

Fig. 1
(Prior Art)

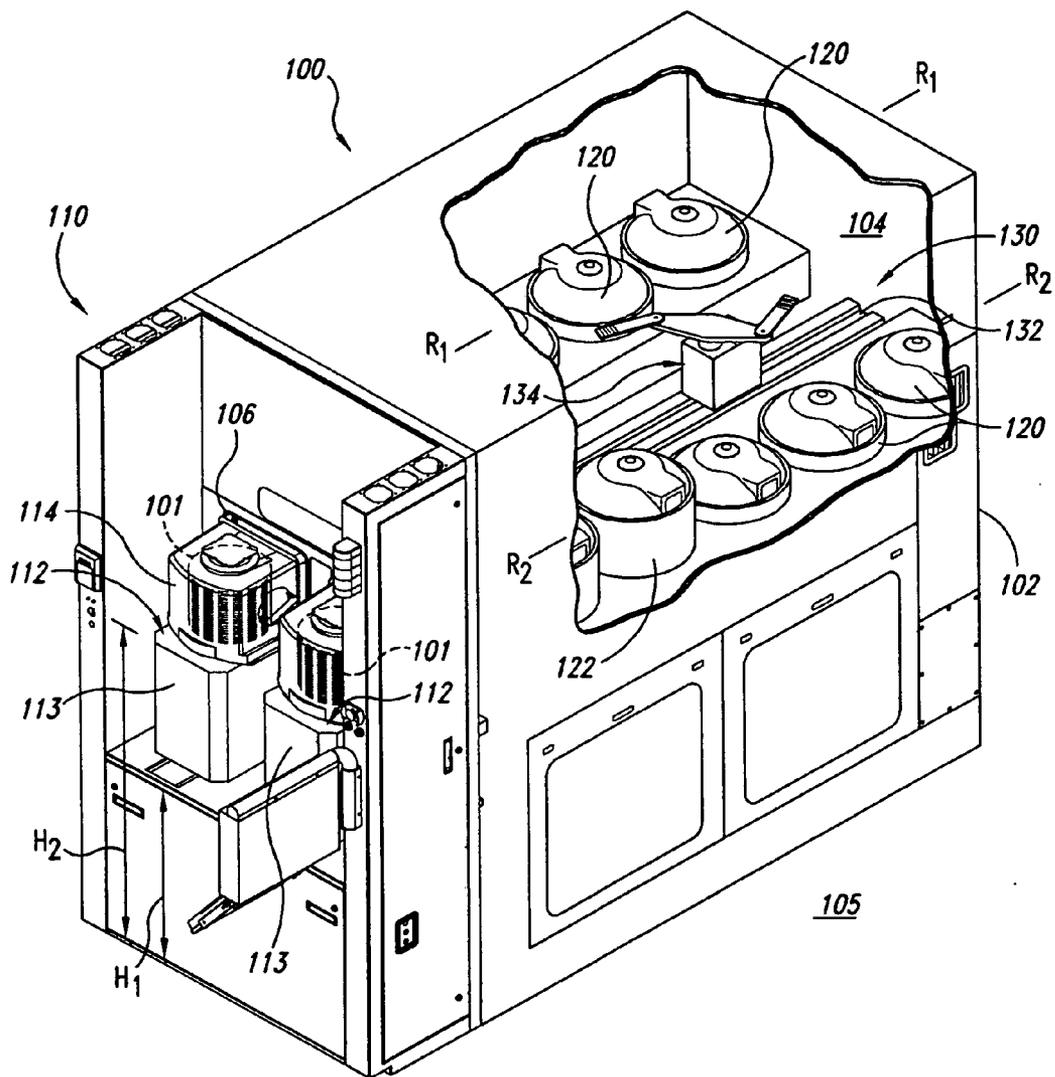


Fig. 2

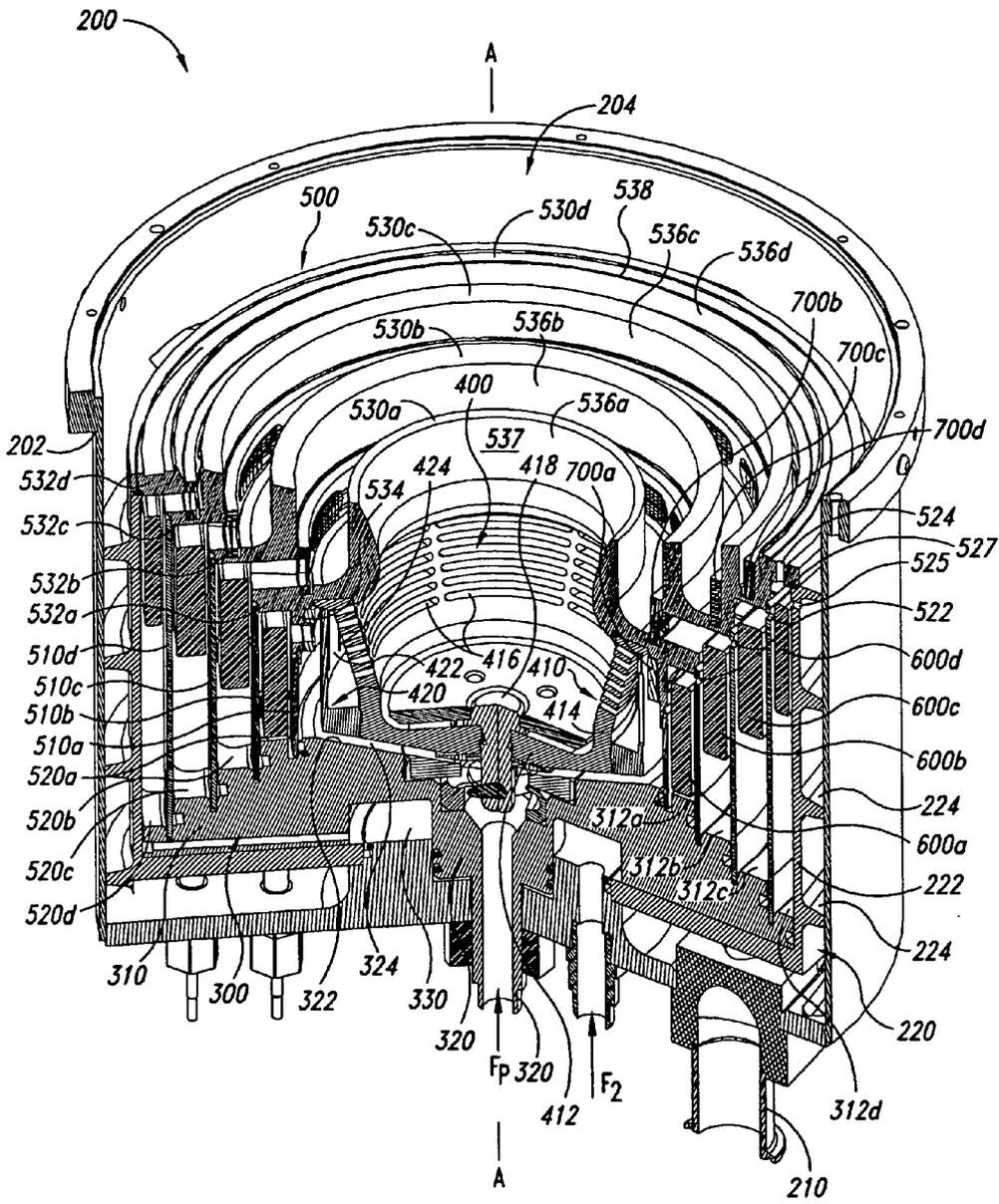
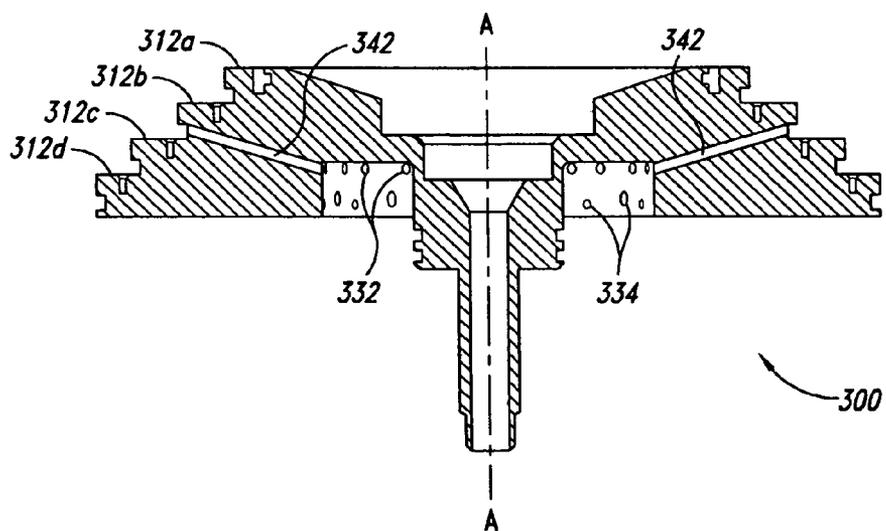
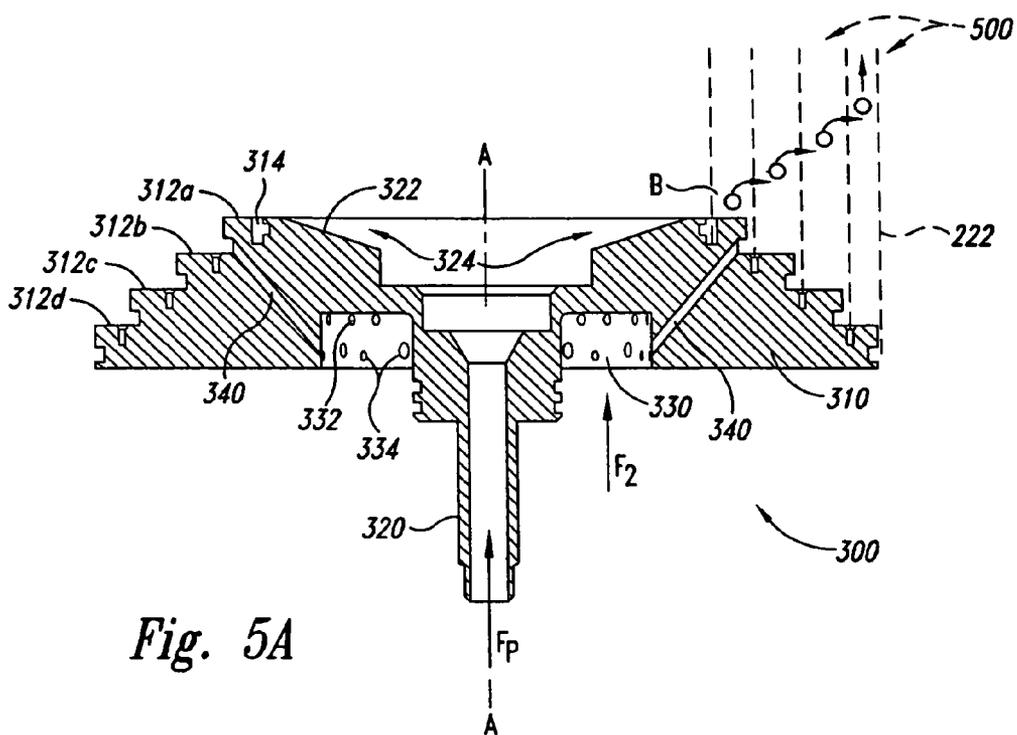


Fig. 4



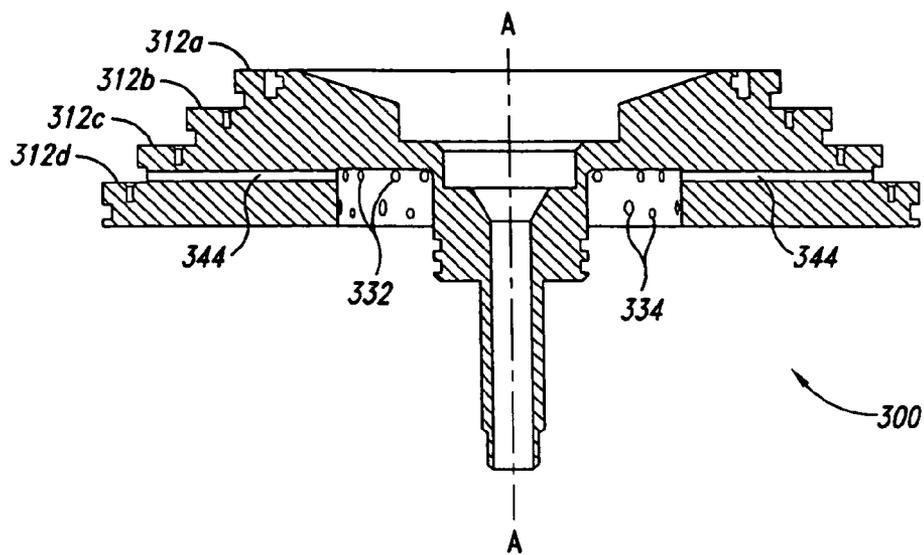


Fig. 5C

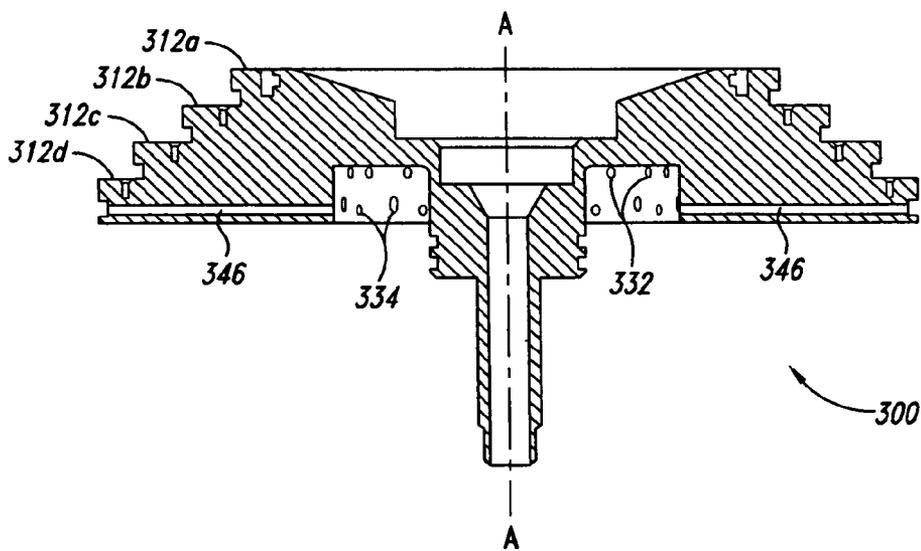


Fig. 5D

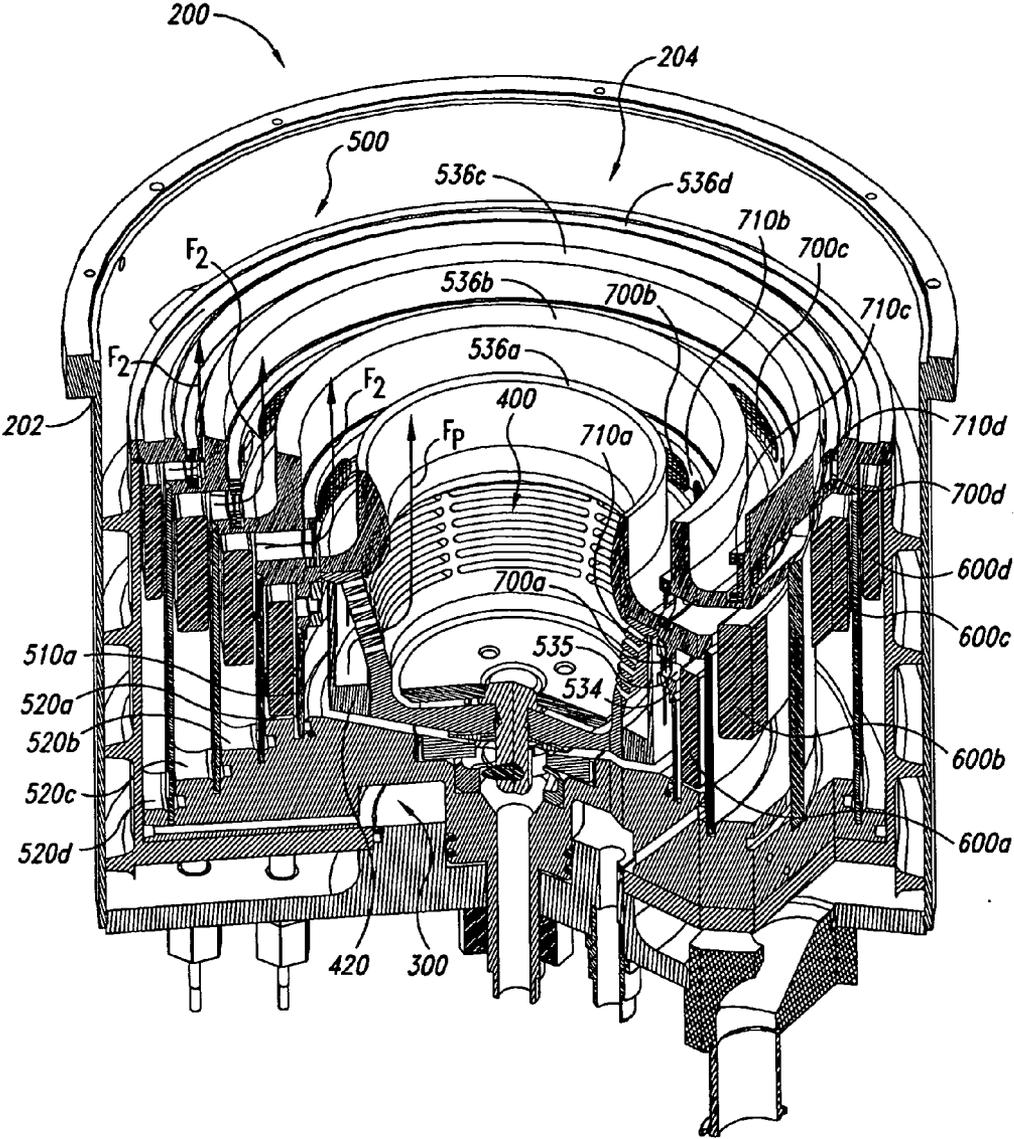


Fig. 6

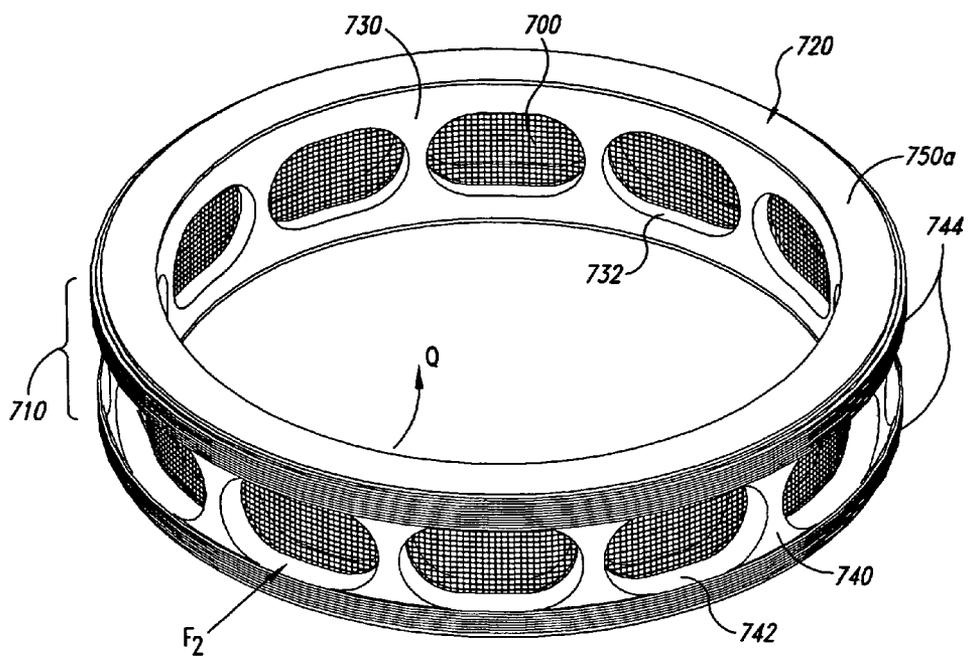


Fig. 7A

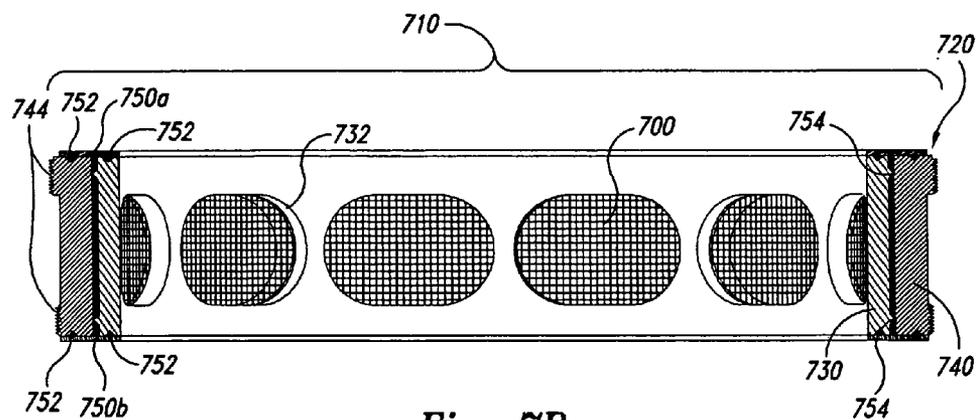


Fig. 7B

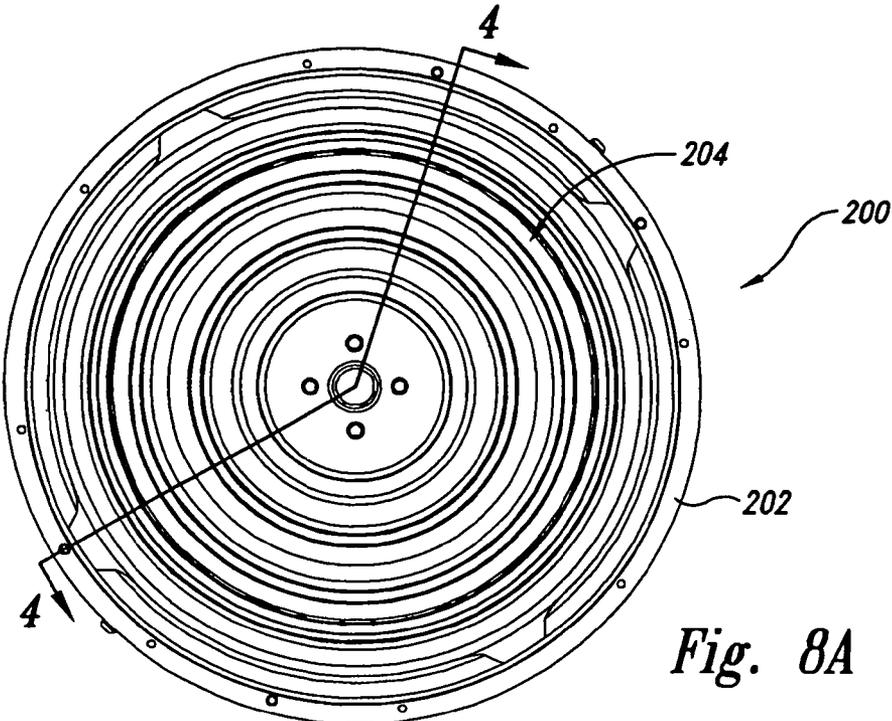


Fig. 8A

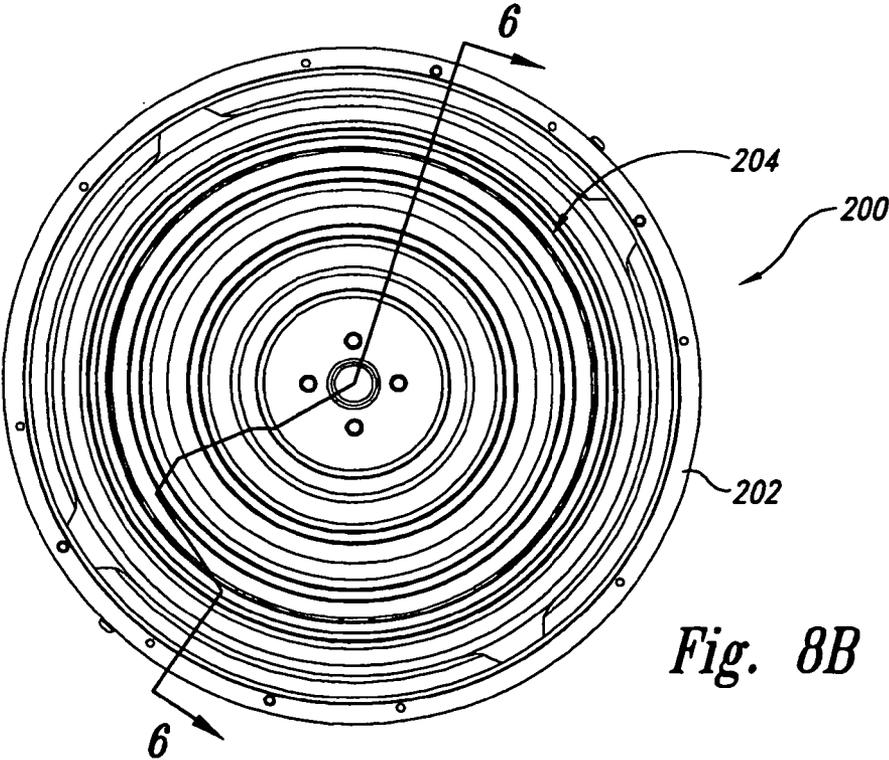


Fig. 8B

**APPARATUS AND METHODS FOR
ELECTROCHEMICAL PROCESSING OF
MICROELECTRONIC WORKPIECES**

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 on Jun. 1, 2001, 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 on Jun. 1, 2001, 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 on Jun. 1, 2001, and identified by Perkins Coie Docket No. 29195.8155US00;

[0005] (d) U.S. patent application entitled "ADAPTABLE ELECTROCHEMICAL PROCESSING CHAMBER," filed on Jun. 1, 2001, and identified by Perkins Coie LLP Docket No. 29195.8156US00;

[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 on Jun. 1, 2001, 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," one 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 subject 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] Another concern of existing plating tools is that the diffusion layer in the electroplating solution adjacent to the surface of the workpiece 5 can be disrupted by gas bubbles or particles. For example, bubbles can be introduced to the plating solution by the plumbing and pumping system of the processing equipment, or they can evolve from inert anodes. Consumable anodes are often used to prevent or reduce the involvement of gas bubbles in the electroplating solution, but these anodes erode and they can form a passivated film surface that must be maintained. Consumable anodes, moreover, often generate particles that can be carried in the plating solution. As a result, gas bubbles and/or particles can flow to the surface of the workpiece 5, which disrupts the uniformity and affects the quality of the plated layer.

[0016] Still another challenge of plating uniform layers is providing a desired electrical field at the surface of the workpiece 5. The distribution of electrical current in the plating solution is a function of the uniformity of the seed layer across the contact surface, the configuration/condition of the anode, and the configuration of the chamber. However, the current density profile on the plating surface can change. For example, the current density profile typically changes during a plating cycle because plating material covers the seed layer, or it can change over a longer period of time because the shape of consumable anodes changes as they erode and the concentration of constituents in the plating solution can change. Therefore, it can be difficult to maintain a desired current density at the surface of the workpiece 5.

SUMMARY

[0017] The present invention is directed toward reaction vessels for electrochemical processing of microelectronic workpieces, processing stations including such reaction vessels, and methods for using these devices. Several embodiments of reaction vessels in accordance with the invention solve the problem of providing a desired mass transfer at the workpiece by configuring the electrodes so that a primary flow guide and/or a field shaping unit in the reaction vessel direct a substantially uniform primary fluid flow toward the workpiece. Additionally, field shaping units in accordance

with several embodiments of the invention create virtual electrodes such that the workpiece is shielded from the electrodes. This allows for the use of larger electrodes to increase electrode life, eliminates the need to "burn-in" electrodes to decrease downtime, and/or provides the capability of manipulating the electrical field by merely controlling the electrical current to one or more of the electrodes in the vessel. Furthermore, additional embodiments of the invention include interface members in the reaction vessel that inhibit particulates, bubbles and other undesirable matter in the reaction vessel from contacting the workpiece to enhance the uniformity and the quality of the finished surface on the workpieces. The interface members can also allow two different types of fluids to be used in the reaction vessel, such as a catholyte and an anolyte, to reduce the need to replenish additives as often and to add more flexibility to designing electrodes and other components in the reaction vessel.

[0018] In one embodiment of the invention, a reaction vessel includes an outer container having an outer wall, a first outlet configured to introduce a primary fluid flow into the outer container, and at least one second outlet configured to introduce a secondary fluid flow into the outer container separate from the primary fluid flow. The reaction vessel can also include a field shaping unit in the outer container and at least one electrode. The field shaping unit can be a dielectric assembly coupled to the second outlet to receive the secondary flow and configured to contain the secondary flow separate from the primary flow through at least a portion of the outer container. The field shaping unit also has at least one electrode compartment through which the secondary flow can pass separately from the primary flow. The electrode is positioned in the electrode compartment.

[0019] In a particular embodiment, the field shaping unit has a compartment assembly having a plurality of electrode compartments and a virtual electrode unit. The compartment assembly can include a plurality of annular walls including an inner or first annular wall centered on a common axis and an outer or second annular wall concentric with the first annular wall and spaced radially outward. The annular walls of the field shaping unit can be positioned inside of outer wall of the outer container so that an annular space between the first and second walls defines a first electrode compartment and an annular space between the second wall and the outer wall defines a second electrode compartment. The reaction vessel of this particular embodiment can have a first annular electrode in the first electrode compartment and/or a second annular electrode in the second electrode compartment.

[0020] The virtual electrode unit can include a plurality of partitions that have lateral sections attached to corresponding annular walls of the electrode compartment and lips that project from the lateral sections. In one embodiment, the first partition has an annular first lip that defines a central opening, and the second partition has an annular second lip surrounding the first lip that defines an annular opening.

[0021] In additional embodiments, the reaction vessel can further include a distributor coupled to the outer container and a primary flow guide in the outer container. The distributor can include the first outlet and the second outlet such that the first outlet introduces the primary fluid flow into the primary flow guide and the second outlet introduces the secondary fluid flow into the field shaping unit separately from the primary flow. The primary flow guide can condition the pri-

mary flow for providing a desired fluid flow to a workpiece processing site. In one particular embodiment, the primary flow guide directs the primary flow through the central opening of the first annular lip of the first partition. The secondary flow is distributed to the electrode compartments of the field shaping unit to establish an electrical field in the reaction vessel.

[0022] In the operation of one embodiment, the primary flow can pass through a first flow channel defined, at least in part, by the primary flow guide and the lip of the first partition. The primary flow can be the dominant flow through the reaction vessel so that it controls the mass transfer at the workpiece. The secondary flow can generally be contained within the field shaping unit so that the electrical field(s) of the electrode(s) are shaped by the virtual electrode unit and the electrode compartments. For example, in the embodiment having first and second annular electrodes, the electrical effect of the first electrode can act as if it is placed in the central opening defined by the lip of the first partition, and the electrical effect of the second electrode can act as if it is placed in the annular opening between the first and second lips. The actual electrodes, however, can be shielded from the workpiece by the field shaping unit such that the size and shape of the actual electrodes does not affect the electrical field perceived by the workpiece.

[0023] One feature of several embodiments is that the field shaping unit shields the workpiece from the electrodes. As a result, the electrodes can be much larger than they could without the field shaping unit because the size and configuration of the actual electrodes does not appreciably affect the electrical field perceived by the workpiece. This is particularly useful when the electrodes are consumable anodes because the increased size of the anodes prolongs their life, which reduces downtime for servicing a tool. Additionally, this reduces the need to "burn-in" anodes because the field shaping element reduces the impact that films on the anodes have on the shape of the electrical field perceived by the workpiece. Both of these benefits significantly improve the operating efficiency of the reaction vessel.

[0024] Another feature of several embodiments of the invention is that they provide a uniform mass transfer at the surface of the workpiece. Because the field shaping unit separates the actual electrodes from the effective area where they are perceived by the workpiece, the actual electrodes can be configured to accommodate internal structure that guides the flow along a more desirable flow path. For example, this allows the primary flow to flow along a central path. Moreover, a particular embodiment includes a central primary flow guide that projects the primary flow radially inward along diametrically opposed vectors that create a highly uniform primary flow velocity in a direction perpendicular to the surface of the workpiece.

[0025] The reaction vessel can also include an interface member carried by the field shaping unit downstream from the electrode. The interface member can be in fluid communication with the secondary flow in the electrode compartment. The interface member, for example, can be a filter and/or an ion-membrane. In either case, the interface member can inhibit particulates (e.g., particles from an anode) and bubbles in the secondary flow from reaching the surface of the workpiece to reduce non-uniformities on the processed surface. This accordingly increases the quality of the surface of

the workpiece. Additionally, in the case of an ion-membrane, the interface member can be configured to prevent fluids from passing between the secondary flow and the primary flow while allowing preferred ions to pass between the flows. This allows the primary flow and the secondary flow to be different types of fluids, such as a catholyte and an anolyte, which reduces the need to replenish additives as often and adds more flexibility to designing electrodes and other features of the reaction vessel.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] FIG. 1 is a schematic diagram of an electroplating chamber in accordance with the prior art.

[0027] 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.

[0028] 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.

[0029] FIG. 4 is an isometric view showing a cross-sectional portion of a processing chamber taken along line 4-4 of FIG. 8A.

[0030] FIGS. 5A-5D are cross-sectional views of a distributor for a processing chamber in accordance with an embodiment of the invention.

[0031] FIG. 6 is an isometric view showing a different cross-sectional portion of the processing chamber of FIG. 4 taken along line 6-6 of FIG. 8B.

[0032] FIG. 7A is an isometric view of an interface assembly for use in a processing chamber in accordance with an embodiment of the invention.

[0033] FIG. 7B is a cross-sectional view of the interface assembly of FIG. 7A.

[0034] FIGS. 8A and 8B are top plan views of a processing chamber that provide a reference for the isometric, cross-sectional views of FIGS. 4 and 6, respectively.

DETAILED DESCRIPTION

[0035] 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. 2-8B.

[0036] 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 are then described with reference to FIGS. 4-8B.

[0037] A. Selected Embodiments of Integrated Tools with Electrochemical Processing Stations

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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 7) 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.

[0043] 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. 4-8B.

[0044] 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.

[0045] B. Selected Embodiments of Reaction Vessels for use in Electrochemical Processing Chambers

[0046] FIGS. 4-8B illustrate several embodiments of reaction vessels 204 for use in the processing chamber 200. As explained above, the housing 202 carries the reaction vessel 204. The housing 202 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.

[0047] The particular embodiment of the reaction vessel 204 shown in FIG. 4 can include a distributor 300 for receiv-

ing 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.

[0048] FIGS. 5A-5D 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. 5A, the distributor **300** can include a body **310** having a plurality of annular steps **312** (identified individually by reference numbers **312a-d**) and annular grooves **314** in the steps **312**. The outermost step **312d** is radially inward of the outer wall **222** (shown in broken lines) of the outer container **220** (FIG. 4), and each of the interior steps **312a-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. 4) 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.

[0049] FIGS. 5A-5D further illustrate one configuration of channels through the body **310** of the distributor **300**. Referring to FIG. 5A, a number of first channels **340** extend from some of the lower orifices **334** to openings at the riser of the first step **312a**. FIG. 5B shows a number of second channels **342** extending from the upper orifices **332** to openings at the

riser of the second step **312b**, and FIG. 5C shows a number of third channels **344** extending from the upper orifices **332** to openings at the riser of the third step **312c**. Similarly, FIG. 5D illustrates a number of fourth channels **346** extending from the lower orifices **334** to the riser of the fourth step **312d**.

[0050] The particular embodiment of the channels **340-346** in FIGS. 5A-5D 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 **312a** can sequentially cascade through the compartments over the second and third steps **312b-c**, and then be removed from the compartment above the fourth step **312d**. The first channel **340** (FIG. 5A) 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 **312a** 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 **312a** 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 **312c**. Thus, the fourth channel **346** extends from the lower orifices **334** to the fourth step **312d**.

[0051] Referring again to FIG. 4, 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**.

[0052] 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.

[0053] FIG. 4 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 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. This allows easy access to the electrode compartments 520 and/or quick removal of the field shaping unit 500 to change the shape of the electric field.

[0054] 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 FIG. 4, the field shaping unit 500 has a first electrode compartment 520*a* defined by a first wall 510*a* and a second wall 510*b*, a second electrode compartment 520*b* defined by the second wall 510*b* and a third wall 510*c*, a third electrode compartment 520*c* defined by the third wall 510*c* and a fourth wall 510*d*, and a fourth electrode compartment 520*d* defined by the fourth wall 510*d* and the outer wall 222 of the container 220. The walls 510*a-d* of this embodiment are concentric annular dividers that 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. 5A-5D. 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.

[0055] 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*. As explained in U.S. application Ser. Nos. 60/206,661, 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.

[0056] 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.

[0057] The field shaping unit 500 can also include a virtual electrode unit coupled to the walls 510 of the compartment assembly for individually shaping the electrical fields produced by the electrodes 600. In the particular embodiment illustrated in FIG. 4, the virtual electrode unit includes first-fourth partitions 530*a-530d*, 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 not be connected to 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.

[0058] 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 that are welded 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. 4, the partitions 530*a-d* are annular horizontal members, and each of the lips 536*a-d* are annular vertical members arranged concentrically about the common axis.

[0059] The walls **510** and the partitions **530a-d** are generally dielectric materials that contain the second flow F_2 of the processing solution for shaping the electric fields generated by the electrodes **600a-d**. The second flow F_2 , for example, can pass (a) through each of the electrode compartments **520a-d**, (b) between the individual partitions **530a-d**, and then (c) upward through the annular openings between the lips **536a-d**. In this embodiment, the secondary flow F_2 through the first electrode compartment **520a** 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 **520b-d** can join the primary flow F_p beyond the top edges of the lips **536a-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. The fluid in the secondary flow F_2 can be prevented from flowing out of the electrode compartments **520a-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**. The field shaping unit **500** can have other configurations that are different than the embodiment shown in FIG. 4. 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 **600a-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 an 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.

[0060] An embodiment of reaction vessel **204** shown in FIG. 4 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 **510a** of the field shaping unit **500**; the primary flow guide **400**; and the interior surface **537** of the first lip **536a**. 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 the rotation of the workpiece can accordingly be controlled to dominate the mass transfer of electroprocessing medium at the workpiece.

[0061] 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** 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 **600a-d** to create "virtual electrodes" at the top of the openings defined by the lips **536a-d** of the partitions. In this particular embodiment, the central opening inside the first lip **536a** defines a first virtual electrode, the annular opening between the first and second lips **536a-b** defines a second virtual electrode, the annular opening between the second and third lips **536b-c** defines a third virtual electrode, and the annular opening between the third and fourth lips **536c-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 **600a-d** so that the effect of the electrodes **600a-d** acts as if they are placed between the top edges of the lips **536a-d**. This allows the actual electrodes **600a-d** to be isolated from the primary fluid flow, which can provide several benefits as explained in more detail below.

[0062] An additional embodiment of the processing chamber **200** includes at least one interface member **700** (identified individually by reference numbers **700a-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.

[0063] FIG. 6 is another isometric view of the reaction vessel **204** of FIG. 4 showing a cross-sectional portion taken along a different cross-section. More specifically, the cross-section of FIG. 4 is shown in FIG. 8A and the cross-section of FIG. 6 is shown in FIG. 8B. Returning now to FIG. 6, this illustration further shows one embodiment for configuring a plurality of interface members **700a-d** relative to the partitions **530a-d** of the field shaping unit **500**. A first interface member **700a** can be attached to the skirt **534** of the first partition **530a** so that a first portion of the secondary flow F_2 flows past the first electrode **600a**, through an opening **535** in the skirt **534**, and then to the first interface member **700a**. Another portion of the secondary flow F_2 can flow past the second electrode **600b** to the second interface member **700b**. Similarly, portions of the secondary flow F_2 can flow past the third and fourth electrodes **600c-d** to the third and fourth interface members **700c-d**.

[0064] When the interface members **700a-d** are filters or ion-membranes that allow the fluid in the secondary flow F_2 to pass through the interface members **700a-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 **520a** can

pass through the opening 535 in the skirt 534 and the first interface member 700a, and then into a plenum between the first wall 510a 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 520b-d and then through the annular openings between the lips 536a-d. The second-fourth interface members 700b-d can accordingly be attached to the field shaping unit 500 downstream from the second-fourth electrodes 600b-d.

[0065] In the particular embodiment shown in FIG. 6, the second interface member 700b is positioned vertically between the first and second partitions 530a-b, the third interface member 700c is positioned vertically between the second and third partitions 530b-c, and the fourth interface member 700d is positioned vertically between the third and fourth partitions 530c-d. The interface assemblies 710a-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 510a-d (FIG. 4). This prevents aggregations of bubbles that could potentially disrupt the electrical field from an individual electrode.

[0066] FIGS. 7A and 7B 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. 7A). 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 536a-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 750a extending around the top of the frames 730 and 740 and a bottom band 750b extending around the bottom of the frames 730 and 740. The top and bottom bands 750a-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 520a-d (FIG. 6).

[0067] 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.

[0068] 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 on-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.

[0069] 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 thus 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.

[0070] 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.

1-90. (canceled)

91. A reactor for electrochemical processing of microelectronic workpieces, comprising:

- a reaction vessel;
- a first electrode compartment and a second electrode compartment concentric with the first electrode compartment, wherein the first and second electrode compartments are in the reaction vessel;
- a first electrode in the first electrode compartment and a second electrode in the second electrode compartment;
- a dielectric section extending laterally inward into the reaction vessel to shield at least a portion of a workpiece from an electrical field produced by at least one of the electrodes; and

an interface member in the reaction vessel between the dielectric section and at least one of the first and second electrodes, wherein the interface member is configured to prevent selected matter in the processing fluid from passing to the workpiece.

92. The reactor of claim 91 wherein the interface member comprises an ion-membrane through which selected ions can pass.

93. The reactor of claim 92 wherein the ion-membrane comprises a perfluorinated membrane.

94. The reactor of claim 91 wherein the interface member comprises a filter.

95. The reactor of claim 94 wherein the filter comprises a porous member.

96. The reactor of claim 91 wherein the first electrode comprises a first annular conductive member and the second electrode comprises a second annular conductive member, and wherein the first annular conductive member is the innermost electrode in the reaction vessel.

97. The reactor of claim 91 wherein the dielectric section comprises a first lateral dielectric section of a field shaping unit in the reaction vessel, and the first lateral dielectric section of the field shaping unit is positioned over the first electrode.

98. The reactor of claim 97 wherein the field shaping unit further comprises a second lateral dielectric section positioned over the second electrode.

99. The reactor of claim 91 wherein the dielectric section is positioned over an outer concentric electrode.

100. A reactor for electrochemically processing a micro-electronic workpiece, comprising:

- a reaction vessel having a workpiece processing zone;
- a first electrode compartment in the reaction vessel below the processing zone;
- a second electrode compartment in the reaction vessel below the processing zone and concentric with the first electrode compartment;
- a dielectric section extending radially inward into the reaction vessel;
- an interface member in the reaction vessel configured to prevent selected matter from passing from the electrode compartments to the processing zone; and
- a first electrode in the first electrode compartment and a second electrode in the second electrode compartment.

101. The reactor of claim 100 wherein the interface member comprises an ion-membrane through which selected ions can pass.

102. The reactor of claim 101 wherein the ion-membrane comprises a perfluorinated membrane.

103. The reactor of claim 100 wherein the interface member comprises a filter.

104. The reactor of claim 103 wherein the filter comprises a porous member.

105. The reactor of claim 100 wherein the first electrode comprises a first annular conductive member and the second electrode comprises a second annular conductive member, and wherein the first annular conductive member is the innermost electrode in the reaction vessel.

106. The reactor of claim 100 wherein the dielectric section comprises a first lateral dielectric section of a field shaping

unit in the reaction vessel, and the first lateral dielectric section of the field shaping unit is positioned over the first electrode.

107. The reactor of claim 106 wherein the field shaping unit further comprises a second lateral dielectric section positioned over the second electrode.

108. The reactor of claim 100 wherein the dielectric section is positioned over an outer concentric electrode.

109. A reactor for electrochemical processing of micro-electronic workpieces, comprising:

- a reaction vessel having a workpiece processing zone;
- a first electrode compartment in the reaction vessel located below the processing zone;
- a second electrode compartment in the reaction vessel located below the processing zone and concentric with the first electrode compartment;
- a first electrode in the first electrode compartment and a second electrode in the second electrode compartment;
- a dielectric section extending laterally inward into the reaction vessel; and
- an ion-membrane in the reaction vessel between the processing zone and at least one of the first and second electrodes, wherein the ion-membrane is configured such that selected ions can pass through the ion-membrane.

110. The reactor of claim 109 wherein the ion-membrane comprises a perfluorinated membrane that is permeable to copper ions.

111. The reactor of claim 109 wherein the ion-membrane is impermeable to processing fluid.

112. A reactor for electrochemically processing micro-electronic workpieces, comprising:

- a reaction vessel having a weir;
- a first electrode compartment and a second electrode compartment concentric with the first electrode compartment, wherein the first and second electrode compartments are in the reaction vessel and below the weir;
- a first electrode in the first electrode compartment and a second electrode in the second electrode compartment;
- a field shaping unit in the reaction vessel configured to obstruct at least a portion of a workpiece at the weir from at least a portion of at least one of the first and second electrodes; and
- an interface member in the reaction vessel between the weir and at least one of the first and second electrodes, wherein the interface member is configured to prevent selected matter in the processing fluid from passing to the weir.

113. A reactor for electrochemically processing micro-electronic workpieces, comprising:

- a reaction vessel having a workpiece processing zone;
- a plurality of electrode compartments in the reaction vessel and below the processing zone;
- a first electrode in one of the electrode compartments and a second electrode in another of the electrode compartments;

means for shaping an electrical field in the reaction vessel by shielding at least a portion of a workpiece at the workpiece processing zone from at least a portion of an electrical field generated by at least one of first electrode and/or the second electrode; and

means for preventing selected matter in the processing fluid from passing from the first and second electrodes to the processing zone.

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