embodiment of the invention provides a method of effectuating assembly of an electrochemical processing chamber. In this method, a reaction vessel is provided, the reaction vessel having an outer wall and a plurality of electrodes, adjacent electrodes being spaced from one another to define a wall-receiving space therebetween. A replaceable first field shaping unit is provided, the first field shaping unit having a wall adapted to be received in the wall-receiving space between the electrodes and a first virtual electrode unit coupled to the wall. The first virtual electrode unit defines a first set of virtual electrodes having predefined relative positions. A second field shaping unit is provided, the second field shaping unit having a wall adapted to be received in the wall-receiving space between the electrodes and a second virtual electrode unit coupled to the wall. The second virtual electrode unit defines a second set of virtual electrodes having predefined relative positions. At least one functional characteristic of the first field shaping unit is identified and at least one functional characteristic of the second field shaping unit is identified. The identified functional characteristic of the first field shaping unit is different from the identified functional characteristic of the second field shaping unit, enabling a user to select between the first and second field shaping units to adapt the reaction vessel to treat a selected type of workpiece.

[0022] As noted above, other aspects of the invention provide electrochemical processing chambers. One such embodiment includes a reaction vessel, an electrode in an interior of the reaction vessel, and a first virtual electrode unit. The first virtual electrode unit defines a first virtual electrode in fluid communication with the electrode. The first virtual electrode unit is exchangeable for a second virtual electrode unit, without necessitating modification of the electrode, to adapt the processing chamber for treating a different workpiece. Such an adaptable processing chamber permits a manufacturer significant flexibility in producing a variety of products with minimal downtime.

[0023] An electrochemical processing chamber of another embodiment includes a reaction vessel having an inner surface and a first wall spaced from the inner surface of the reaction vessel. The first wall, which may be formed of a dielectric material, electrically separates a first electrode compartment, which receives a first electrode, from a second electrode compartment, which receives a second electrode. A first virtual electrode unit, which may comprise a dielectric material, defines a first virtual electrode in fluid communication with the first electrode compartment. The first virtual electrode unit also defines, in part, a second virtual electrode in fluid communication with the outer electrode compartment. The first virtual electrode unit is exchangeable for a second virtual electrode unit, without necessitating modification of the electrodes, to adapt the processing chamber for treating a different workpiece. Avoiding the need to modify the electrodes in this fashion allows a manufacturer to adapt this embodiment to be used with different workpieces quickly and without need for a separate inventory of different electrodes for each type of workpiece to be produced.

[0024] Yet another embodiment of the invention provides an electrochemical processing chamber including a reaction vessel and a replaceable field shaping unit. The reaction vessel includes a vessel wall and first and second electrodes, the first electrode being spaced radially inwardly of the second electrode. The field shaping unit includes a first wall, which electrically separates a first electrode compartment within which the first electrode is positioned, from a second electrode compartment within which the second electrode is positioned. The field shaping unit also includes a virtual electrode unit including a dielectric first partition coupled to the first wall. The first partition defines a first virtual electrode in fluid communication with the first electrode compartment and defines, in part, a second virtual electrode in fluid communication with the second electrode compartment. The replaceable field shaping unit is removable from the reaction vessel as a unit without necessitating modification of the reaction vessel. If so desired, the first field shaping unit of this embodiment may include a plurality of concentric walls electrically separating a plurality of concentric electrode compartments. The field shaping unit may also comprise a plurality of partitions and define a plurality of virtual electrodes, with a separate virtual electrode in fluid communication with each of the electrode compartments. The unit-based approach to modification afforded by this embodiment can ease transition from one type of workpiece to another.

[0025] An electrochemical processing system in accordance with one additional embodiment of the invention includes a reaction vessel, a replaceable first field shaping unit and a replaceable second field shaping unit. The reaction vessel includes an outer wall and a plurality of annular electrodes spaced from one another to define annular wall-receiving spaces therebetween. The first field shaping unit includes a plurality of concentric walls and a first virtual electrode unit. The walls may be positioned with respect to one another to be received in the wall-receiving spaces between the electrodes to define a plurality of concentric electrode compartments. The first virtual electrode unit may be coupled to the walls adjacent their upper edges and adapted to abut the outer wall of the reaction vessel adjacent the upper edge thereof. The first virtual electrode unit defines a first set of discharge openings having predefined relative positions, each of the discharge openings of the first set being adapted for fluid communication with one of the electrode compartments, with each discharge opening of the first set defining a position of an virtual electrode. The replaceable second field shaping unit is much like the first field shaping unit, but has a second set of discharge openings with relative positions differing from the relative positions of the discharge openings of the first set. The first field shaping unit and the second field shaping unit are each adapted for installation in and removal from the reaction vessel as a unit. Providing such a reaction vessel and different field shaping units allows a manufacturer to configure the electrochemical processing system to meet current production needs with a minimum of difficulty and wasted workpiece-dependent components.

[0026] Still another embodiment of the invention provides an electrochemical processing chamber including a reaction vessel having an interior; an electrode received in the interior of the reaction vessel; a first virtual electrode unit and a first contact assembly. The first virtual electrode unit, which may comprise a dielectric material, defines a first virtual electrode in fluid communication with the electrode. The first contact assembly is adapted to support a workpiece in a predetermined position with respect to the first virtual electrode. The first contact assembly is exchangeable for a second contact assembly and the first virtual electrode unit is exchangeable for a second virtual electrode unit, without necessitating modification of the electrode, to adapt the processing chamber for treating a differently-sized workpiece. Providing exchangeable contact assemblies and exchangeable virtual electrode units in accordance with this embodiment extends functionality of the processing chamber without requiring complex, time-consuming changes to switch from one size of workpiece to another.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] **FIG. 1** is a schematic diagram of an electroplating chamber in accordance with the prior art.

[0028] **FIG. 2** is an isometric view of an electroprocessing machine having electroprocessing stations for processing microelectronic workpieces in accordance with an embodiment of the invention.

[0029] **FIG. 3** is a cross-sectional view of an electroprocessing station having a processing chamber for use in an electroprocessing machine in accordance with an embodiment of the invention. Selected components in **FIG. 3** are shown schematically.

[0030] **FIG. 4** is a schematic cross-sectional view of an electrochemical processing chamber in accordance with one embodiment of the invention.

[0031] **FIG. 5** is a schematic cross-sectional view of the electrochemical processing chamber of **FIG. 4** modified to process a differently-sized workpiece.

[0032] **FIG. 6** is an isometric view showing a cross-sectional portion of a processing chamber taken along line **6-6** of **FIG. 10A**.

[0033] **FIGS. 7A-7D** are cross-sectional views of a distributor for a processing chamber in accordance with an embodiment of the invention.

[0034] **FIG. 8** is an isometric view showing a different cross-sectional portion of the processing chamber of **FIG. 6** taken along line **8-8** of **FIG. 10B**.

[0035] **FIG. 9A** is an isometric view of an interface assembly for use in a processing chamber in accordance with an embodiment of the invention.

[0036] **FIG. 9B** is a cross-sectional view of the interface assembly of **FIG. 9A**.

[0037] **FIGS. 10A and 10B** are top plan views of a processing chamber that provide a reference for the isometric, cross-sectional views of **FIGS. 6 and 8**, respectively.

[0038] **FIG. 11** is an isometric view schematically showing removal of a field shaping unit from the processing chamber of **FIG. 6**.

[0039] **FIG. 12** is an isometric view similar to **FIG. 6**, showing a cross-sectional portion of a processing chamber modified in accordance with another embodiment of the invention.

[0040] **FIG. 13** is a schematic cross-sectional view of the electroprocessing station of **FIG. 3** modified to process a differently-sized workpiece.

DETAILED DESCRIPTION

[0041] The following description discloses the details and features of several embodiments of electrochemical reaction vessels for use in electrochemical processing stations and integrated tools to process microelectronic workpieces. The term "microelectronic workpiece" is used throughout to include a workpiece formed from a substrate upon which and/or in which microelectronic circuits or components, data storage elements or layers, and/or micro-mechanical elements are fabricated. It will be appreciated that several of the details set forth below are provided to describe the following embodiments in a manner sufficient to enable a person skilled in the art to make and use the disclosed embodiments. Several of the details and advantages described below, however, may not be necessary to practice certain embodiments of the invention. Additionally, the invention can also include additional embodiments that are within the scope of the claims, but are not described in detail with respect to **FIGS. 2-13**.

[0042] The operation and features of electrochemical reaction vessels are best understood in light of the environment and equipment in which they can be used to electrochemically process workpieces (e.g., electroplate and/or electropolish). As such, embodiments of integrated tools with processing stations having the electrochemical reaction vessels are initially described with reference to **FIGS. 2 and 3**. The details and features of several embodiments of electrochemical reaction vessels and methods for adapting the vessels to process different types of workpieces are then described with reference to **FIGS. 4-13**.

[0043] A. Selected Embodiments of Integrated Tools with Electrochemical Processing Stations

[0044] **FIG. 2** is an isometric view of a processing machine **100** having an electrochemical processing station **120** in accordance with an embodiment of the invention. A portion of the processing machine **100** is shown in a cut-away view to illustrate selected internal components. In one aspect of this embodiment, the processing machine **100** can include a cabinet **102** having an interior region **104** defining an interior enclosure that is at least partially isolated from an exterior region **105**. The cabinet **102** can also include a plurality of apertures **106** (only one shown in **FIG. 1**) through which microelectronic workpieces **101** can ingress and egress between the interior region **104** and a load/unload station **110**.

[0045] The load/unload station **110** can have two container supports **112** that are each housed in a protective shroud **113**. The container supports **112** are configured to position workpiece containers **114** relative to the apertures **106** in the cabinet **102**. The workpiece containers **114** can each house a plurality of microelectronic workpieces **101** in a "mini" clean environment for carrying a plurality of workpieces through other environments that are not at clean room standards. Each of the workpiece containers **114** is accessible from the interior region **104** of the cabinet **102** through the apertures **106**.

[**0046**] The processing machine **100** can also include a plurality of electrochemical processing stations **120** and a transfer device **130** in the interior region **104** of the cabinet **102**. The processing machine **100**, for example, can be a plating tool that also includes clean/etch capsules **122**, electroless plating stations, annealing stations, and/or metrology stations.

[**0047**] The transfer device **130** includes a linear track **132** extending in a lengthwise direction of the interior region **104** between the processing stations. The transfer device **130** can further include a robot unit **134** carried by the track **132**. In the particular embodiment shown in **FIG. 2**, a first set of processing stations is arranged along a first row R_1-R_1 and a second set of processing stations is arranged along a second row R_2-R_2. The linear track **132** extends between the first and second rows of processing stations, and the robot unit **134** can access any of the processing stations along the track **132**.

[**0048**] **FIG. 3** illustrates an embodiment of an electrochemical-processing chamber **120** having a head assembly **150** and a processing chamber **200**. The head assembly **150** includes a spin motor **152**, a rotor **154** coupled to the spin motor **152**, and a contact assembly **160** carried by the rotor **154**. The rotor **154** can have a backing plate **155** and a seal **156**. The backing plate **155** can move transverse to a workpiece **101** (arrow T) between a first position in which the backing plate **155** contacts a backside of the workpiece **101** (shown in solid lines in **FIG. 3**) and a second position in which it is spaced apart from the backside of the workpiece **101** (shown in broken lines in **FIG. 3**). The contact assembly **160** can have a support member **162**, a plurality of contacts **164** carried by the support member **162**, and a plurality of shafts **166** extending between the support member **162** and the rotor **154**. The contacts **164** can be ring-type spring contacts or other types of contacts that are configured to engage a portion of the seed-layer on the workpiece **101**. Commercially available head assemblies **150** and contact assemblies **160** can be used in the electroprocessing chamber **120**. Particular suitable head assemblies **150** and contact assemblies **160** are disclosed in U.S. Pat. Nos. 6,228,232 and 6,080,691; and U.S. application Ser. Nos. 09/385,784; 09/386,803; 09/386,610; 09/386,197; 09/501,002; 09/733,608; and 09/804,696, all of which are herein incorporated by reference.

[**0049**] The processing chamber **200** includes an outer housing **202** (shown schematically in **FIG. 3**) and a reaction vessel **204** (also shown schematically in **FIG. 3**) in the housing **202**. The reaction vessel **204** carries at least one electrode (not shown in **FIG. 3**) and directs a flow of electroprocessing solution to the workpiece **101**. The electroprocessing solution, for example, can flow over a weir (arrow F) and into the external housing **202**, which captures the electroprocessing solution and sends it back to a tank. Several embodiments of reaction vessels **204** are shown and described in detail with reference to **FIGS. 4-12**.

[**0050**] In operation the head assembly **150** holds the workpiece at a workpiece-processing site of the reaction vessel **204** so that at least a plating surface of the workpiece engages the electroprocessing solution. An electrical field is established in the solution by applying an electrical potential between the plating surface of the workpiece via the contact assembly **160** and one or more electrodes in the reaction vessel **204**. For example, the contact assembly **160** can be biased with a negative potential with respect to the electrode(s) in the reaction vessel **204** to plate materials onto the workpiece. On the other hand the contact assembly **160** can be biased with a positive potential with respect to the electrode(s) in the reaction vessel **204** to (a) de-plate or electropolish plated material from the workpiece or (b) deposit other materials (e.g., electrophoric resist). In general, therefore, materials can be deposited on or removed from the workpiece with the workpiece acting as a cathode or an anode depending upon the particular type of material used in the electrochemical process.

[**0051**] B. Selected Embodiments of Reaction Vessels for use in Electrochemical Processing Chambers

[**0052**] **FIGS. 4, 5** and **13** schematically illustrate aspects of processing chambers **200** in accordance with certain embodiments of the invention. Several embodiments of reaction vessels **204** for use in processing chambers **200** are shown in more detail in **FIGS. 6-12**.

[**0053**] The processing chamber **200** of **FIG. 4** includes a reaction vessel **204** positioned beneath a contact assembly **160**. The contact assembly **160** carries a workpiece **101** which may be brought into contact with the electroprocessing solution in the reaction vessel **204**. For ease of explanation, **FIG. 4** shows the contact assembly **160** and workpiece **101** spaced above the position they would occupy with respect to the reaction vessel in processing the workpiece.

[**0054**] The reaction vessel **204** of **FIG. 4** has a plurality of annular electrodes **600***a-d* received therein. This particular embodiment employs four separate electrodes **600***a-d*, but it should be understood that any number of electrodes could be employed. While it is anticipated that there will be at least one electrode, there can be more than the four electrodes shown in **FIG. 4**. The electrodes may be connected to a common power supply **610**, or each of the electrodes **600** may be provided with a separate power supply. **FIG. 4** shows a power supply **610** electrically coupled to the contact assembly and to a power supply controller **625**, which may independently control the power delivered to each of the electrodes **600***a-d*. In this fashion, a desired potential may be created between the workpiece **101** and each of the electrodes **600**.

[**0055**] The electrodes **600** in **FIG. 4** are housed in electrically separate electrode compartments **520**. These electrode compartments **520** may be defined by a plurality of walls **510** received in the interior of the reaction vessel **204**. In particular, a first electrode compartment **520***a* is defined by a first wall **510***a* and a second wall **510***b*, a second electrode compartment **520***b* is defined by the second wall **510***b* and a third wall **510***c*, a third electrode compartment **520***c* is defined by the third wall **510***c* and a fourth wall **510***d*, and a fourth electrode compartment **520***d* is defined by the fourth wall **510***d* and the outer wall **222** of the reaction vessel **204**. The walls **510***a-d* of this embodiment are concentric annular dividers that define annular electrode compartments **520***a-d*.

[**0056**] The processing chamber **200** also includes a virtual electrode unit **530** which individually shapes the electrical fields produced by the electrodes **600***a-d*. This virtual electrode unit **530** may define one or more "virtual electrodes" that define the effective shape, size and position of the electrical field perceived by the workpiece. In one embodiment of the invention, the virtual electrode unit **530** defines a separate virtual electrode associated with each of the electrode compartments **520***a-d*. Hence, a first virtual electrode VE_1 is associated with the first electrode compartment **520***a*, a second virtual electrode VE_2 is associated with the second electrode compartment **520***b*, a third virtual electrode VE_3 is associated with the third electrode compartment **520***c*, and a fourth virtual electrode VE_4 is associated with the fourth electrode compartment **520***d*. Each of the virtual electrodes VE may be electrically connected to the electrode **600** received in the associated electrode compartment **520**.

[0057] In one embodiment, the virtual electrodes VE are electrically associated with the electrode **600** in the associated electrode compartment **520** via flow of an electrically conductive processing fluid through the electrode compartment. As a result, each of the virtual electrodes VE receive an electrical potential with respect to the workpiece **101** from the associated electrode **600**. Processing fluid may be delivered to the various electrode compartments via a distributor **300**. For example, fluid from the distributor **300** will flow upwardly through the fourth electrode compartment **520***d*, passing over the fourth electrode **600***d*, then flow upwardly through the fourth virtual electrode VE_4 via a flow conduit in the virtual electrode unit **530**. In this embodiment, therefore, the shape and size of each virtual electrode is defined by the shape and size of an opening in the virtual electrode unit **530** in fluid communication with one of the electrode compartments. Other embodiments of the invention may utilize virtual electrodes which need not be defined by the passage of fluid through an opening. As explained below in connection with **FIG. 8**, for example, ion-permeable membranes may limit the passage of bulk fluid from the electrode compartments **520***b-d*, instead merely passing ions through the membrane and to the associated virtual electrode.

[0058] In one embodiment, one or more of the walls **510***a-d* are coupled to the virtual electrode unit **530** to define a field shaping unit **500**. Coupling the walls **510** to the virtual electrode unit **530** allows the field shaping unit to be removed from the reaction vessel as a unit. In one embodiment detailed below, the electrodes **600** remain in place in the reaction vessel **204** when the field shaping unit **500** is removed. If so desired, however, the electrodes **600** may be carried by the field shaping unit **500**, such as by attaching electrodes **600** to the walls **510** or providing an electrically conductive coating on the walls **510** which can be electrically coupled to the power supply **620** or power supply controller **625** when the walls **510** are received in the reaction vessel **204** for processing a workpiece.

[0059] **FIG. 5** illustrates the processing chamber **200** of **FIG. 4**, also in a schematic fashion. In **FIG. 5**, however, the processing chamber **200** has been modified to process a workpiece **101***a* which is smaller than the workpiece **101** shown in **FIG. 4**. Many features of the processing chamber **200** shown in **FIG. 5** can be the same as those described in connection with **FIG. 4**, and thus like reference numbers refer to like parts in these Figures. The primary differences between the embodiment of **FIG. 4** and the embodiment of **FIG. 5** relate to the contact assembly and the virtual electrode assembly. In particular, the contact assembly **161** of **FIG. 5** is adapted to hold a smaller workpiece than is the contact assembly **160** of **FIG. 4** and the virtual electrode unit **540** in **FIG. 5** defines a different arrangement of virtual electrodes VE than does the virtual electrode unit **530** of **FIG. 4**.

[0060] The virtual electrode unit **530** in **FIG. 4** has virtual electrodes VE_{1-4} which are sized and have relative positions adapted to process the larger first workpiece **101**. The virtual electrodes VE_{1-4} of the virtual electrode unit **540** in **FIG. 5** may have different sizes and/or relative positions from the virtual electrodes VE_{1-4} in the virtual electrode unit **530** in **FIG. 4**. In particular, the virtual electrodes VE of **FIG. 4** may be optimized for processing the first workpiece **101** whereas the virtual electrodes VE of **FIG. 5** may be optimized for processing the second workpiece **101***a*. As a consequence, the effective electrical field in the vicinity of the workpiece can be changed depending on the particular needs of different workpieces.

[0061] The processing chamber **200** may be modified from the configuration shown in **FIG. 4** to the configuration shown in **FIG. 5** by replacing the contact assembly **160** with a new contact assembly **161** and by replacing the virtual electrode unit **530** with a new virtual electrode unit **540**. In some circumstances, it may not be necessary to replace the contact assembly, for example, when the two workpieces **101** and **101***a* are the same size, but have different processing requirements requiring different electrical fields. Hence, the processing chamber **200** can be quickly and easily modified from one configuration adapted to process a first workpiece **101** to a different configuration adapted to process a second workpiece **101***a* simply by replacing one virtual electrode unit **530** with a different virtual electrode unit **540**. If the walls **510** are coupled to the virtual electrode unit **530** for removal of the field shaping unit **500** as a unit, the other virtual electrode unit **540** may also have walls **510** coupled thereto to define a different field shaping unit which can be placed in the reaction vessel **204** in the same position previously occupied by the previous field shaping unit **500**. Similarly, if the electrodes **600** are carried by the walls **510** of the initial field shaping unit **500** shown in **FIG. 4** for removal therewith as a unit, the replacement field shaping unit may also have electrodes **600** carried by its walls **510**.

[0062] Hence, in accordance with several embodiments of the invention, a processing chamber **200** can be modified to process different workpieces in a simple, straightforward manner. In one embodiment explained below, this simplifies modifying an existing processing chamber **200** from a first configuration for treating a first workpiece to a second configuration for treating a different second workpiece. In another embodiment explained below, this enables a manufacturer greater flexibility in manufacturing processing lines customized to treat different workpieces.

[0063] **FIG. 6** more specifically illustrates an embodiment of a housing **202** receiving a reaction vessel **204** similar, in some respects, to the reaction vessel **204** shown schematically in **FIG. 4**. As many features of the reaction vessel **204** shown in **FIG. 6** can be the same as those described with reference to **FIGS. 4 and 5**, like reference numbers refer to like parts in these Figures. The housing **202** in **FIG. 6** can have a drain **210** for returning the processing fluid that flows out of the reaction vessel **204** to a storage tank, and a plurality of openings for receiving inlets and electrical fittings. The reaction vessel **204** can include an outer container **220** having an outer wall **222** spaced radially inwardly of the housing **202**. The outer container **220** can also have a spiral spacer **224** between the outer wall **222** and the housing **202** to provide a spiral ramp (i.e., a helix) on which the processing fluid can flow downward to the bottom of the housing **202**. The spiral ramp reduces the turbulence of the return fluid to inhibit entrainment of gasses in the return fluid.

[0064] **FIGS. 4 and 5** illustrate reaction vessels **204** with distributors **300** receiving a flow of fluid from a single inlet. The particular embodiment of the reaction vessel **204** shown in **FIG. 6**, however, can include a distributor **300** for receiving a primary fluid flow F_p and a secondary fluid flow F_2, a primary flow guide **400** coupled to the distributor **300** to condition the primary fluid flow F_p, and a field shaping unit **500** coupled to the distributor **300** to contain the secondary flow F_2 in a manner that shapes the electrical field in the reaction vessel **204**. The reaction vessel **204** can also include at least one electrode **600** in a compartment of the field shaping unit **500** and at least one filter or other type of interface member **700** carried by the field shaping unit **500** downstream from the electrode. The primary flow guide **400** can condition the primary flow F_p by projecting this flow radially inwardly relative to a common axis A-A, and a portion of the field shaping unit **500** directs the conditioned primary flow F_p toward the workpiece. In several embodiments, the primary flow passing through the primary flow guide **400** and the center of the field shaping unit **500** controls the mass transfer of processing solution at the surface of the workpiece. The field shaping unit **500** also defines the shape the electric field, and it can influence the mass transfer at the surface of the workpiece if the secondary flow passes through the field shaping unit. The reaction vessel **204** can also have other configurations of components to guide the primary flow F_p and the secondary flow F_2 through the processing chamber **200**. The reaction vessel **204**, for example, may not have a distributor in the processing chamber, but rather separate fluid lines with individual flows can be coupled to the vessel **204** to provide a desired distribution of fluid through the primary flow guide **400** and the field shaping unit. For example, the reaction vessel **204** can have a first outlet in the outer container **220** for introducing the primary flow into the reaction vessel and a second outlet in the outer container for introducing the secondary flow into the reaction vessel **204**. Each of these components is explained in more detail below.

[0065] **FIGS. 7A-7D** illustrate an embodiment of the distributor **300** for directing the primary fluid flow to the primary flow guide **400** and the secondary fluid flow to the field shaping unit **500**. Referring to **FIG. 7A**, the distributor **300** can include a body **310** having a plurality of annular steps **312** (identified individually by reference numbers **312***a-d*) and annular grooves **314** in the steps **312**. The outermost step **312***d* is radially inward of the outer wall **222** (shown in broken lines) of the outer container **220** (**FIG. 6**), and each of the interior steps **312***a-c* can carry an annular wall (shown in broken lines) of the field shaping unit **500** in a corresponding groove **314**. The distributor **300** can also include a first inlet **320** for receiving the primary flow F_p and a plenum **330** for receiving the secondary flow F_2. The first inlet **320** can have an inclined, annular cavity **322** to form a passageway **324** (best shown in **FIG. 6**) for directing the primary fluid flow F_p under the primary flow guide **400**. The distributor **300** can also have a plurality of upper orifices **332** along an upper part of the plenum **330** and a plurality of lower orifices **334** along a lower part of the plenum **330**. As explained in more detail below, the upper and lower orifices are open to channels through the body **310** to distribute the secondary flow F_2 to the risers of the steps **312**. The distributor **300** can also have other configurations, such as a "step-less" disk or non-circular shapes.

[0066] **FIGS. 7A-7D** further illustrate one configuration of channels through the body **310** of the distributor **300**. Referring to **FIG. 7A**, a number of first channels **340** extend from some of the lower orifices **334** to openings at the riser of the first step **312***a*. **FIG. 7B** shows a number of second channels **342** extending from the upper orifices **332** to openings at the riser of the second step **312***b*, and **FIG. 7C** shows a number of third channels **344** extending from the upper orifices **332** to openings at the riser of the third step **312***c*. Similarly, **FIG. 7D** illustrates a number of fourth channels **346** extending from the lower orifices **334** to the riser of the fourth step **312***d*.

[0067] The particular embodiment of the channels **340-346** in **FIGS. 7A-7D** are configured to transport bubbles that collect in the plenum **330** radially outward as far as practical so that these bubbles can be captured and removed from the secondary flow F_2. This is beneficial because the field shaping unit **500** removes bubbles from the secondary flow F_2 by sequentially transporting the bubbles radially outwardly through electrode compartments. For example, a bubble B in the compartment above the first step **312***a* can sequentially cascade through the compartments over the second and third steps **312***b-c*, and then be removed from the compartment above the fourth step **312***d*. The first channel **340** (**FIG. 7A**) accordingly carries fluid from the lower orifices **334** where bubbles are less likely to collect to reduce the amount of gas that needs to cascade from the inner compartment above the first step **312***a* all the way out to the outer compartment. The bubbles in the secondary flow F_2 are more likely to collect at the top of the plenum **330** before passing through the channels **340-346**. The upper orifices **332** are accordingly coupled to the second channel **342** and the third channel **344** to deliver these bubbles outward beyond the first step **312***a* so that they do not need to cascade through so many compartments. In this embodiment, the upper orifices **332** are not connected to the fourth channels **346** because this would create a channel that inclines downwardly from the common axis such that it may conflict with the groove **314** in the third step **312***c*. Thus, the fourth channel **346** extends from the lower orifices **334** to the fourth step **312***d*.

[0068] Referring again to **FIG. 6**, the primary flow guide **400** receives the primary fluid flow F_p via the first inlet **320** of the distributor **300**. In one embodiment, the primary flow guide **400** includes an inner baffle **410** and an outer baffle **420**. The inner baffle can have a base **412** and a wall **414** projecting upward and radially outward from the base **412**. The wall **414**, for example, can have an inverted frusto-conical shape and a plurality of apertures **416**. The apertures **416** can be holes, elongated slots or other types of openings. In the illustrated embodiment, the apertures **416** are annularly extending radial slots that slant upward relative to the common axis to project the primary flow radially inward and upward relative to the common axis along a plurality of diametrically opposed vectors. The inner baffle **410** can also include a locking member **418** that couples the inner baffle **410** to the distributor **300**.

[**0069**] The outer baffle **420** can include an outer wall **422** with a plurality of apertures **424**. In this embodiment, the apertures **424** are elongated slots extending in a direction transverse to the apertures **416** of the inner baffle **410**. The primary flow F_p flows through (a) the first inlet **320**, (b) the passageway **324** under the base **412** of the inner baffle **410**, (c) the apertures **424** of the outer baffle **420**, and then (d) the apertures **416** of the inner baffle **410**. The combination of the outer baffle **420** and the inner baffle **410** conditions the direction of the flow at the exit of the apertures **416** in the inner baffle **410**. The primary flow guide **400** can thus project the primary flow along diametrically opposed vectors that are inclined upward relative to the common axis to create a fluid flow that has a highly uniform velocity. In alternate embodiments, the apertures **416** do not slant upward relative to the common axis such that they can project the primary flow normal, or even downward, relative to the common axis.

[**0070**] **FIG. 6** also illustrates an embodiment of the field shaping unit **500** that receives the primary fluid flow F_p downstream from the primary flow guide **400**. The field shaping unit **500** also contains the second fluid flow F_2 and shapes the electrical field within the reaction vessel **204**. In this embodiment, the field shaping unit **500** has a compartment structure with a plurality of walls **510** (identified individually by reference numbers **510***a-d*) that define a plurality of electrode compartments **520** (identified individually by reference numbers **520***a-d*). The walls **510** can be annular skirts or dividers, and they can be received in one of the annular grooves **314** in the distributor **300**. In one embodiment, the walls **510** are not fixed to the distributor **300** so that the field shaping unit **500** can be quickly removed from the distributor **300**. For example, each of the walls **510** may have a lower edge which is releasably received in the annular grooves **314** in the distributor **300**. This allows easy access to the electrode compartments **520** and/or quick removal of the field shaping unit **500** as a unit to change the shape of the electric field, as explained in more detail below.

[**0071**] The field shaping unit **500** can have at least one wall **510** outward from the primary flow guide **400** to prevent the primary flow F_p from contacting an electrode. In the particular embodiment shown in **FIGS. 6 and 8**, the field shaping unit **500** has a first electrode compartment **520***a* between the first and second walls **510***a-b*, a second electrode compartment **520***b* between the second and third walls **510***b-c*, a third electrode compartment **520***c* between the third and fourth walls **510***c-d*, and a fourth electrode compartment **520***d* between the fourth wall **510***d* and the outer wall **222** of the container **220**. Although the walls **510***a-d* of **FIG. 6** define annular electrode compartments **520***a-d*, alternate embodiments of the field shaping unit can have walls with different configurations to create non-annular electrode compartments and/or each electrode compartment can be further divided into cells. The second-fourth walls **510***b-d* can also include holes **522** for allowing bubbles in the first-third electrode compartments **520***a-c* to "cascade" radially outward to the next outward electrode compartment **520** as explained above with respect to **FIGS. 7A-7D**. The bubbles can then exit the fourth electrode compartment **520***d* through an exit hole **525** through the outer wall **222**. In an alternate embodiment, the bubbles can exit through an exit hole **524**.

[**0072**] The electrode compartments **520** provide electrically discrete compartments to house an electrode assembly having at least one electrode and generally two or more electrodes **600** (identified individually by reference numbers **600***a-d*). The electrodes **600** can be annular members (e.g., annular rings or arcuate sections) that are configured to fit within annular electrode compartments, or they can have other shapes appropriate for the particular workpiece (e.g., rectilinear). In the illustrated embodiment, for example, the electrode assembly includes a first annular electrode **600***a* in the first electrode compartment **520***a*, a second annular electrode **600***b* in the second electrode compartment **520***b*, a third annular electrode **600***c* in the third electrode compartment **520***c*, and a fourth annular electrode **600***d* in the fourth electrode compartment **520***d*. The electrodes **600** may be supported in the reaction vessel **204** in any suitable fashion. In the particular embodiment shown in **FIG. 6**, the electrodes are supported by pillars **602** which extend upwardly from a bottom of the reaction vessel **204**. These pillars **602** may be hollow, serving as a guide for wires **604** connecting the electrodes **600** to power supplies. As explained in U.S. Application No. 60/206,661, Ser. Nos. 09/845,505, and 09/804,697, all of which are incorporated herein by reference, each of the electrodes **600***a-d* can be biased with the same or different potentials with respect to the workpiece to control the current density across the surface of the workpiece. In alternate embodiments, the electrodes **600** can be non-circular shapes or sections of other shapes.

[**0073**] Embodiments of the reaction vessel **204** that include a plurality of electrodes provide several benefits for plating or electropolishing. In plating applications, for example, the electrodes **600** can be biased with respect to the workpiece at different potentials to provide uniform plating on different workpieces even though the seed layers vary from one another or the bath(s) of electroprocessing solution have different conductivities and/or concentrations of constituents. Additionally, another the benefit of having a multiple electrode design is that plating can be controlled to achieve different final fill thicknesses of plated layers or different plating rates during a plating cycle or in different plating cycles. Other benefits of particular embodiments are that the current density can be controlled to (a) provide a uniform current density during feature filling and/or (b) achieve plating to specific film profiles across a workpiece (e.g., concave, convex, flat). Accordingly, the multiple electrode configurations in which the electrodes are separate from one another provide several benefits for controlling the electrochemical process to (a) compensate for deficiencies or differences in seed layers between workpieces, (b) adjust for variances in baths of electroprocessing solutions, and/or (c) achieve predetermined feature filling or film profiles.

[**0074**] In the illustrated embodiment, the adjacent electrodes **600** are spaced from one another to define annular spaces for receiving a wall **510**. Hence, the second wall **510***b* is received in the annular space between the first electrode **600***a* and the second electrode **600***b*, the third wall **510***c* is received in the annular space between the second electrode **600***b* and the third electrode **600***c*, and the fourth wall **510***d* is received in the annular space between the third electrode **600***c* and the fourth electrode **600***d*. In one embodiment, the annular spaces between the electrodes **600** are sufficiently large to allow the walls to slide therein for removal and installation of the walls **510** in the reaction vessel **204** without modifying the electrodes **600**. If so desired, spacers (not shown) may be positioned between the walls **510** and the adjacent electrodes **600** to help center the electrodes **600** within their respective electrode compartments **520**.

[**0075**] The field shaping unit **500** can also include a virtual electrode unit **530** coupled to the walls **510** of the compartment assembly for individually shaping the electrical fields produced by the electrodes **600**. In this particular embodiment, the virtual electrode unit includes first-fourth partitions **530***a*-**530***d*, respectively. The first partition **530***a* can have a first section **532***a* coupled to the second wall **510***b*, a skirt **534** depending downward above the first wall **510***a*, and a lip **536***a* projecting upwardly. The lip **536***a* has an interior surface **537** that directs the primary flow F_p exiting from the primary flow guide **400**. The second partition **530***b* can have a first section **532***b* coupled to the third wall **510***c* and a lip **536***b* projecting upward from the first section **532***b*, the third partition **530***c* can have a first section **532***c* coupled to the fourth wall **510***d* and a lip **536***c* projecting upward from the first section **532***c*, and the fourth partition **530***d* can have a first section **532***d* carried by the outer wall **222** of the container **220** and a lip **536***d* projecting upward from the first section **532***d*. The fourth partition **530***d* may simply abut the outer wall **222** so that the field shaping unit **500** can be quickly removed from the vessel **204** by simply lifting the virtual electrode unit. The interface between the fourth partition **530***d* and the outer wall **222** is sealed by a seal **527** to inhibit both the fluid and the electrical current from leaking out of the fourth electrode compartment **520***d*. The seal **527** can be a lip seal. Additionally, each of the sections **532***a-d* can be lateral sections extending transverse to the common axis.

[**0076**] In one embodiment, each of the individual partition elements **530***a-d* are joined together so the virtual electrode unit **530** can be removed from the reaction vessel as a unit rather than separately as discrete elements. For example, the individual partitions **530***a-d* can be machined from or molded into a single piece of dielectric material, or they can be individual dielectric members welded or otherwise joined together. In alternate embodiments, the individual partitions **530***a-d* are not attached to each other and/or they can have different configurations. In the particular embodiment shown in **FIG. 6**, the first sections **532***a-d* of the partitions **530***a-d* are annular horizontal members and each of the lips **536***a-d* are annular vertical members arranged concentrically.

[**0077**] The walls **510***a-d* and the virtual electrode unit **530** are generally dielectric materials that contain the second flow F_2 of the processing solution for shaping the electric fields generated by the electrodes **600***a-d*. The second flow F_2, for example, can pass (a) through each of the electrode compartments **520***a-d*, (b) between the individual partitions **530***a-d*, and then (c) upward through the annular openings between the lips **536***a-d*. In this embodiment, the secondary flow F_2 through the first electrode compartment **520***a* can join the primary flow F_p in an antechamber just before the primary flow guide **400**, and the secondary flow through the second-fourth electrode compartments **520***b-d* can join the primary flow F_p beyond the top edges of the lips **536***a-d*. The flow of electroprocessing solution then flows over a shield weir attached at rim **538** and into the gap between the housing **202** and the outer wall **222** of the container **220** as disclosed in International Application No. PCT/US00/10120. As explained below with reference to **FIG. 6**, the fluid in the secondary flow F_2 can be prevented from flowing out of the electrode compartments **520***a-d* to join the primary flow F_p while still allowing electrical current to pass from the electrodes **600** to the primary flow. In this alternate embodiment, the secondary flow F_2 can exit the reaction vessel **204** through the holes **522** in the walls **510** and the hole **525** in the outer wall **222**. In still additional embodiments in which the fluid of the secondary flow does not join the primary flow, a duct can be coupled to the exit hole **525** in the outer wall **222** so that a return flow of the secondary flow passing out of the field shaping unit **500** does not mix with the return flow of the primary flow passing down the spiral ramp outside of the outer wall **222**.

[**0078**] The field shaping unit **500** can have other configurations that are different than the embodiment shown in **FIG. 6**. For example, the electrode compartment assembly can have only a single wall **510** defining a single electrode compartment **520**, and the reaction vessel **204** can include only a single electrode **600**. The field shaping unit of either embodiment still separates the primary and secondary flows so that the primary flow does not engage the electrode, and thus it shields the workpiece from the single electrode. One advantage of shielding the workpiece from the electrodes **600***a-d* is that the electrodes can accordingly be much larger than they could be without the field shaping unit because the size of the electrodes does not have effect on the electrical field presented to the workpiece. This is particularly useful in situations that use consumable electrodes because increasing the size of the electrodes prolongs the life of each electrode, which reduces downtime for servicing and replacing electrodes.

[**0079**] An embodiment of reaction vessel **204** shown in **FIG. 6** can accordingly have a first conduit system for conditioning and directing the primary fluid flow F_p to the workpiece, and a second conduit system for conditioning and directing the secondary fluid flow F_2. The first conduit system, for example, can include the inlet **320** of the distributor **300**; the channel **324** between the base **412** of the primary flow guide **400** and the inclined cavity **322** of the distributor **300**; a plenum between the wall **422** of the outer baffle **420** and the first wall **510***a* of the field shaping unit **500**; the primary flow guide **400**; and the interior surface **537** of the first lip **536***a*. The first conduit system conditions the direction of the primary fluid flow F_p by passing it through the primary flow guide **400** and along the interior surface **537** so that the velocity of the primary flow F_p normal to the workpiece is at least substantially uniform across the surface of the workpiece. The primary flow F_p and rotation of the workpiece can accordingly be controlled to dominate the mass transfer of electroprocessing medium at the workpiece.

[**0080**] The second conduit system, for example, can include the plenum **330** and the channels **340**-**346** of the distributor **300**, the walls **510** of the field shaping unit **500**, and the partitions **530***a-d* of the field shaping unit **500**. The secondary flow F_2 contacts the electrodes **600** to establish individual electrical fields in the field shaping unit **500** that are electrically coupled to the primary flow F_p. The field shaping unit **500**, for example, separates the individual electrical fields created by the electrodes **600***a-d* to create "virtual electrodes" at the top of the openings defined by the lips **536***a-d* of the partitions. In this particular embodiment, the central opening inside the first lip **536***a* defines a first virtual electrode, the annular opening between the first and second lips **536***a-b* defines a second virtual electrode, the annular opening between the second and third lips **536***b-c* defines a third virtual electrode, and the annular opening between the third and fourth lips **536***c-d* defines a fourth virtual electrode. These are "virtual electrodes" because the field shaping unit **500** shapes the individual electrical fields of the actual electrodes **600***a-d* so that the effect of the electrodes **600***a-d* acts as if they are placed between the top edges of the lips **536***a-d*. This allows the actual electrodes **600***a-d* to be isolated from the primary fluid flow, which can provide several benefits as explained in more detail below.

[0081] An additional embodiment of the processing chamber **200** includes at least one interface member **700** (identified individually by reference numbers **700***a-d*) for further conditioning the secondary flow F_2 of electroprocessing solution. The interface members **700**, for example, can be filters that capture particles in the secondary flow that were generated by the electrodes (i.e., anodes) or other sources of particles. The filter-type interface members **700** can also inhibit bubbles in the secondary flow F_2 from passing into the primary flow F_p of electroprocessing solution. This effectively forces the bubbles to pass radially outwardly through the holes **522** in the walls **510** of the field shaping unit **500**. In alternate embodiments, the interface members **700** can be ion-membranes that allow ions in the secondary flow F_2 to pass through the interface members **700**. The ion-membrane interface members **700** can be selected to (a) allow the fluid of the electroprocessing solution and ions to pass through the interface member **700**, or (b) allow only the desired ions to pass through the interface member such that the fluid itself is prevented from passing beyond the ion-membrane.

[0082] **FIG. 8** is another isometric view of the reaction vessel **204** of **FIG. 6** showing a cross-sectional portion taken along a different cross-section. More specifically, the cross-section of **FIG. 6** is shown in **FIG. 10A** and the cross-section of **FIG. 8** is shown in **FIG. 10B**. Returning now to **FIG. 8**, this illustration further shows one embodiment for configuring a plurality of interface members **700***a-d* relative to the partitions **530***a-d* of the field shaping unit **500**. A first interface member **700***a* can be attached to the skirt **534** of the first partition **530***a* so that a first portion of the secondary flow F_2 flows past the first electrode **600***a*, through an opening **535** in the skirt **534**, and then to the first interface member **700***a*. Another portion of the secondary flow F_2 can flow past the second electrode **600***b* to the second interface member **700***b*. Similarly, portions of the secondary flow F_2 can flow past the third and fourth electrodes **600***c-d* to the third and fourth interface members **700***c-d*.

[0083] When the interface members **700***a-d* are filters or ion-membranes that allow the fluid in the secondary flow F_2 to pass through the interface members **700***a-d*, the secondary flow F_2 joins the primary fluid flow F_p. The portion of the secondary flow F_2 in the first electrode compartment **520***a* can pass through the opening **535** in the skirt **534** and the first interface member **700***a*, and then into a plenum between the first wall **510***a* and the outer wall **422** of the baffle **420**. This portion of the secondary flow F_2 accordingly joins the primary flow F_p and passes through the primary flow guide **400**. The other portions of the secondary flow F_2 in this particular embodiment pass through the second-fourth electrode compartments **520***b-d* and then through the annular openings between the lips **536***a-d*. The second-fourth interface members **700***b-d* can accordingly be attached to the field shaping unit **500** downstream from the second-fourth electrodes **600***b-d*.

[0084] In the particular embodiment shown in **FIG. 8**, the second interface member **700***b* is positioned vertically between the first and second partitions **530***a-b*, the third interface member **700***c* is positioned vertically between the second and third partitions **530***b-c*, and the fourth interface member **700***d* is positioned vertically between the third and fourth partitions **530***c-d*. The interface assemblies **710***a-d* are generally installed vertically, or at least at an upwardly inclined angle relative to horizontal, to force the bubbles to rise so that they can escape through the holes **522** in the walls **510***a-d* (**FIG. 6**). This prevents aggregations of bubbles that could potentially disrupt the electrical field from an individual electrode.

[0085] **FIGS. 9A and 9B** illustrate an interface assembly **710** for mounting the interface members **700** to the field shaping unit **500** in accordance with an embodiment of the invention. The interface assembly **710** can include an annular interface member **700** and a fixture **720** for holding the interface member **700**. The fixture **720** can include a first frame **730** having a plurality of openings **732** and a second frame **740** having a plurality of openings **742** (best shown in **FIG. 9A**). The holes **732** in the first frame can be aligned with the holes **742** in the second frame **740**. The second frame can further include a plurality of annular teeth **744** extending around the perimeter of the second frame. It will be appreciated that the teeth **744** can alternatively extend in a different direction on the exterior surface of the second frame **740** in other embodiments, but the teeth **744** generally extend around the perimeter of the second frame **740** in a top annular band and a lower annular band to provide annular seals with the partitions **536***a-d* (**FIG. 6**). The interface member **700** can be pressed between the first frame **730** and the second frame **740** to securely hold the interface member **700** in place. The interface assembly **710** can also include a top band **750***a* extending around the top of the frames **730** and **740** and a bottom band **750***b* extending around the bottom of the frames **730** and **740**. The top and bottom bands **750***a-b* can be welded to the frames **730** and **740** by annular welds **752**. Additionally, the first and second frames **730** and **740** can be welded to each other by welds **754**. It will be appreciated that the interface assembly **710** can have several different embodiments that are defined by the configuration of the field shaping unit **500** (**FIG. 6**) and the particular configuration of the electrode compartments **520***a-d* (**FIG. 6**).

[0086] When the interface member **700** is a filter material that allows the secondary flow F_2 of electroprocessing solution to pass through the holes **732** in the first frame **730**, the post-filtered portion of the solution continues along a path (arrow Q) to join the primary fluid flow F_p as described above. One suitable material for a filter-type interface member **700** is POREX®, which is a porous plastic that filters particles to prevent them from passing through the interface member. In plating systems that use consumable anodes (e.g., phosphorized copper or nickel sulfamate), the interface member **700** can prevent the particles generated by the anodes from reaching the plating surface of the workpiece.

[0087] In alternate embodiments in which the interface member **700** is an ion-membrane, the interface member **700** can be permeable to preferred ions to allow these ions to pass through the interface member **700** and into the primary fluid flow F_p. One suitable ion-membrane is NAFION® perfluorinated membranes manufactured by DuPont®. In one application for copper plating, a NAFION **450** ion-selective membrane is used. Other suitable types of ion-membranes for plating can be polymers that are permeable to many cations, but reject anions and non-polar species. It will be appreciated that in electropolishing applications, the interface member **700** may be selected to be permeable to anions, but reject cations and non-polar species. The preferred ions can be transferred through the ion-membrane interface member **700** by a driving force, such as a difference in concentration of ions on either side of the membrane, a difference in electrical potential, or hydrostatic pressure.

[0088] Using an ion-membrane that prevents the fluid of the electroprocessing solution from passing through the interface member **700** allows the electrical current to pass through the interface member while filtering out particles, organic additives and bubbles in the fluid. For example, in plating applications in which the interface member **700** is permeable to cations, the primary fluid flow F_p that contacts the workpiece can be a catholyte and the secondary fluid flow F_2 that does not contact the workpiece can be a separate anolyte because these fluids do not mix in this embodiment. A benefit of having separate anolyte and catholyte fluid flows is that it eliminates the consumption of additives at the anodes and the need to replenish the additives as often. Additionally, this feature combined with the "virtual electrode" aspect of the reaction vessel **204** reduces the need to "burn-in" anodes for insuring a consistent black film over the anodes for predictable current distribution because the current distribution is controlled by the configuration of the field shaping unit **500**. Another advantage is that it also eliminates the need to have a predictable consumption of additives in the secondary flow F_2 because the additives to the secondary flow F_2 do not effect the primary fluid flow F_p when the two fluids are separated from each other.

[0089] Referring to **FIG. 8** again, the interface assemblies **710***a-d* are generally installed so that the interface members **700***a-d* are vertical or at least at an upwardly inclined angle relative to horizontal. The vertical arrangement of the interface assemblies **710***a-d* is advantageous because the interface members **700** force the bubbles to rise so that they can escape through the holes **522** in the walls **510***a-d* (**FIG. 6**). This prevents aggregations of bubbles that could potentially disrupt the electrical field from an individual anode.

[0090] From time to time, it may be desirable to modify a particular reaction vessel **204** from a first configuration for processing a first type of workpiece **5** to a second configuration for processing a different second type of workpiece **5**. For example, a reaction vessel **204** adapted to treat a first size of workpiece, e.g., to electroplate a semiconductor wafer having a 300 mm diameter, is not well suited to treat differently sized workpieces, e.g., to electroplate 200 mm semiconductor wafers, to yield consistent, high-quality products. The two types of workpieces need not be different shapes to merit alteration of the electric field and/or flow pattern of processing fluid. For example, the workpieces may require plating of a different material or a different thickness of the same material, or the workpieces surfaces may have different conductivities.

[0091] One embodiment of the present invention provides a reaction vessel **204** which can be easily modified to treat different workpieces and which can be easily disassembled for access to the electrodes **600** therein. In this embodiment, at least the virtual electrode unit **530** of the field shaping unit **500** can be easily removed from the reaction vessel **204** and replaced with a different virtual electrode unit adapted for treating a different workpiece.

[0092] As seen in **FIGS. 6 and 8**, the outer partition **530***d* may simply rest atop the upper edge of the outer wall **222** of the reaction vessel **204** without being securely affixed thereto. As noted above, each of the individual partitions **530***a-d* may be joined together, enabling the virtual electrode unit **530** to be removed from the reaction vessel **204** as a unit rather than separately as discrete elements. In the particular embodiment shown in **FIG. 6**, an upper edge of each of the walls **510***a-d* is coupled to a separate partition **530***a-d*, respectively, and the lower edge of each of the walls **510** may be releasably received in an annular recess **314** in the distributor **300**. The walls **510** may also be slidably received in annular spaces between adjacent pairs of electrodes **600**, as noted above. As a consequence, the entire field shaping unit **500**, not just the virtual electrode unit **530**, may be removed from the reaction vessel as a unit.

[0093] **FIG. 11** illustrates removal of the field shaping unit **500** from the reaction vessel **204**. As can be seen in this view, the virtual electrode unit **530** and the walls **510** (only the outer wall **510***d* being visible in **FIG. 11**) of the field shaping unit **500** are removed from the reaction vessel **204** as a unit. The electrodes **600** remain in place in the reaction vessel, supported by the pillars (**602** in **FIG. 6**). Removing the field shaping unit **500** in this fashion allows ready access to the electrodes, e.g., for periodic inspection and maintenance or for scheduled replacement of consumable anodes. It also permits replacement of the field shaping unit **500** with a different field shaping unit better adapted for use with a different workpiece.

[0094] **FIG. 12** is an isometric view of an embodiment of the processing chamber **200** with a different virtual electrode unit **540** therein. Many features of the processing chamber **200** shown in **FIG. 12** can be the same as those described above with reference to **FIG. 6**, and thus like reference numbers refer to like parts in these Figures. The primary difference between the embodiment of **FIG. 6** and the embodiment of **FIG. 12** is that the virtual electrode unit **540** in **FIG. 12** defines a different flow pattern than does the virtual electrode unit **530** of **FIG. 6**.

[0095] The general structure of the virtual electrode units **530** and **540** are similar. Hence, the virtual electrode unit **540** of **FIG. 12** includes first-fourth partitions **540***a*-**540***d*, respectively. The first partition **540***a* can have a first section **542***a* coupled to the second wall **510***b*, a skirt **544** depending downward above the first wall **510***a*, and a lip **546***a* projecting upwardly. The lip **546***a* has an interior surface **547** that directs the primary flow F_p exiting from the primary flow guide **400**. The second partition **540***b* can have a first section **542***b* coupled to the third wall **510***c* and a lip **546***b* projecting from the first section **542***b*, the third partition

540*c* can have a first section **542***c* coupled to the fourth wall **510***d* and a lip **546***c* projecting upward from the first section **542***c*, and the fourth partition **540***d* can have a first section **542***d* which engages the outer wall **222** of the container **220** and a lip **546***d* projecting from the first section **542***d*. As with the virtual electrode unit **530** described above, the partitions **540***a-d* may be joined together so the virtual electrode unit **540** can be removed from the reaction vessel as a unit. In the particular embodiment shown in **FIG. 12**, the first sections **542***a-d* of the partitions **540***a-d* are annular horizontal members and each of the lips **546***a-d* are annular vertical members that are arranged concentrically.

[0096] The two virtual electrode units **530** and **540** functionally differ in that the partitions **540***a-d* in **FIG. 12** define gaps between adjacent lips **546** having different relative positions with respect to the common axis A-A from the gaps defined between adjacent lips **536** of the partitions **530***a-d* in **FIG. 6**. As explained above, these gaps may define the discharge outlets for the processing fluid and, hence, the relative positions and sizes of the virtual electrodes. As a practical matter, these virtual electrodes define the shape of the electrical field in the processing fluid. As a consequence, replacing the virtual electrode unit **530** of **FIG. 6** with the virtual electrode unit **540** of **FIG. 12** will alter the effective electrical field adjacent the workpiece. Comparing **FIGS. 6 and 12**, it can be seen that the first sections **542***a-d* and lips **546***a-d* of partitions **540***a-d* in **FIG. 12** are longer than the first sections **532***a-d* and lips **536***a-d* of partitions **530***a-d* in **FIG. 6**. As a result, the virtual electrodes defined by the virtual electrode unit **540** are positioned higher within and closer to the common axis A-A of the reaction vessel **204** than the virtual electrodes of **FIG. 6**. The processing chamber **200** of **FIG. 12** with virtual electrode unit **540** may be better adapted for use with a smaller workpiece than is the processing chamber **200** of **FIG. 6** with virtual electrode unit **530**.

[0097] The walls **510** in **FIG. 12** are received in the same spaces between adjacent electrodes **600** as are the walls **510** in **FIG. 6**. In one embodiment, the virtual electrode units **530** and **540** merely abut the walls **510**, but the walls **510** remain in place when either of the virtual electrode units are removed. In such an embodiment, the virtual electrode units **530** and **540** may have recesses or abutments at the same relative positions so that they will abut the upper edges of the walls **510** when one virtual electrode unit replaces the other. This enables one to alter the electric field in the processing chamber **200** without altering any other parts of the processing chamber. In an alternative embodiment, the walls **510** are coupled to the virtual electrode unit **540** and the field shaping unit **502** may be removed as a unit. This would be directly analogous to the embodiment shown in **FIG. 11**, with the field shaping unit **502** of **FIG. 12** being readily substitutable for the field shaping unit **500** of **FIG. 6**. To ensure that the walls **510** are properly arranged to be received in the annular spaces between adjacent electrodes **600**, the relative positions of the walls **510** of the field shaping unit **502** (**FIG. 12**) may be the same as the relative positions of the walls **510** of the field shaping unit **500** (**FIG. 6**).

[0098] C. Methods of Treating Different Workpieces with the Same Electrochemical Processing Chamber

[0099] As noted above, certain embodiments of the present invention provide methods enabling a single electrochemical processing chamber to be used to treat different workpieces. In the following discussion of different embodiments of these methods, reference is made to the processing chambers **200** shown in **FIGS. 6 and 12**. It should be understood that this is solely for purposes of convenience, however, and that various methods of the invention may be carried out with processing chambers which differ from those illustrated in these drawings or which do not include all of the detailed features shown in the drawings.

[0100] One embodiment of the invention provides a method for modifying an electrochemical processing chamber **200** from a first configuration for treating a first workpiece **101** (shown in **FIG. 3**) to a second configuration for treating a different second workpiece **101***a* (shown in **FIG. 13**). The second workpiece **101***a* may differ from the first in terms of size (as in the illustrated embodiment), electrical properties, or a variety of other features, as noted above. An electrochemical processing chamber **200** is initially configured to treat the first workpiece **101**. For example, the electrochemical processing chamber **200** of **FIG. 6** may include a first virtual electrode unit **530** which defines a plurality of virtual electrodes sized and positioned to electroplate a metal on a particular type of workpiece, e.g., a 300 mm semiconductor wafer. One of these workpieces will be positioned in the contact assembly **160** (**FIG. 3**) and the contact assembly **160** may be positioned over the reaction vessel **204** with a surface of the workpiece in contact with a processing solution in the reaction vessel **204**. The workpiece may then be treated with the electrochemical processing chamber **200**. When using the apparatus shown in **FIG. 6**, this could include delivering a primary fluid flow F_p through the first inlet **320** and delivering a secondary fluid flow F_2 through the plenum **330**. An electrical potential may be applied to the electrodes **600** and the secondary fluid flow F_2 may pass through the electrode compartments **320***a-d*, through the discharge openings defined by the virtual electrode unit **530**, and into electrical contact with the primary fluid flow F_p.

[0101] After the first workpiece **101** is treated, the electrochemical processing chamber **200** may be modified to treat a different second workpiece **101***a*, e.g., a 200 mm semiconductor wafer. As suggested in **FIG. 11**, this may be achieved by lifting the contact assembly **160** and removing the initial virtual electrode unit **530** of **FIG. 6** from the reaction vessel **204**. Thereafter, a different virtual electrode unit **540** (**FIG. 12**) may be installed in the reaction vessel. In one embodiment, the initial virtual electrode unit **530** is removed as a unit, but the walls **510** remain in place. The second virtual electrode unit **540** may then be installed by placing it atop the upper edges of the same walls **510**. In an alternative embodiment, the walls **510** are coupled to the first virtual electrode unit **530** and the entire field shaping unit **500** of **FIG. 6** is removed as a unit. Thereafter, the second field shaping unit **502** may be installed in the reaction vessel **204**, yielding an electrochemical processing chamber **200** essentially as shown in **FIG. 12**. When installing the second field shaping unit **502** in the reaction vessel **204**, the walls **510** of the second field shaping unit **502** may be inserted in the annular spaces between adjacent electrodes previously occupied by the walls **510** of the first field shaping unit **500**. Similarly, the lower edges of the walls **510** of the second field shaping unit **502** may be positioned in the annular recesses **314** in the distributor **310** previously occupied by lower edges of the walls **510** of the first field shaping unit **500**.

[0102] After the electrochemical processing chamber **200** has been adapted for treating the second type of workpiece, one of the second workpieces may be treated with the modified electrochemical processing chamber **200**. The process may substantially parallel that outlined above in connection with treating the first workpiece. Depending on the nature of the contact assembly **160** being used and the differences between the workpieces, it may be necessary to replace the contact assembly **160** used to treat the first workpiece **101** with a different contact assembly **161** better suited to handle the second type of workpiece **101***a*. **FIG. 13** schematically illustrates the electrochemical processing chamber of **FIG. 3** modified for use with a smaller second workpiece **101***a*. In **FIG. 13**, the contact assembly **160** of **FIG. 3** has been replaced with a smaller contact assembly **161** sized to accommodate the smaller workpiece **101***a* carried thereby. The rotor **154** and backing plate **155** of **FIG. 3** may also replaced with like components better adapted to mate with the smaller contact assembly **161**. Once the second workpiece **101***a* is properly positioned in an appropriate contact assembly **161**, the contact assembly **161** may be positioned over the reaction vessel **204** with a surface of the workpiece in contact with a processing solution, the primary and secondary fluid flows F_p and F_2 may be established and power may be applied to the electrodes **600**, as outlined above in connection with treatment of the first workpiece.

[0103] As noted above, the virtual electrodes defined by the first virtual electrode unit **530 (FIG. 6)** may be sized and shaped to optimize electrochemical processing for the first workpiece and the virtual electrodes defined by the second virtual electrode unit **540 (FIG. 12)** may be sized and shaped to optimize electrode chemical processing for the second workpiece. Simply by replacing the first field shaping unit **500** with the second field shaping unit **502** thereby permits the same electrochemical processing chamber **200** to be optimized for treating two different workpieces without necessitating modification of the electrodes **600** in the reaction vessel **204**. This is indirect contrast to conventional single wafer processing chambers **1** such as that shown in **FIG. 1**, wherein attempting to adapt the processing chamber for use with differently sized workpieces would necessitate significant modifications. These modifications would include removing the anode **4** and primary flow guide **6** and replacing them with new, different parts. The electrical connection of the anode **4** to its power supply can complicate this exchange, particularly as compared to the simple modification process afforded by this embodiment of the present invention.

[0104] Another embodiment of the present invention permits a manufacturer to effectuate electrochemical treatment of two different workpieces by providing an initial electrochemical processing chamber **200** and a second virtual electrode unit **540** and giving the user appropriate instructions. The initial electrochemical processing chamber **200** may be substantially the same as that shown in **FIG. 6** and include a virtual electrode unit **530** optimized for treating the first workpiece. The second virtual electrode unit **540** may define virtual electrodes having predefined relative positions optimized for treating the second workpiece. The user may be instructed to treat the first workpiece with the initial electrochemical processing chamber **200**; to replace the first virtual electrode unit **530** with the second virtual electrode unit **540**, thereby modifying the initial electrochemical processing chamber by repositioning the virtual electrodes without necessity of altering the electrodes of the reaction vessel; and to treat the second workpiece with the modified electrochemical processing chamber. The user may be instructed in any appropriate way. This may include written communication such as a written instruction manual, hands-on training, and/or videotaped instruction, for example.

[0105] An alternative embodiment of the invention provides a method of effectuating assembly of an electrochemical processing chamber **200**. This embodiment includes providing a reaction vessel **204** having an outer wall **222**, a plurality of electrodes (e.g., **600***a* and **600***b*), and a wall-receiving space between adjacent electrodes. A replaceable first field shaping unit (e.g., the field shaping unit **500** of **FIG. 6**) is provided. The first field shaping unit **500** has at least one wall (e.g., wall **510***b*) adapted to be received in the wall-receiving space between the electrodes **600**. The first field shaping unit has a first virtual electrode unit **530** coupled to the wall **510**. The first virtual electrode unit **530** defines a first set of virtual electrodes (e.g., VE_1 and VE_2) having predefined relative positions. A second field shaping unit **500** (e.g., the one shown in **FIG. 8**) is provided, with the second field shaping unit **500** also having at least one wall (e.g., wall **510***b*) adapted to be received in the wall-receiving space between the electrodes **600**. The second field shaping unit **500** has a second virtual electrode unit **540** coupled to the wall **510** and defining a second set of virtual electrodes (e.g., VE_1 and VE_2) having predefined relative positions.

[0106] At least one functional characteristic of the first field shaping unit **500** is identified and at least one functional characteristic of the second field shaping unit **500** is identified. The identified functional characteristic of the first field shaping unit **500** is different from the identified functional characteristic of the second field shaping unit **500**. For example, the first field shaping unit **500** may be identified as being adapted for use with a particular size of workpiece, such as a 300 mm semiconductor wafer, and the second field shaping unit may be identified as being adapted for use with a different size of workpiece, such as a 200 mm semiconductor wafer. This identifying information may enable a user to select between the first and second field shaping units to adapt the reaction vessel to treat a selected type of workpiece.

[0107] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

1-20. (canceled)

21. An electrochemical processing chamber, comprising:

a reaction vessel having an interior;

an electrode received in the interior of the reaction vessel; and

a first virtual electrode unit comprising a dielectric material and defining a first virtual electrode in fluid communication with the electrode, the first virtual electrode unit being exchangeable for a second virtual electrode unit, without necessitating modification of the electrode, to adapt the processing chamber for treating a differently-sized workpiece.

22. An electrochemical processing chamber, comprising:

a reaction vessel having an inner surface;

a first wall spaced from the inner surface of the reaction vessel, the first wall being formed of a dielectric material and electrically separating a first electrode compartment from a second electrode compartment;

a first electrode positioned in the first electrode compartment and a second electrode positioned in the second electrode compartment; and

a first virtual electrode unit comprising a dielectric material and defining a first virtual electrode in fluid communication with the first electrode compartment, the first partition also defining, in part, a second virtual electrode in fluid communication with the outer electrode compartment, the first virtual electrode unit being exchangeable for a second virtual electrode unit, without necessitating modification of the electrodes, to adapt the processing chamber for treating a differently-sized workpiece.

23. The electrochemical processing chamber of claim 22 wherein the first virtual electrode unit comprises a first partition having a first section extending radially inwardly from the first wall and a lip defining a circular opening.

24. The electrochemical processing chamber of claim 22 wherein the first wall is carried by the first virtual electrode unit and is removable therewith as a unit when exchanging the first virtual electrode unit for the second virtual electrode unit.

25. The electrochemical processing chamber of claim 22 further comprising a flow distributor having a first fluid outlet associated with the first electrode compartment and a second fluid outlet associated with the second electrode compartment.

26. The electrochemical processing chamber of claim 25 wherein the first wall is carried by the first virtual electrode unit and the first wall has a lower edge releasably received in an annular recess in the flow distributor positioned between the first fluid outlet and the second fluid outlet.

27. The electrochemical processing chamber of claim 22 wherein the first virtual electrode comprises a central discharge opening through which fluid may flow.

28. The electrochemical processing chamber of claim 27 wherein the first virtual electrode receives an electrical potential via flow of an electrically conductive fluid over the first electrode and upwardly through the first virtual electrode.

29. The electrochemical processing chamber of claim 27 wherein the second virtual electrode comprises an annular opening through which fluid may flow.

30. The electrochemical processing chamber of claim 29 wherein the second virtual electrode receives an electrical potential via flow of an electrically conductive fluid over the second electrode and upwardly through the second virtual electrode.

31. The electrochemical processing chamber of claim 22 wherein the first virtual electrode receives a first electrical potential from the first electrode.

32. The electrochemical processing chamber of claim 31 wherein the second virtual electrode receives a second electrical potential from the second electrode.

33. The electrochemical processing chamber of claim 22 wherein the electrodes are anodes.

34. An electrochemical processing chamber, comprising:

a plurality of concentric walls defining a plurality of concentric annular electrode compartments, the walls being formed of a dielectric material;

a plurality of electrodes, each of the electrode compartments having at least one of the electrodes positioned therein;

a fluid distributor having a plurality of fluid channels, each of the electrode compartments being in fluid communication with at least one of the fluid channels; and

a first virtual electrode unit formed of a dielectric material, the first virtual electrode unit defining a plurality of flow conduits, with at least one of the flow conduits being in fluid communication with each of the electrode compartments, the first virtual electrode unit being exchangeable for a second virtual electrode unit, without modification of any of the electrodes, to adapt the processing chamber for treating a differently-sized workpiece.

35. The electrochemical processing chamber of claim 34 wherein the walls are coupled to the first virtual electrode unit and can be removed therewith as a unit.

36. The electrochemical processing chamber of claim 34 wherein the walls are carried by the fluid distributor and remain attached thereto when the virtual electrode unit is removed.

37. The electrochemical processing chamber of claim 34 wherein the virtual electrode unit comprises a plurality of partitions, with one partition being associated with each of the walls.

38. The electrochemical processing chamber of claim 37 wherein the plurality of partitions are joined to one another such that the virtual electrode unit may be exchanged as a unit.

39. The electrochemical processing chamber of claim 34 further comprising a second virtual electrode unit exchangeable for the first virtual electrode unit, each of the first and second virtual electrode units being adapted to adjoin the walls at the same radial distances from a center line of the processing chamber.

40. The electrochemical processing chamber of claim 34 an inner one of the flow conduits of the first virtual electrode unit defines a central discharge opening and each of the other flow conduits of the first virtual electrode unit defines concentric annular discharge openings.

41. The electrochemical processing chamber of claim 40 wherein each of the flow conduits defines a separately controllable virtual electrode.

42. The electrochemical processing chamber of claim 34 wherein each of the flow conduits defines a separately controllable virtual electrode.

43. The electrochemical processing chamber of claim 34 wherein the first virtual electrode unit comprises a plurality of partitions, each partition being having a first section and a lip, the first section being coupled to one of the walls and extending radially inwardly therefrom, the lip defining a circular opening.

44. The electrochemical processing chamber of claim 34 further comprising a flow distributor having a plurality of fluid conduits, with one fluid conduit being in fluid communication with each of the electrode compartments.

45. The electrochemical processing chamber of claim 44 wherein the walls are carried by the first virtual electrode unit and each of the walls has a lower edge releasably received in a separate annular recess in the flow distributor.

46. An electrochemical processing chamber, comprising:

a reaction vessel comprising:

a vessel wall defining an interior of the reaction vessel; and

first and second electrodes, the first electrode being spaced radially inwardly of the second electrode; and

a replaceable field shaping unit comprising:

a first wall removably received in the interior of the reaction vessel, the first wall being formed of a dielectric material and electrically separating a first electrode compartment from a second electrode compartment, the first electrode being positioned within the first electrode compartment and the second electrode being positioned within the second electrode compartment;

a virtual electrode unit comprising a first partition formed of a dielectric material and coupled to the first wall, the first partition defining a first virtual electrode in fluid communication with the first electrode compartment and defining, in part, a second virtual electrode in fluid communication with the second electrode compartment;

the replaceable field shaping unit being removable from the reaction vessel as a unit without necessitating modification of the reaction vessel.

47. The electrochemical processing chamber of claim 46 wherein the reaction vessel has an outer wall with an upper edge, an outer portion of the virtual electrode unit engaging the upper edge of the outer wall in defining the second electrode compartment.

48. An electrochemical processing chamber, comprising:

a replaceable first field shaping unit comprising:

a plurality of concentric walls electrically separating a plurality of concentric electrode compartments; and

a virtual electrode unit comprising a plurality of partitions, each of the walls having a separate partition coupled thereto, the virtual electrode unit defining a plurality of virtual electrodes, with a separate virtual electrode in fluid communication with each of the electrode compartments; and

a reaction vessel comprising:

a vessel wall defining an interior receiving the walls of the first replaceable field shaping unit; and

a plurality of electrodes, at least one of the electrodes being positioned in each of the electrode compartments;

the replaceable first field shaping unit being removable from the reaction vessel as a unit for replacement with a second field shaping unit, without necessitating modification of any of the plurality of electrodes, to adapt the electrochemical processing chamber for use with a differently-sized workpiece.

49. The electrochemical processing chamber of claim 48 wherein the second field shaping unit comprises:

a plurality of concentric walls adapted to electrically separate a plurality of concentric electrode compartments when the plurality of walls is installed in the interior of the reaction vessel; and

a virtual electrode unit comprising a plurality of partitions, each of the walls having a separate partition coupled thereto, the virtual electrode unit defining a plurality of virtual electrodes, with a separate virtual electrode in fluid communication with each of the electrode compartments when the second field shaping unit replaces the first field shaping unit;

a relative arrangement of the virtual electrodes of the second replaceable field shaping unit being different from a relative arrangement of the virtual electrodes of the first field shaping unit, thereby facilitating adaptation of the electrochemical processing chamber for use with the differently-sized workpiece.

50. The electrochemical processing chamber of claim 48 further comprising a flow distributor having a plurality of fluid conduits, with one fluid conduit being in fluid communication with each of the electrode compartments.

51. The electrochemical processing chamber of claim 50 wherein each of the walls has a lower edge releasably received in a separate annular recess in the flow distributor.

52. An electrochemical processing system, comprising:

a reaction vessel having an outer wall and a plurality of concentric, annular electrodes, adjacent electrodes being spaced from one another to define annular wall-receiving spaces therebetween;

a replaceable first field shaping unit comprising:

a plurality of concentric walls formed of a dielectric material and having upper edges, the walls being positioned with respect to one another to be received in the wall-receiving spaces between the electrodes to define a plurality of concentric electrode compartments with at least one of the electrodes being received within each of the electrode compartments; and

a first virtual electrode unit formed of a dielectric material and coupled to the walls adjacent their upper edges, the first virtual electrode unit being adapted to abut the outer wall of the reaction vessel, the first virtual electrode unit defining a first set of discharge openings having predefined relative positions, each of the discharge openings of the first set being adapted for fluid communication with one of the electrode compartments, each discharge opening of the first set defining a position of a virtual electrode; and

a replaceable second field shaping unit comprising:

a plurality of concentric walls formed of a dielectric material and having upper edges, the walls being positioned with respect to one another to be received in the wall-receiving spaces between the electrodes to define a plurality of concentric electrode compartments with at least one of the electrodes being received within each of the electrode compartments; and

a second virtual electrode unit formed of a dielectric material and coupled to the walls adjacent their upper edges, the second virtual electrode unit being adapted to abut the outer wall of the reaction vessel, the second virtual electrode unit defining a second set of discharge openings having predefined relative positions, the relative positions of the discharge openings of the second set differing from the relative positions of the discharge openings of the first set, each of the discharge openings of the second set being adapted for fluid communication with one of the electrode compartments, each discharge opening of the second set defining a position of an virtual electrode;

the first field shaping unit and the second field shaping unit each being adapted for installation in and removal from the reaction vessel as a unit.

53. The electrochemical processing chamber of claim 52 wherein the reaction vessel further comprises a flow distributor adapted to deliver processing fluid to each of the electrode compartments defined when the first field shaping unit or the second field shaping unit is installed in the reaction vessel.

54. The electrochemical processing chamber of claim 53 wherein the flow distributor includes a plurality of spaced-apart annular recesses, each of the walls of each of the field shaping units having a lower edge sized to be releasably received in one of the annular recesses when the field shaping unit is installed in the reaction vessel.

55. The electrochemical processing chamber of claim 53 further comprising a first contact assembly adapted to support a first workpiece above the electrodes in a predefined position with respect to the virtual electrodes of the first field shaping unit.

56. The electrochemical processing chamber of claim 55 further comprising a second contact assembly adapted to support a second workpiece above the electrodes in a predefined position with respect to the virtual electrodes of the second field shaping unit.

57. An electrochemical processing chamber, comprising:

a reaction vessel having an interior;

an electrode received in the interior of the reaction vessel;

a first virtual electrode unit comprising a dielectric material and defining a first virtual electrode in fluid communication with the electrode; and

a first contact assembly adapted to support workpiece in a predetermined position with respect to the first virtual electrode;

the first contact assembly being exchangeable for a second contact assembly and the first virtual electrode unit being exchangeable for a second virtual electrode unit, without necessitating modification of the electrode, to adapt the processing chamber for treating a differently-sized workpiece.

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