US 20050034999A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2005/0034999 A1**
Lee et al. (43) **Pub. Date: Feb. 17, 2005**

(54) **METHODS AND APPARATUS FOR ELECTRICALLY AND/OR CHEMICALLY-MECHANICALLY REMOVING CONDUCTIVE MATERIAL FROM A MICROELECTRONIC SUBSTRATE**

(76) Inventors: **Whonchee Lee**, Boise, ID (US); **Scott G. Meikle**, Boise, ID (US); **Scott E. Moore**, Meridian, ID (US)

Correspondence Address:
PERKINS COIE LLP
PATENT-SEA
P.O. BOX 1247
SEATTLE, WA 98111-1247 (US)

(21) Appl. No.: **10/926,202**

(22) Filed: **Aug. 24, 2004**

Related U.S. Application Data

(60) Division of application No. 09/888,002, filed on Jun. 21, 2001, which is a continuation-in-part of application No. 09/651,779, filed on Aug. 30, 2000.

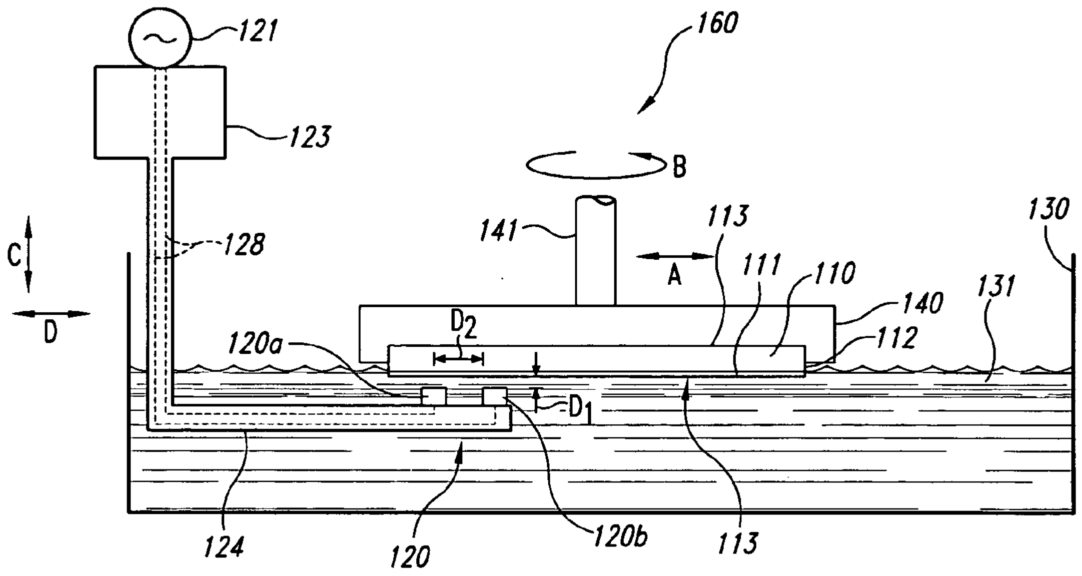
Publication Classification

(51) **Int. Cl.**^{7} **H01L 29/00**

(52) **U.S. Cl.** **205/640**

(57) **ABSTRACT**

A method and apparatus for removing conductive material from a microelectronic substrate. In one embodiment, a support member supports a microelectronic substrate relative to a material removal medium, which can include first and second electrodes and a polishing pad. One or more electrolytes are disposed between the electrodes and the microelectronic substrate to electrically link the electrodes to the microelectronic substrate. The electrodes are then coupled to a source of varying current that electrically removes the conductive material from the substrate. The microelectronic substrate and/or the electrodes can be moved relative to each other to position the electrodes relative to a selected portion of the microelectronic substrate, and/or to polish the microelectronic substrate. The material removal medium can remove gas formed during the process from the microelectronic substrate and/or the electrodes. The medium can also have different first and second electrical characteristics to provide different levels of electrical coupling to different regions of the microelectronic substrate.



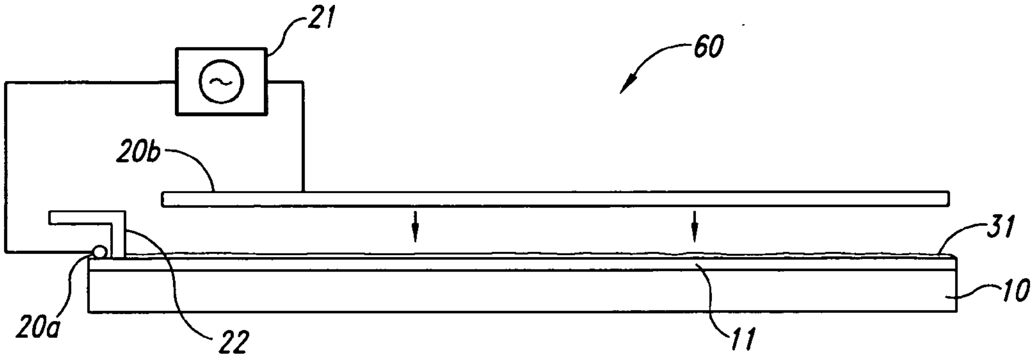


Fig. 1
(Prior Art)

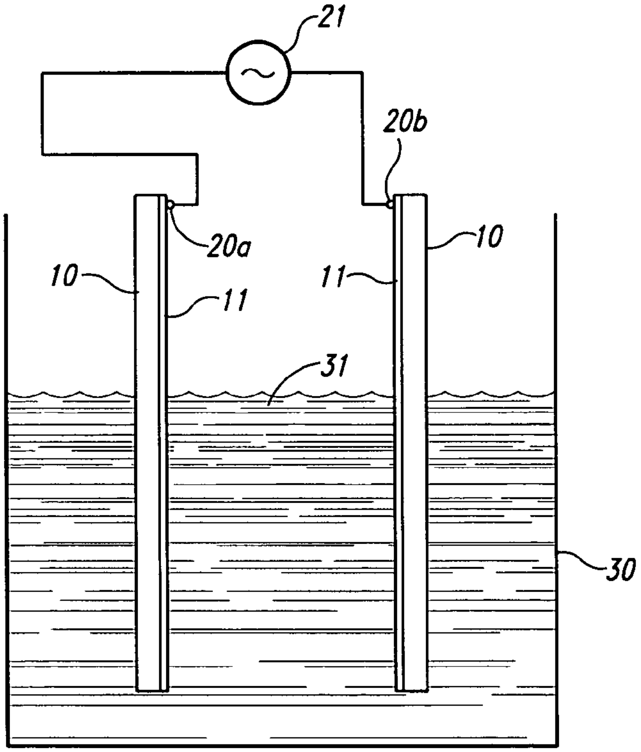
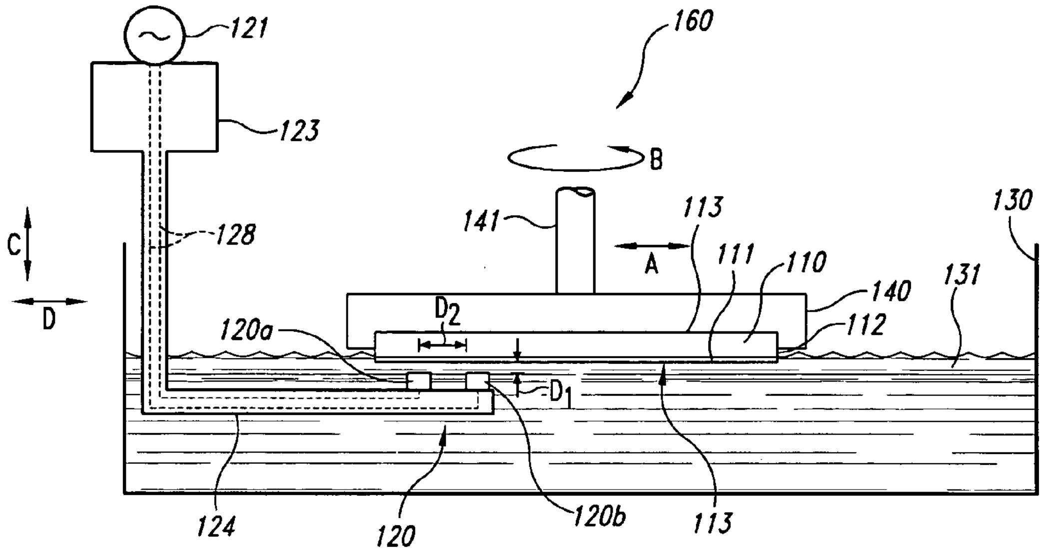


Fig. 2
(Prior Art)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120b
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Fig. 3

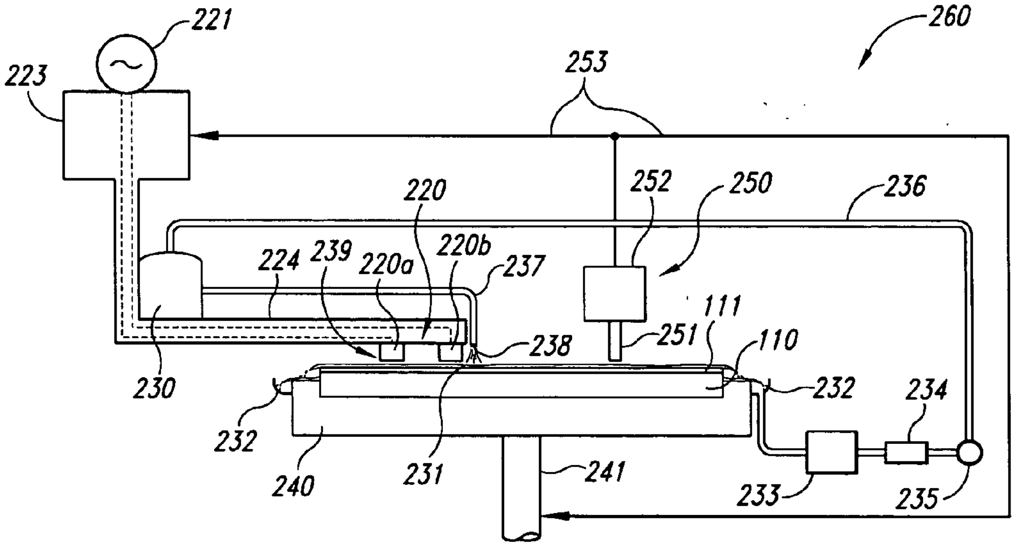
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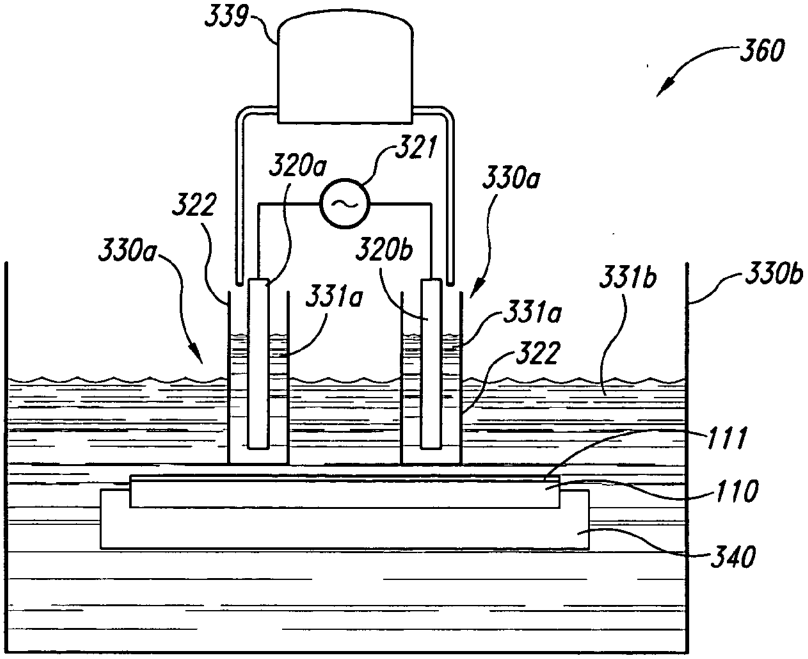
Fig. 4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321
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Fig. 5

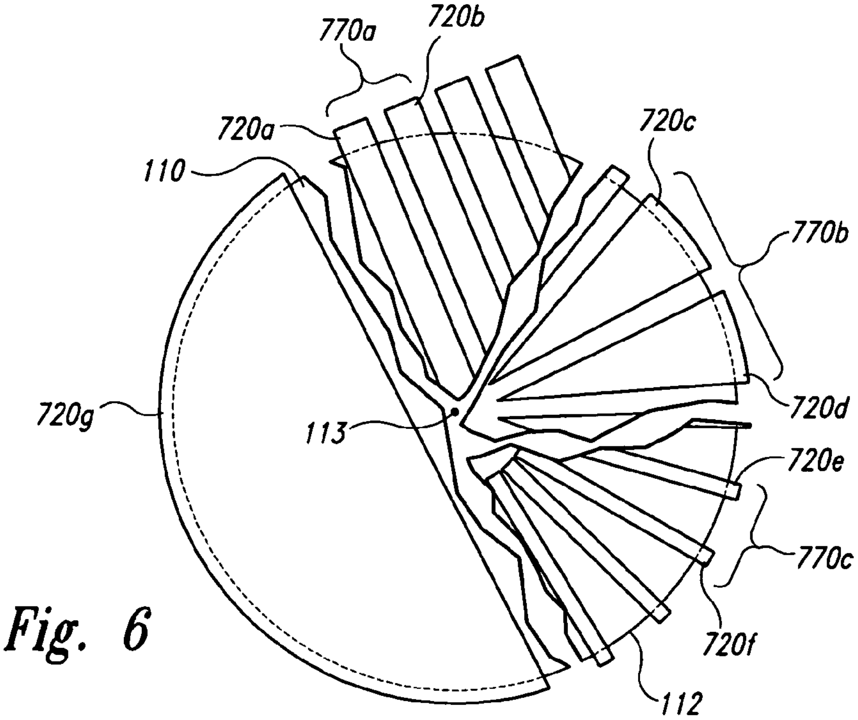
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Fig. 6

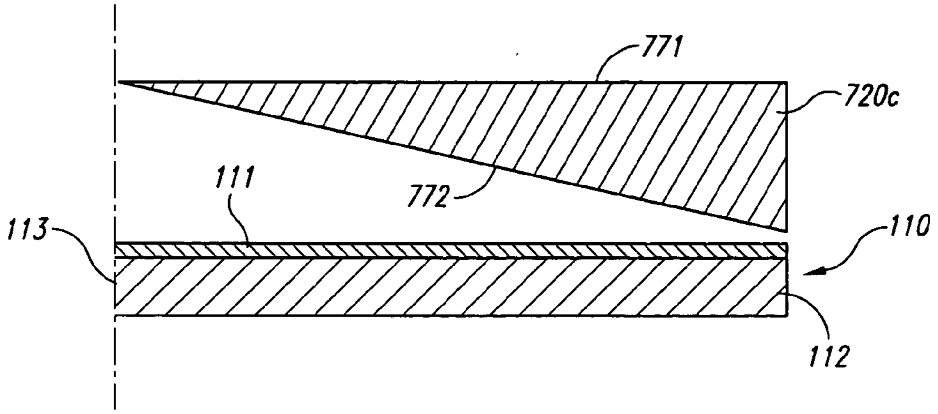
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Fig. 7

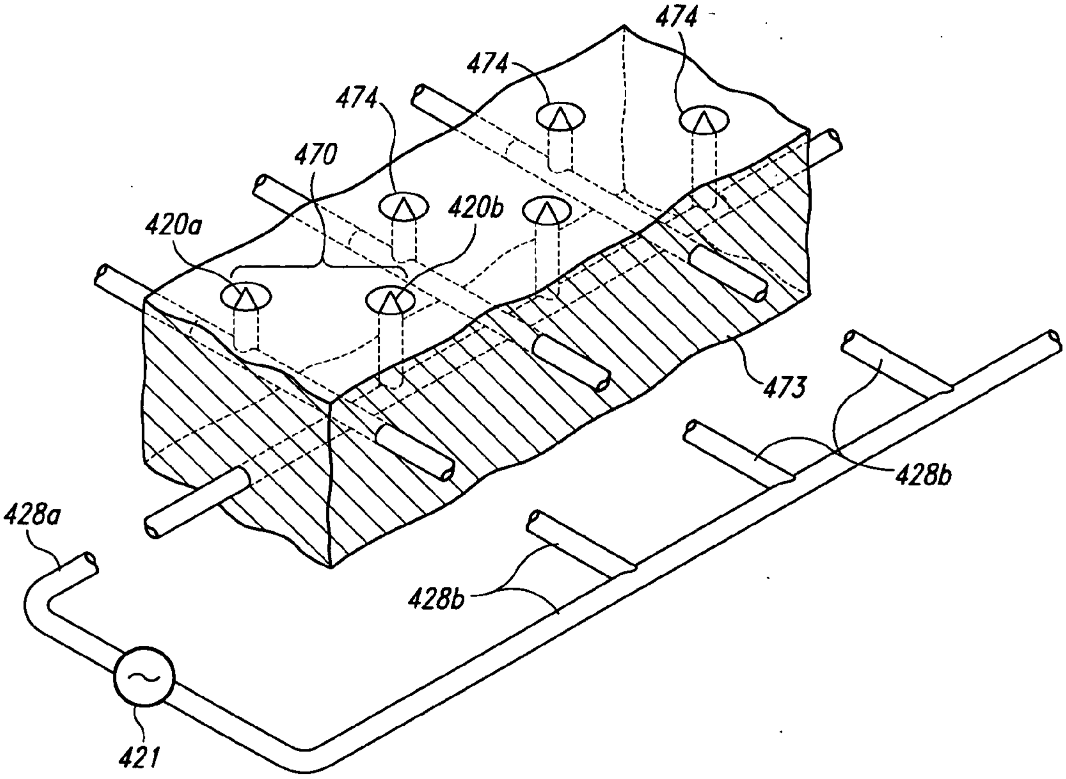
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Fig. 8A

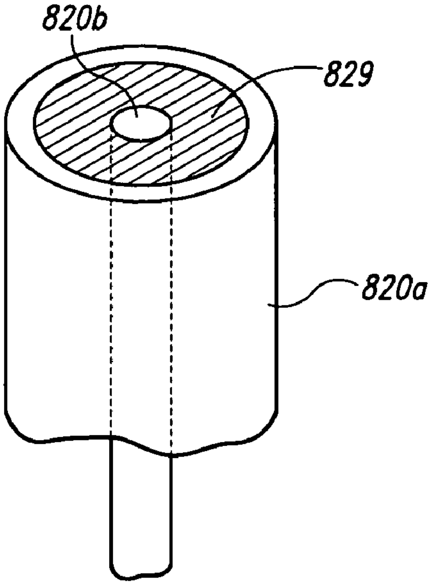

Fig. 8B

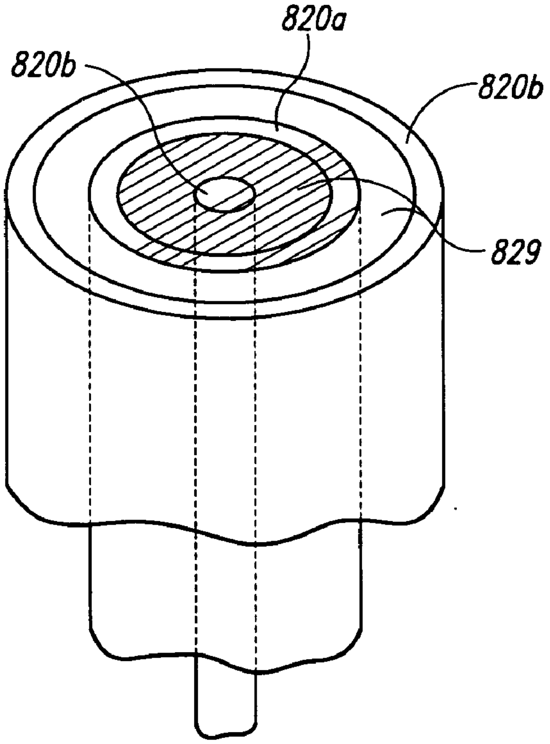

Fig. 8C

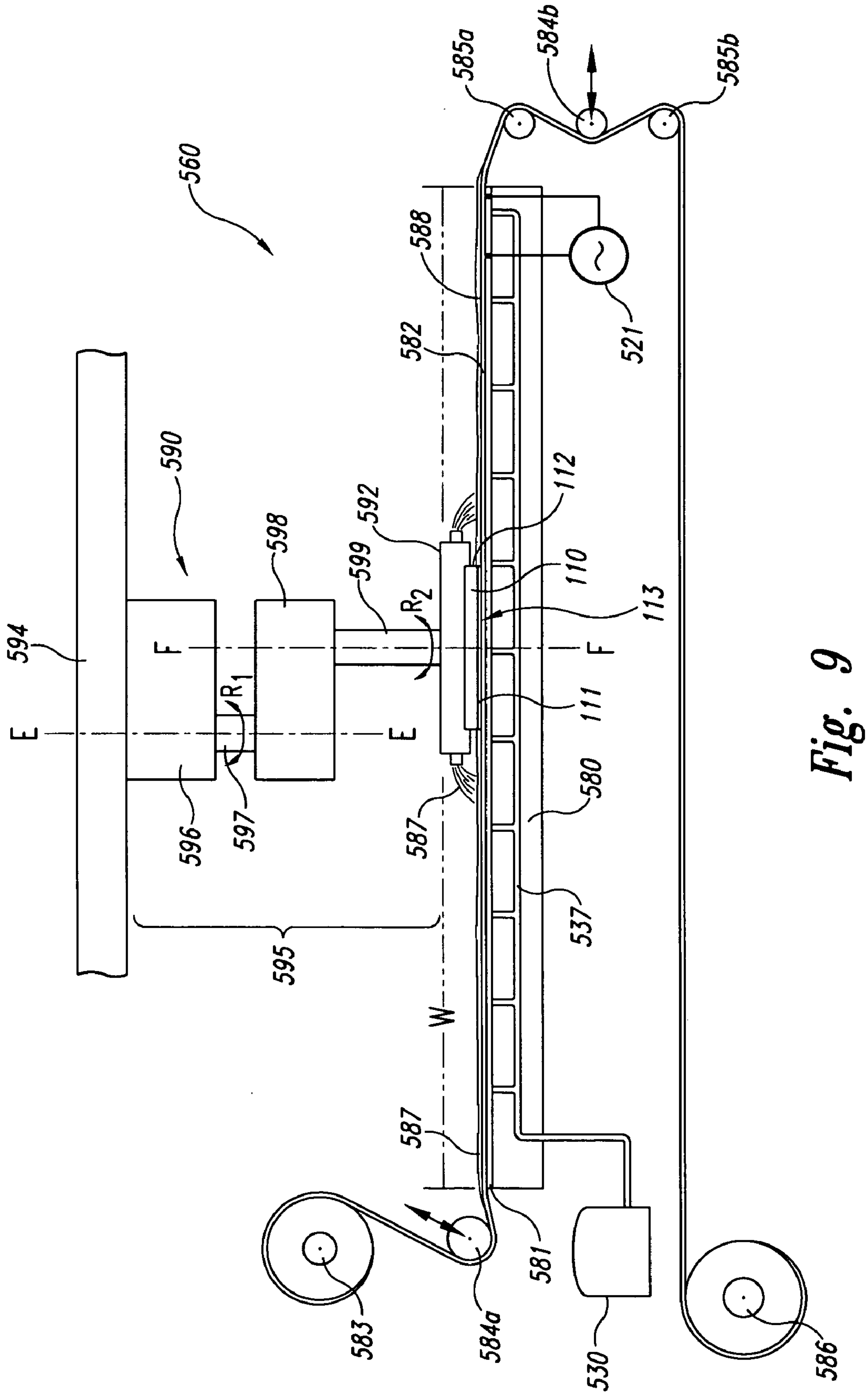
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Fig. 9

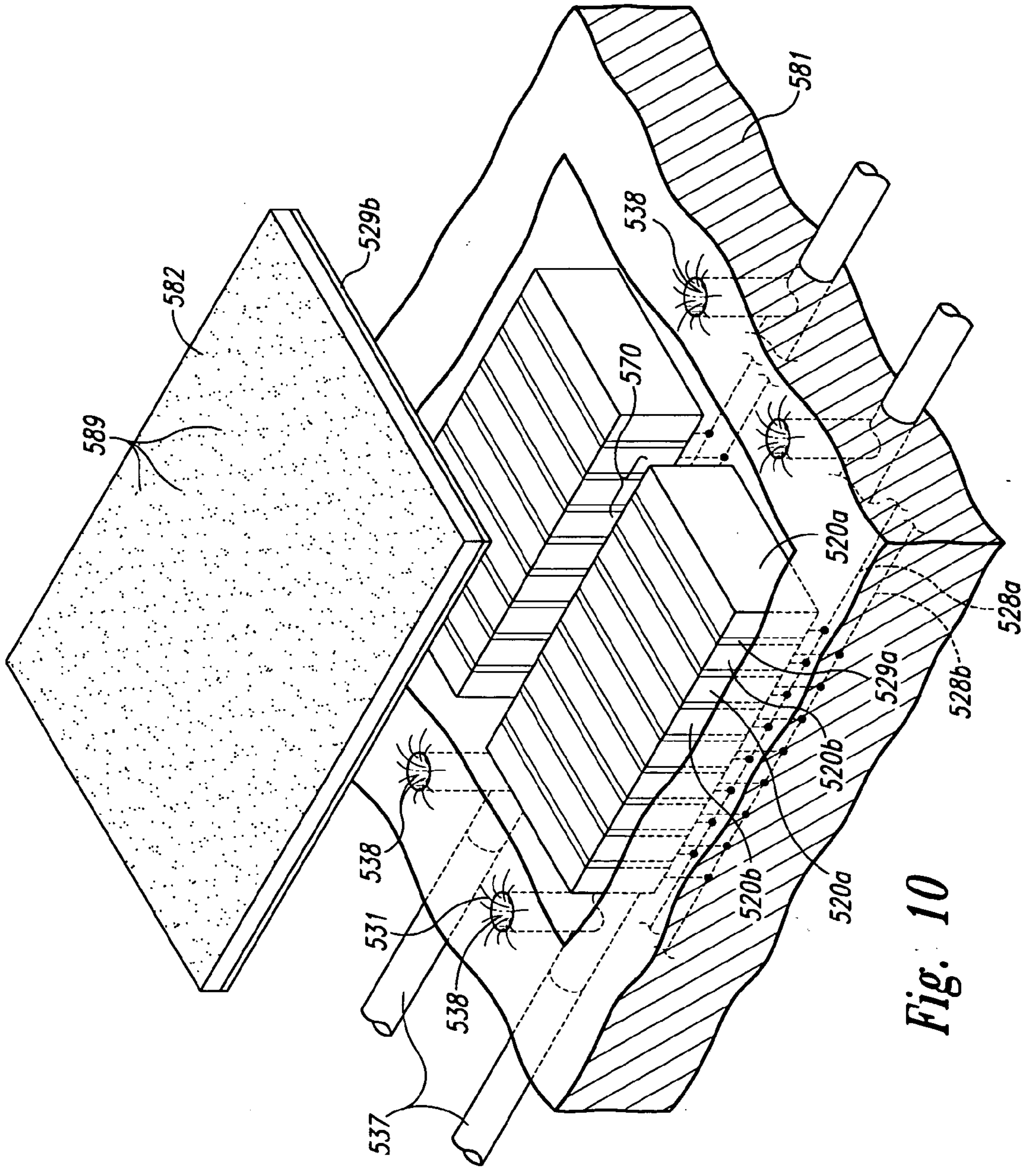
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Fig. 10

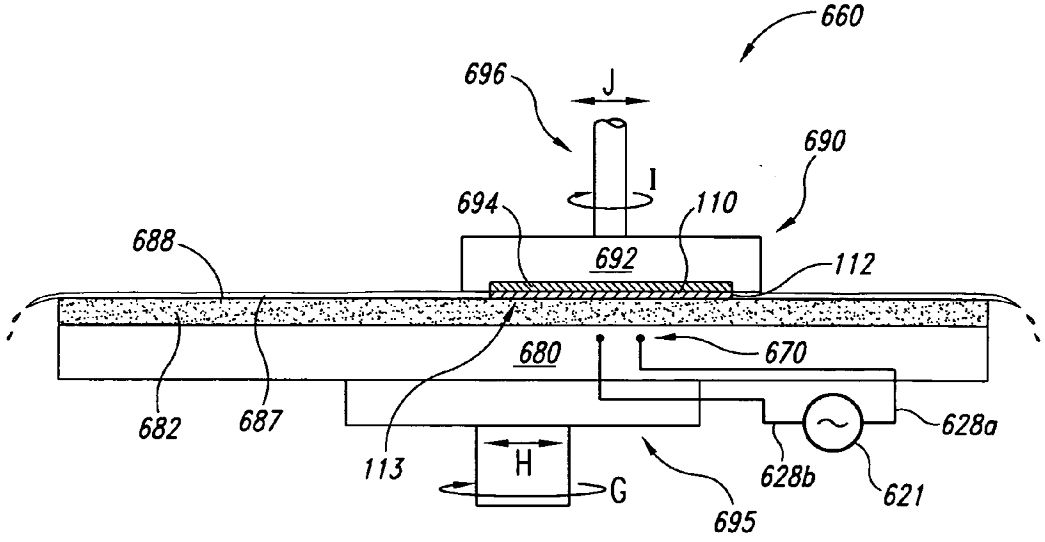

Fig. 11

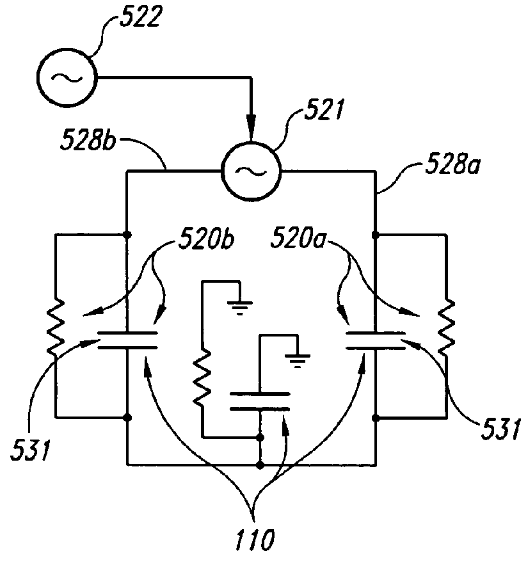

Fig. 12A

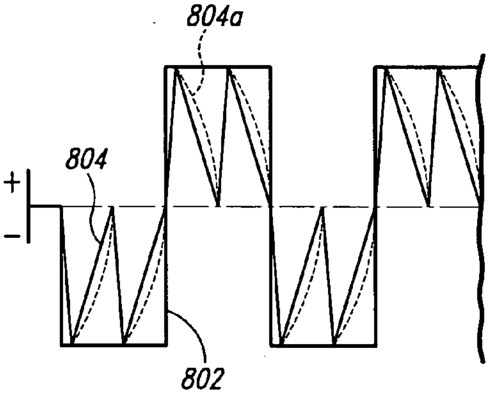

Fig. 12B

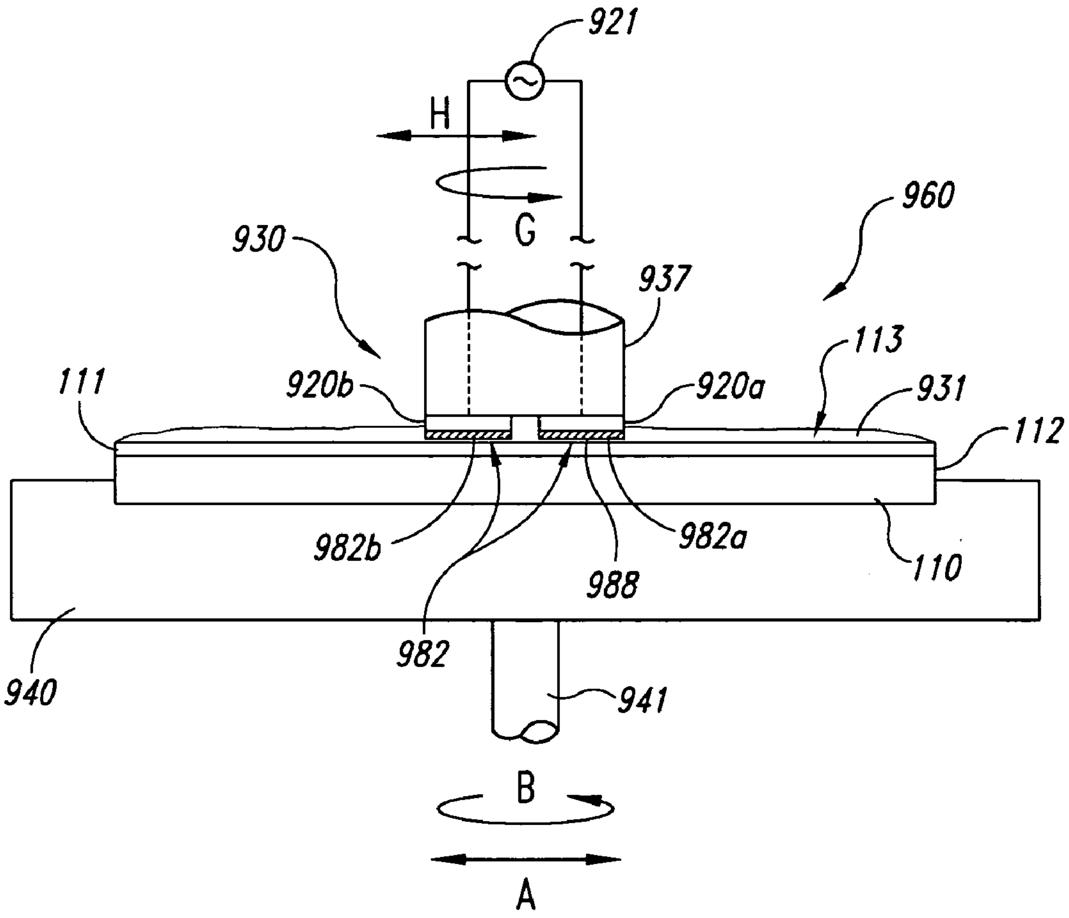
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Fig. 13

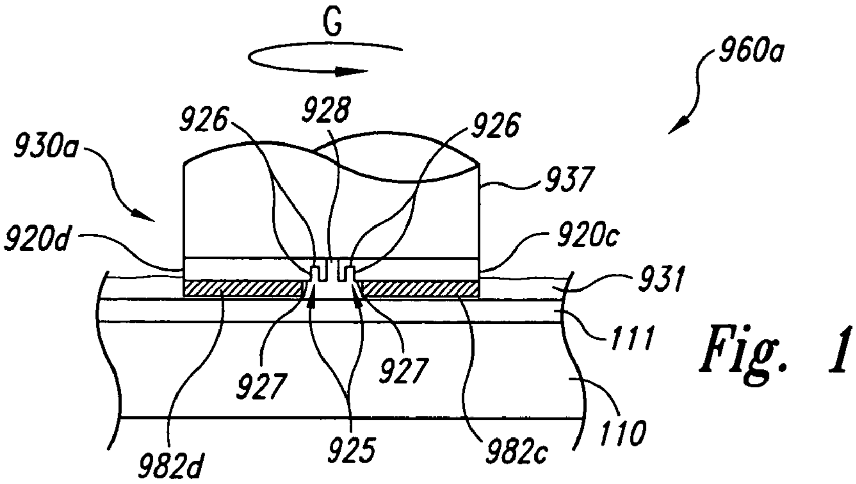

Fig. 14A

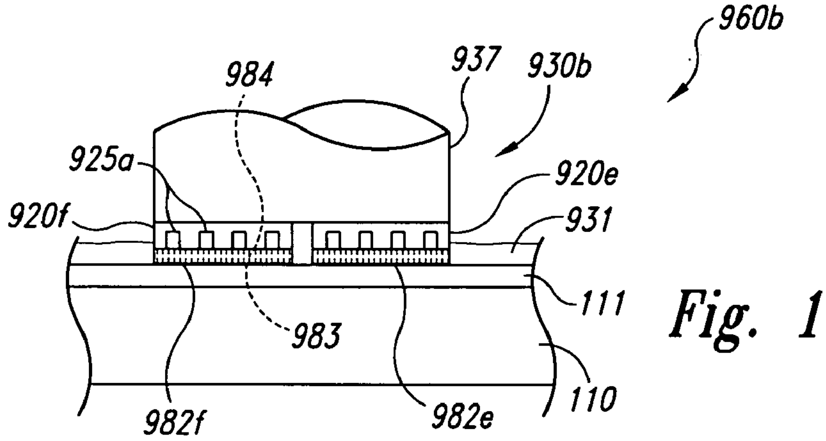

Fig. 14B

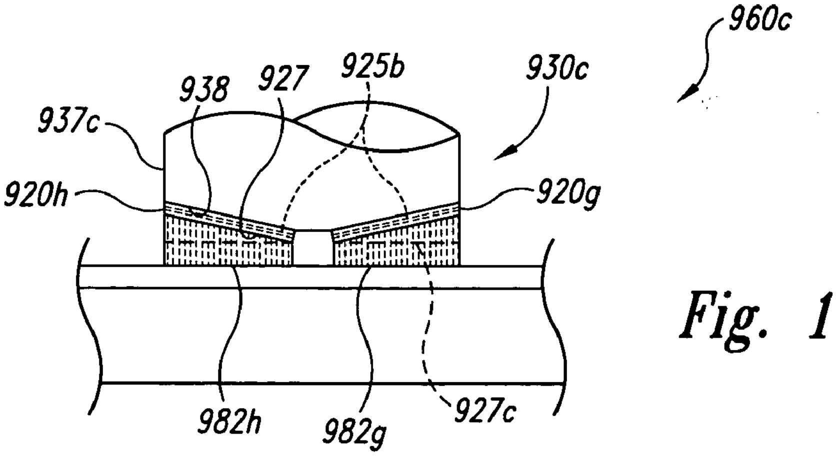

Fig. 14C

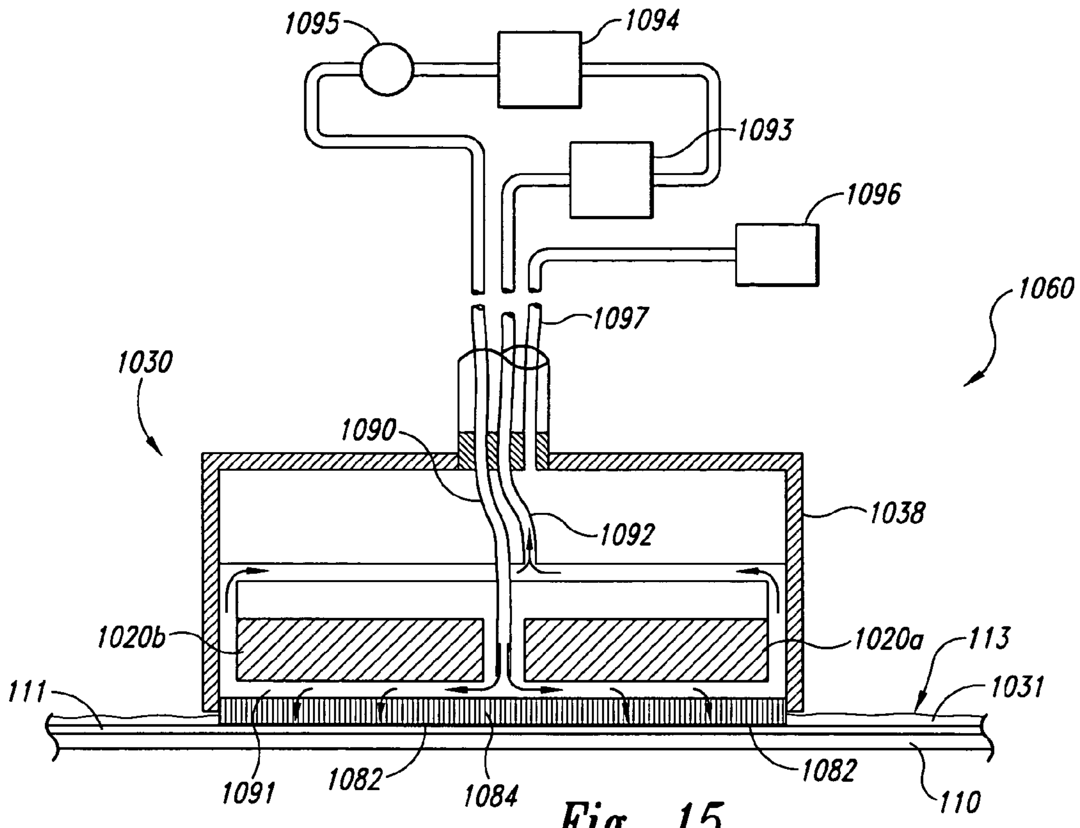
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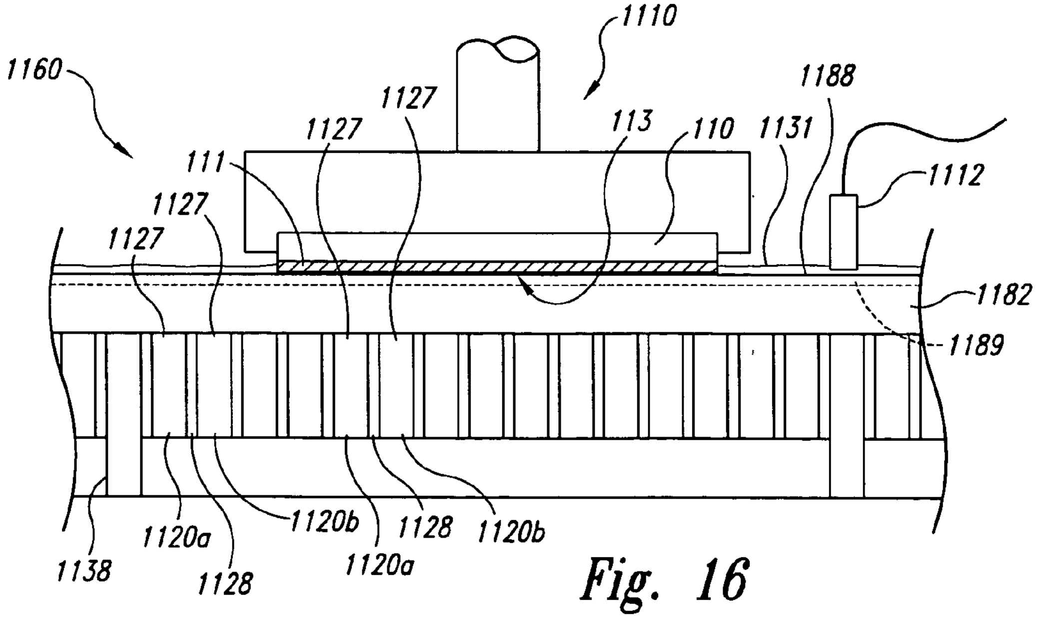
Fig. 15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1120b

Fig. 16

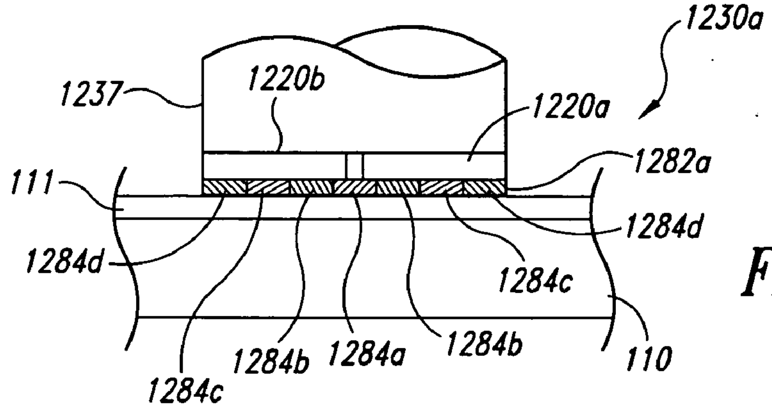

Fig. 17A

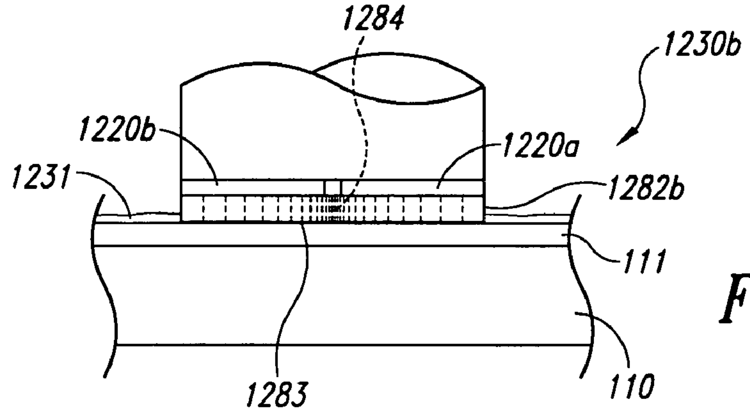

Fig. 17B

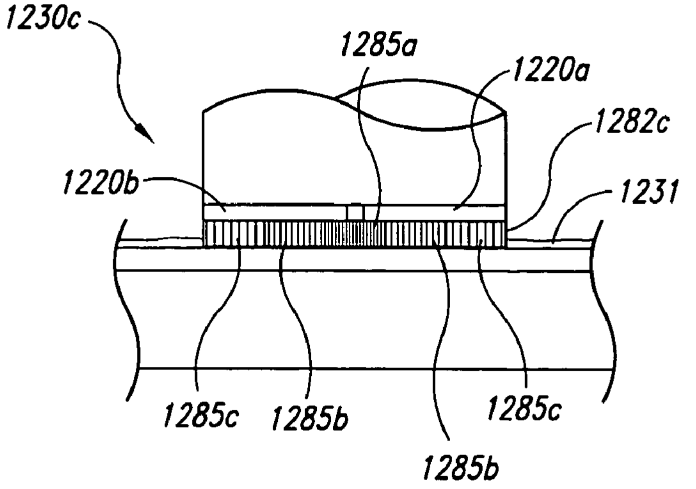

Fig. 17C

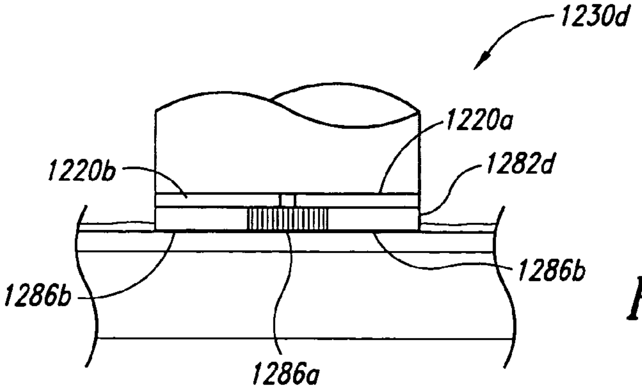

Fig. 17D

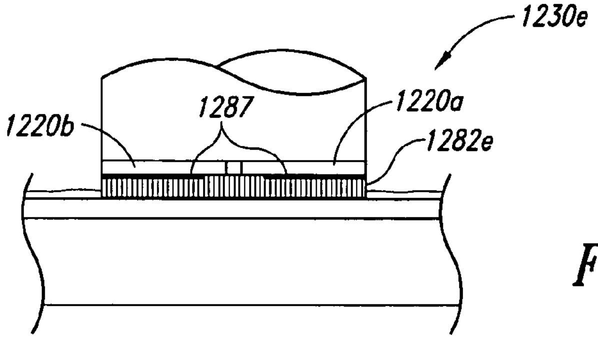

Fig. 17E

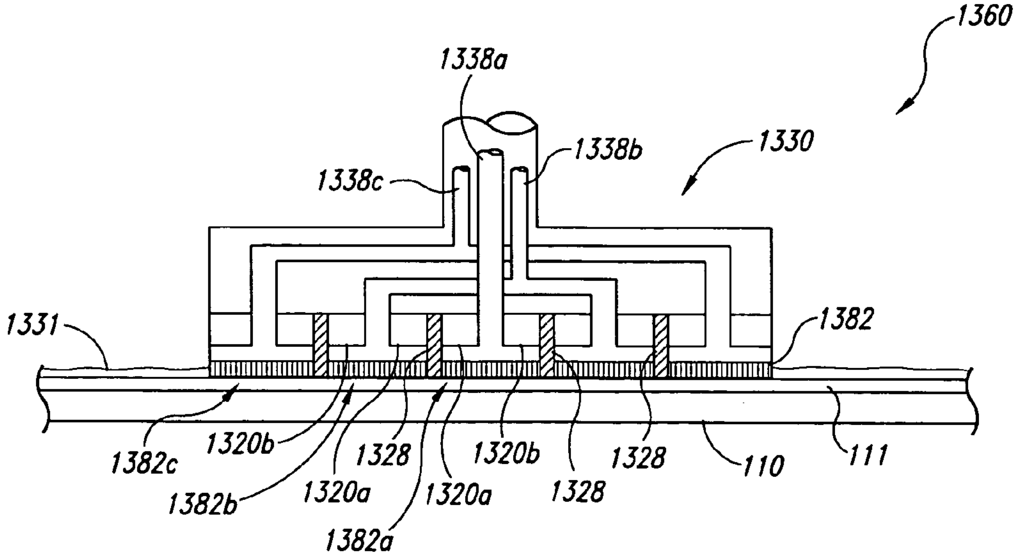

Fig. 18

METHODS AND APPARATUS FOR ELECTRICALLY AND/OR CHEMICALLY-MECHANICALLY REMOVING CONDUCTIVE MATERIAL FROM A MICROELECTRONIC SUBSTRATE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation-in-part of U.S. application Ser. No. 09/651,779 (attorney docket number 108298515US), titled "Methods and Apparatus for Removing Conductive Material From a Microelectronic Substrate," filed Aug. 30, 2000, and U.S. application No. ______ (attorney docket number 108298515US1), titled "Methods and Apparatus for Electrical, Mechanical and/or Chemical Removal of Conductive Material From a Microelectronic Substrate," filed concurrently herewith, and U.S. application No. ______ (attorney docket number 108298515US2), titled "Microelectronic Substrate Having Conductive Material With Blunt Cornered Apertures, and Associated Methods for Removing Conductive Material," filed concurrently herewith, all incorporated herein in their entireties by reference.

TECHNICAL FIELD

[0002] This invention relates to methods and apparatuses for removing conductive material from microelectronic substrates.

BACKGROUND

[0003] Microelectronic substrates and substrate assemblies typically include a semiconductor material having features, such as memory cells, that are linked with conductive lines. The conductive lines can be formed by first forming trenches or other recesses in the semiconductor material, and then overlaying a conductive material (such as a metal) in the trenches. The conductive material is then selectively removed to leave conductive lines extending from one feature in the semiconductor material to another.

[0004] Electrolytic techniques have been used to both deposit and remove metallic layers from semiconductor substrates. For example, an alternating current can be applied to a conductive layer via an intermediate electrolyte to remove portions of the layer. In one arrangement, shown in **FIG. 1**, a conventional apparatus **60** includes a first electrode **20***a* and a second electrode **20***b* coupled to a current source **21**. The first electrode **20***a* is attached directly to a metallic layer **11** of a semiconductor substrate **10** and the second electrode **20***b* is at least partially immersed in a liquid electrolyte **31** disposed on the surface of the metallic layer **11** by moving the second electrode downwardly until it contacts the electrolyte **31**. A barrier **22** protects the first electrode **20***a* from direct contact with the electrolyte **31**. The current source **21** applies alternating current to the substrate **10** via the electrodes **20***a* and **20***b* and the electrolyte **31** to remove conductive material from the conductive layer **11**. The alternating current signal can have a variety of wave forms, such as those disclosed by Frankenthal et al. in a publication entitled, "Electroetching of Platinum in the Titanium-Platinum-Gold Metallization on Silicon Integrated Circuits" (Bell Laboratories), incorporated herein in its entirety by reference.

[0005] One drawback with the arrangement shown in **FIG. 1** is that it may not be possible to remove material from the conductive layer **11** in the region where the first electrode **20***a* is attached because the barrier **22** prevents the electrolyte **31** from contacting the substrate **10** in this region. Alternatively, if the first electrode **20***a* contacts the electrolyte in this region, the electrolytic process can degrade the first electrode **20***a*. Still a further drawback is that the electrolytic process may not uniformly remove material from the substrate **10**. For example, "islands" of residual conductive material having no direct electrical connection to the first electrode **20***a* may develop in the conductive layer **11**. The residual conductive material can interfere with the formation and/or operation of the conductive lines, and it may be difficult or impossible to remove with the electrolytic process unless the first electrode **20***a* is repositioned to be coupled to such "islands."

[0006] One approach to addressing some of the foregoing drawbacks is to attach a plurality of first electrodes **20***a* around the periphery of the substrate **10** to increase the uniformity with which the conductive material is removed. However, islands of conductive material may still remain despite the additional first electrodes **20***a*. Another approach is to form the electrodes **20***a* and **20***b* from an inert material, such as carbon, and remove the barrier **22** to increase the area of the conductive layer **11** in contact with the electrolyte **31**. However, such inert electrodes may not be as effective as more reactive electrodes at removing the conductive material, and the inert electrodes may still leave residual conductive material on the substrate **10**.

[0007] **FIG. 2** shows still another approach to addressing some of the foregoing drawbacks in which two substrates **10** are partially immersed in a vessel **30** containing the electrolyte **31**. The first electrode **20***a* is attached to one substrate **10** and the second electrode **20***b* is attached to the other substrate **10**. An advantage of this approach is that the electrodes **20***a* and **20***b* do not contact the electrolyte. However, islands of conductive material may still remain after the electrolytic process is complete, and it may be difficult to remove conductive material from the points at which the electrodes **20***a* and **20***b* are attached to the substrates **10**.

[0008] International Application PCT/US00/08336 (published as WO/00/59682) discloses an apparatus having a first chamber for applying a conductive material to a semiconductor wafer, and a second chamber for removing conductive material from the semiconductor wafer by electropolishing or chemical-mechanical polishing. The second chamber includes an anode having a paint roller configuration with a cylindrical mechanical pad that contacts both an electrolyte bath and the face of the wafer as the anode and the wafer rotate about perpendicular axes. A cathode, which can include a conductive liquid isolated from the electrolytic bath, is electrically coupled to an edge of the wafer. One drawback with this device is that it, too, can leave islands of residual conductive material on the wafer.

[0009] Another drawback with some conventional devices is that they may not adequately control gas bubbles that evolve during the electrolytic process. These bubbles can collect on the electrode and/or the microelectronic substrate and can interfere with the uniform removal of material from the substrate. Still further, conventional electrolytic processes may not provide adequate control over the rate at which material is removed from the substrate, or the location on the substrate from which the material is removed.

SUMMARY

[0010] The present invention is directed toward methods in apparatuses for removing conductive materials from microelectronic substrates. A method in accordance with one embodiment of the invention includes spacing first and second conductive electrodes apart from the microelectronic substrate. The method can further include disposing an electrolyte between the microelectronic substrate and both the first and second electrodes, with both the first and second electrodes in fluid communication with the electrolyte. At least part of the conductive material is removed from the microelectronic substrate by passing a varying current through at least one of the first and second electrodes while the electrodes are spaced apart from the conductive material of the substrate. The method can further include removing gas from a region between the microelectronic substrate and at least one of the electrodes while the conductive material is removed from the microelectronic substrate. In a further aspect of the invention, the microelectronic substrate can be engaged with a polishing surface of a polishing pad and at least one of the microelectronic substrate and the polishing pad can be moved relative to the other while the varying current is passed through the conductive material.

[0011] A method in accordance with another aspect of the invention includes aligning a first portion of the microelectronic substrate with a first portion of a material removal medium having first electrical characteristics. The method can further include aligning a second portion of the microelectronic substrate with a second portion of the material removal medium having second electrical characteristics different than the first electrical characteristics. The conductive material can be engaged with a polishing surface of the material removal medium and at least a portion of the electrically conductive material can be removed from the microelectronic substrate by passing a varying electrical current through the conductive material while engaging the conductive material with the material removal medium and moving at least one of the substrate and medium relative to the other.

[0012] The invention is also directed toward an apparatus for removing conductive material from a microelectronic substrate. In one aspect of the invention, the apparatus can include a support member having at least one engaging surface to support a microelectronic substrate. A material removal medium is positioned proximate to the support member. The material removal medium can include a first electrode and a second electrode positioned to be spaced apart from the microelectronic substrate when the microelectronic substrate is supported by the support member. At least one of the first and second electrodes is coupleable to a source of varying electrical current. The material removal medium can further include a gas removal surface positioned to remove gas from a region proximate to the microelectronic substrate and/or at least one of the first and second electrodes during operation.

[0013] In another aspect of the invention, the material removal medium can include a polishing surface positioned to engage the microelectronic substrate when the substrate is supported by the support member. At least one of the medium and the support member can be movable relative to the other and the medium can include a first region with a first electrical characteristic and a second region with a second electrical characteristic different than the first electrical characteristic. The first region can be aligned with a first portion of the microelectronic substrate and the second region can be aligned with a second portion of the microelectronic substrate when the polishing surface is engaged with the microelectronic substrate. First and second electrodes are positioned proximate to the polishing surface with at least one of the electrodes being coupleable to a source of varying electrical current.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] **FIG. 1** is a partially schematic, side elevational view of an apparatus for removing conductive material from a semiconductor substrate in accordance with the prior art.

[0015] **FIG. 2** is a partially schematic side, elevational view of another apparatus for removing conductive material from two semiconductor substrates in accordance with the prior art.

[0016] **FIG. 3** is a partially schematic, side elevational view of an apparatus having a support member and a pair of electrodes for removing conductive material from a microelectronic substrate in accordance with an embodiment of the invention.

[0017] **FIG. 4** is a partially schematic, side elevational view of an apparatus for removing conductive material and sensing characteristics of the microelectronic substrate from which the material is removed in accordance with another embodiment of the invention.

[0018] **FIG. 5** is a partially schematic, side elevational view of an apparatus that includes two electrolytes in accordance with still another embodiment of the invention.

[0019] **FIG. 6** is a partially schematic, plan view of a substrate adjacent to a plurality of electrodes in accordance with still further embodiments of the invention.

[0020] **FIG. 7** is a cross-sectional, side elevational view of an electrode and a substrate in accordance with yet another embodiment of the invention.

[0021] **FIG. 8A** is a partially schematic, isometric view of a portion of a support for housing electrode pairs in accordance with still another embodiment of the invention.

[0022] **FIGS. 8B-8C** are isometric views of electrodes in accordance with still further embodiments of the invention.

[0023] **FIG. 9** is a partially schematic, side elevational view of an apparatus for both planarizing and electrolytically processing microelectronic substrates in accordance with yet another embodiment of the invention.

[0024] **FIG. 10** is a partially schematic, partially exploded isometric view of a planarizing pad and a plurality of electrodes in accordance with still another embodiment of the invention.

[0025] **FIG. 11** is a partially schematic, side elevational view of an apparatus for both planarizing and electrolytically processing microelectronic substrates in accordance with still another embodiment of the invention.

[0026] FIGS. 12A-B schematically illustrate a circuit and waveform for electrolytically processing a microelectronic substrate in accordance with yet another embodiment of the invention.

[0027] **FIG. 13** is a partially schematic, side elevational view of an apparatus for both mechanically and electrolytically processing microelectronic substrates in accordance with yet another embodiment of the invention.

[0028] **FIGS. 14A-14C** schematically illustrate material removal media in accordance with still further embodiments of the invention.

[0029] **FIG. 15** is a partially schematic, side elevational view of an apparatus having a pressurized housing for both mechanically and electrolytically processing microelectronic substrates in accordance with still another embodiment of the invention.

[0030] **FIG. 16** is a partially schematic, side elevational view of an apparatus having an ultrasonic transducer and a polishing pad with channels for removing gas during mechanical and electrolytic processing of microelectronic substrates in accordance with another embodiment of the invention.

[0031] **FIGS. 17A-17E** schematically illustrate material removal media having spatially varying electrical characteristics in accordance with yet another embodiment of the invention.

[0032] **FIG. 18** is a partially schematic, side elevational view of an apparatus for delivering a plurality of electrolytic fluids during planarizing and electrolytically processing microelectronic substrates in accordance with yet another embodiment of the invention.

DETAILED DESCRIPTION

[0033] The present disclosure describes methods and apparatuses for removing conductive materials from a microelectronic substrate and/or substrate assembly used in the fabrication of microelectronic devices. Many specific details of certain embodiments of the invention are set forth in the following description and in **FIGS. 3-18** to provide a thorough understanding of these embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, or that the invention may be practiced without several of the details described below.

[0034] **FIG. 3** is a partially schematic, side elevational view of an apparatus **160** for removing conductive material from a microelectronic substrate or substrate assembly **110** in accordance with an embodiment of the invention. In one aspect of is this embodiment, the apparatus **160** includes a vessel **130** containing an electrolyte **131**, which can be in a liquid or a gel state. As used herein, the terms electrolyte and electrolytic fluid refer generally to electrolytic liquids and gels. Structures in fluid communication with electrolytic fluids are accordingly in fluid communication with electrolytic liquids or gels.

[0035] The microelectronic substrate **110** has an edge surface **112** and two face surfaces **113**. A support member **140** supports the microelectronic substrate **110** relative to the vessel **130** so that a conductive layer **111** on at least one of the face surfaces **113** of the substrate **110** contacts the electrolyte **131**. The conductive layer **111** can include metals such as platinum, tungsten, tantalum, gold, copper, or other conductive materials. In another aspect of this embodiment, the support member **140** is coupled to a substrate drive unit **141** that moves the support member **140** and the substrate **110** relative to the vessel **130**. For example, the substrate drive unit **141** can translate the support member **140** (as indicated by arrow "A") and/or rotate the support member **140** (as indicated by arrow "B").

[0036] The apparatus **160** can further include a first electrode **120***a* and a second electrode **120***b* (referred to collectively as electrodes **120**) supported relative to the microelectronic substrate **110** by a support member **124**. In one aspect of this embodiment, the support arm **124** is coupled to an electrode drive unit **123** for moving the electrodes **120** relative to the microelectronic substrate **110**. For example, the electrode drive unit **123** can move the electrodes toward and away from the conductive layer **111** of the microelectronic substrate **110**, (as indicated by arrow "C"), and/or transversely (as indicated by arrow "D") in a plane generally parallel to the conductive layer **111**. Alternatively, the electrode drive unit **123** can move the electrodes in other fashions, or the electrode drive unit **123** can be eliminated when the substrate drive unit **141** provides sufficient relative motion between the substrate **110** and the electrodes **120**.

[0037] In either embodiment described above with reference to **FIG. 3**, the electrodes **120** are coupled to a current source **121** with leads **128** for supplying electrical current to the electrolyte **131** and the conductive layer **111**. In operation, the current source **121** supplies an alternating current (single phase or multiphase) to the electrodes **120**. The current passes through the electrolyte **131** and reacts electrochemically with the conductive layer **111** to remove material (for example, atoms or groups of atoms) from the conductive layer **111**. The electrodes **120** and/or the substrate **110** can be moved relative to each other to remove material from selected portions of the conductive layer **111**, or from the entire conductive layer **111**.

[0038] In one aspect of an embodiment of the apparatus **160** shown in **FIG. 3**, a distance D_1 between the electrodes **120** and the conductive layer **111** is set to be smaller than a distance D_2 between the first electrode **120***a* and the second electrode **120***b*. Furthermore, the electrolyte **131** generally has a higher resistance than the conductive layer **111**. Accordingly, the alternating current follows the path of least resistance from the first electrode **120***a*, through the electrolyte **131** to the conductive layer **111** and back through the electrolyte **131** to the second electrode **120***b*, rather than from the first electrode **120***a* directly through the electrolyte **131** to the second electrode **120***b*. Alternatively, a low dielectric material (not shown) can be positioned between the first electrode **120***a* and the second electrode **120***b* to decouple direct electrical communication between the electrodes **120** that does not first pass through the conductive layer **111**.

[0039] One feature of an embodiment of the apparatus **160** shown in **FIG. 3** is that the electrodes **120** do not contact the conductive layer **111** of the substrate **110**. An advantage of this arrangement is that it can eliminate the residual conductive material resulting from a direct electrical connection between the electrodes **120** and the conductive layer **111**, described above with reference to **FIGS. 1 and 2**. For example, the apparatus **160** can eliminate residual conductive material adjacent to the contact region between the electrodes and the conductive layer because the electrodes **120** do not contact the conductive layer **111**.

[**0040**] Another feature of an embodiment of the apparatus **160** described above with reference to **FIG. 3** is that the substrate **110** and/or the electrodes **120** can move relative to the other to position the electrodes **120** at any point adjacent to the conductive layer **111**. An advantage of this arrangement is that the electrodes **120** can be sequentially positioned adjacent to every portion of the conductive layer to remove material from the entire conductive layer **111**. Alternatively, when it is desired to remove only selected portions of the conductive layer **111**, the electrodes **120** can be moved to those selected portions, leaving the remaining portions of the conductive layer **111** intact.

[**0041**] **FIG. 4** is a partially schematic, side elevational view of an apparatus **260** that includes a support member **240** positioned to support the substrate **110** in accordance with another embodiment of the invention. In one aspect of this embodiment, the support member **240** supports the substrate **110** with the conductive layer **111** facing upwardly. A substrate drive unit **241** can move the support member **240** and the substrate **110**, as described above with reference to **FIG. 3**. First and second electrodes **220***a* and **220***b* are positioned above the conductive layer **111** and are coupled to a current source **221**. A support member **224** supports the electrodes **220** relative to the substrate **110** and is coupled to an electrode drive unit **223** to move the electrodes **220** over the surface of the support conductive layer **111** in a manner generally similar to that described above with reference to **FIG. 3**.

[**0042**] In one aspect of the embodiment shown in **FIG. 4**, the apparatus **260** further includes an electrolyte vessel **230** having a supply conduit **237** with an aperture **238** positioned proximate to the electrodes **220**. Accordingly, an electrolyte **231** can be disposed locally in an interface region **239** between the electrodes **220** and the conductive layer **111**, without necessarily covering the entire conductive layer **111**. The electrolyte **231** and the conductive material removed from the conductive layer **111** flow over the substrate **110** and collect in an electrolyte receptacle **232**. The mixture of electrolyte **231** and conductive material can flow to a reclaimer **233** that removes most of the conductive material from the electrolyte **231**. A filter **234** positioned downstream of the reclaimer **233** provides additional filtration of the electrolyte **231** and a pump **235** returns the reconditioned electrolyte **231** to the electrolyte vessel **230** via a return line **236**.

[**0043**] In another aspect of the embodiment shown in **FIG. 4**, the apparatus **260** can include a sensor assembly **250** having a sensor **251** positioned proximate to the conductive layer **111**, and a sensor control unit **252** coupled to the sensor **251** for processing signals generated by the sensor **251**. The control unit **252** can also move the sensor **251** relative to the substrate **110**. In a further aspect of this embodiment, the sensor assembly **250** can be coupled via a feedback path **253** to the electrode drive unit **223** and/or the substrate drive unit **241**. Accordingly, the sensor **251** can determine which areas of the conductive layer **111** require additional material removal and can move the electrodes **220** and/or the substrate **10** relative to each other to position the electrodes **220** over those areas. Alternatively, (for example, when the removal process is highly repeatable), the electrodes **220** and/or the substrate **110** can move relative to each other according to a pre-determined motion schedule.

[**0044**] The sensor **251** and the sensor control unit **252** can have any of a number of suitable configurations. For example, in one embodiment, the sensor **251** can be an optical sensor that detects removal of the conductive layer **111** by detecting a change in the intensity, wavelength or phase shift of the light reflected from the substrate **110** when the conductive material is removed. Alternatively, the sensor **251** can emit and detect reflections of radiation having other wavelengths, for example, x-ray radiation. In still another embodiment, the sensor **251** can measure a change in resistance or capacitance of the conductive layer **111** between two selected points. In a further aspect of this embodiment, one or both of the electrodes **220** can perform the function of the sensor **251** (as well as the material removal function described above), eliminating the need for a separate sensor **251**. In still further embodiments, the sensor **251** can detect a change in the voltage and/or current drawn from the current supply **221** as the conductive layer **111** is removed.

[**0045**] In any of the embodiments described above with reference to **FIG. 4**, the sensor **251** can be positioned apart from the electrolyte **231** because the electrolyte **231** is concentrated in the interface region **239** between the electrodes **220** and the conductive layer **111**. Accordingly, the accuracy with which the sensor **251** determines the progress of the electrolytic process can be improved because the electrolyte **231** will be less likely to interfere with the operation of the sensor **251**. For example, when the sensor **251** is an optical sensor, the electrolyte **231** will be less likely to distort the radiation reflected from the surface of the substrate **110** because the sensor **251** is positioned away from the interface region **239**.

[**0046**] Another feature of an embodiment of the apparatus **260** described above with reference to **FIG. 4** is that the electrolyte **231** supplied to the interface region **239** is continually replenished, either with a reconditioned electrolyte or a fresh electrolyte. An advantage of this feature is that the electrochemical reaction between the electrodes **220** and the conductive layer **111** can be maintained at a high and consistent level.

[**0047**] **FIG. 5** is a partially schematic, side elevational view of an apparatus **360** that directs alternating current to the substrate **110** through a first electrolyte **331***a* and a second electrolyte **331***b*. In one aspect of this embodiment, the first electrolyte **331***a* is disposed in two first electrolyte vessels **330***a*, and the second electrolyte **331***b* is disposed in a second electrolyte vessel **330***b*. The first electrolyte vessels **330***a* are partially submerged in the second electrolyte **331***b*. The apparatus **360** can further include electrodes **320**, shown as a first electrode **320***a* and a second electrode **320***b*, each coupled to a current supply **321** and each housed in one of the first electrolyte vessels **330***a*. Alternatively, one of the electrodes **320** can be coupled to ground. The electrodes **320** can include materials such as silver, platinum, copper and/or other materials, and the first electrolyte **331***a* can include sodium chloride, potassium chloride, copper sulfate and/or other electrolytes that are compatible with the material forming the electrodes **320**.

[**0048**] In one aspect of this embodiment, the first electrolyte vessels **330***a* include a flow restrictor **322**, such as a permeable isolation membrane formed from Teflon™, sintered materials such as sintered glass, quartz or sapphire, or other suitable porous materials that allow ions to pass back and forth between the first electrolyte vessels **330***a* and the second electrolyte vessel **330***b*, but do not allow the second electrolyte **330***b* to pass inwardly toward the electrodes **320** (for example, in a manner generally similar to a salt bridge). Alternatively, the first electrolyte **331***a* can be supplied to the electrode vessels **330***a* from a first electrolyte source **339** at a pressure and rate sufficient to direct the first electrolyte **331***a* outwardly through the flow restrictor **322** without allowing the first electrolyte **331***a* or the second electrolyte **330***b* to return through the flow restrictor **322**. In either embodiment, the second electrolyte **331***b* remains electrically coupled to the electrodes **320** by the flow of the first electrolyte **331***a* through the restrictor **322**.

[**0049**] In one aspect of this embodiment, the apparatus **360** can also include a support member **340** that supports the substrate **110** with the conductive layer **111** facing toward the electrodes **320**. For example, the support member **340** can be positioned in the second electrolyte vessel **330***b*. In a further aspect of this embodiment, the support member **340** and/or the electrodes **320** can be movable relative to each other by one or more drive units (not shown).

[**0050**] One feature of an embodiment of the apparatus **360** described above with reference to **FIG. 5** is that the first electrolyte **331***a* can be selected to be compatible with the electrodes **320**. An advantage of this feature is that the first electrolyte **331***a* can be less likely than conventional electrolytes to degrade the electrodes **320**. Conversely, the second electrolyte **331***b* can be selected without regard to the effect it has on the electrodes **320** because it is chemically isolated from the electrodes **320** by the flow restrictor **322**. Accordingly, the second electrolyte **331***b* can include hydrochloric acid or another agent that reacts aggressively with the conductive layer **111** of the substrate **110**.

[**0051**] **FIG. 6** is a top plan view of the microelectronic substrate **110** positioned beneath a plurality of electrodes having shapes and configurations in accordance with several embodiments of the invention. For purposes of illustration, several different types of electrodes are shown positioned proximate to the same microelectronic substrate **110**; however, in practice, electrodes of the same type can be positioned relative to a single microelectronic substrate **110**.

[**0052**] In one embodiment, electrodes **720***a* and **720***b* can be grouped to form an electrode pair **770***a*, with each electrode **720***a* and **720***b* coupled to an opposite terminal of a current supply **121** (**FIG. 3**). The electrodes **770***a* and **770***b* can have an elongated or strip-type shape and can be arranged to extend parallel to each other over the diameter of the substrate **110**. The spacing between adjacent electrodes of an electrode pair **370***a* can be selected to direct the electrical current into the substrate **110**, as described above with reference to **FIG. 3**.

[**0053**] In an alternate embodiment, electrodes **720***c* and **720***d* can be grouped to form an electrode pair **770***b*, and each electrode **720***c* and **720***d* can have a wedge or "pie" shape that tapers inwardly toward the center of the microelectronic substrate **110**. In still another embodiment, narrow, strip-type electrodes **720***e* and **720***f* can be grouped to form electrode pairs **770***c*, with each electrode **720***e* and **720***f* extending radially outwardly from the center **113** of the microelectronic substrate **110** toward the periphery **112** of the microelectronic substrate **110**.

[**0054**] In still another embodiment, a single electrode **720***g* can extend over approximately half the area of the microelectronic substrate **110** and can have a semicircular planform shape. The electrode **720***g* can be grouped with another electrode (not shown) having a shape corresponding to a mirror image of the electrode **720***g*, and both electrodes can be coupled to the current source **121** to provide alternating current to the microelectronic substrate in any of the manners described above with reference to **FIGS. 3-5**.

[**0055**] **FIG. 7** is a partially schematic, cross-sectional side elevational view of a portion of the substrate **110** positioned beneath the electrode **720***c* described above with reference to **FIG. 6**. In one aspect of this embodiment, the electrode **720***c* has an upper surface **771** and a lower surface **772** opposite the upper surface **771** and facing the conductive layer **111** of the substrate **110**. The lower surface **772** can taper downwardly from the center **113** of the substrate **110** toward the perimeter **112** of the substrate **110** in one aspect of this embodiment to give the electrode **720***c* a wedge-shaped profile. Alternatively, the electrode **720***c* can have a plate-type configuration with the lower surface **772** positioned as shown in **FIG. 7** and the upper surface **771** parallel to the lower surface **772**. One feature of either embodiment is that the electrical coupling between the electrode **720***c* and the substrate **110** can be stronger toward the periphery **112** of the substrate **110** than toward the center **113** of the substrate **110**. This feature can be advantageous when the periphery **112** of the substrate **110** moves relative to the electrode **720***c* at a faster rate than does the center **113** of the substrate **110**, for example, when the substrate **110** rotates about its center **113**. Accordingly, the electrode **720***c* can be shaped to account for relative motion between the electrode and the substrate **110**.

[**0056**] In other embodiments, the electrode **720***c* can have other shapes. For example, the lower surface **772** can have a curved rather than a flat profile. Alternatively, any of the electrodes described above with reference to **FIG. 6** (or other electrodes having shapes other than those shown in **FIG. 6**) can have a sloped or curved lower surface. In still further embodiments, the electrodes can have other shapes that account for relative motion between the electrodes and the substrate **110**.

[**0057**] **FIG. 8A** is a partially schematic view of an electrode support **473** for supporting a plurality of electrodes in accordance with another embodiment of the invention. In one aspect of this embodiment, the electrode support **473** can include a plurality of electrode apertures **474**, each of which houses either a first electrode **420***a* or a second electrode **420***b*. The first electrodes **420***a* are coupled through the apertures **474** to a first lead **428***a* and the second electrodes **420***b* are coupled to a second lead **428***b*. Both of the leads **428***a* and **428***b* are coupled to a current supply **421**. Accordingly, each pair **470** of first and second electrodes **420***a* and **420***b* defines part of a circuit that is completed by the substrate **110** and the electrolyte(s) described above with reference to **FIGS. 3-5**.

[**0058**] In one aspect of this embodiment, the first lead **428***a* can be offset from the second lead **428***b* to reduce the likelihood for short circuits and/or capacitive coupling between the leads. In a further aspect of this embodiment, the electrode support **473** can have a configuration generally similar to any of those described above with reference to **FIGS. 1-7**. For example, any of the individual electrodes (e.g., **320***a*, **320***c*, **320***e*, or **320***g*) described above with reference to **FIG. 6** can be replaced with an electrode support **473** having the same overall shape and including a plurality of apertures **474**, each of which houses one of the first electrodes **420***a* or the second electrodes **420***b*.

[0059] In still a further aspect of this embodiment, the electrode pairs **470** shown in **FIG. 8A** can be arranged in a manner that corresponds to the proximity between the electrodes **420***a*, **420***b* and the microelectronic substrate **110** (**FIG. 7**), and/or the electrode pairs **470** can be arranged to correspond to the rate of relative motion between the electrodes **420***a*, **420***b* and the microelectronic substrate **110**. For example, the electrode pairs **470** can be more heavily concentrated in the periphery **112** of the substrate **110** or other regions where the relative velocity between the electrode pairs **470** and the substrate **110** is relatively high (see **FIG. 7**). Accordingly, the increased concentration of electrode pairs **470** can provide an increased electrolytic current to compensate for the high relative velocity. Furthermore, the first electrode **420***a* and the second electrode **420***b* of each electrode pair **470** can be relatively close together in regions (such as the periphery **112** of the substrate **110**) where the electrodes are close to the conductive layer **111** (see **FIG. 7**) because the close proximity to the conductive layer **111** reduces the likelihood for direct electrical coupling between the first electrode **420***a* and the second electrode **420***b*. In still a further aspect of this embodiment the amplitude, frequency and/or waveform shape supplied to different electrode pairs **470** can vary depending on factors such as the spacing between the electrode pair **470** and the microelectronic substrate **110**, and the relative velocity between the electrode pair **470** and the microelectronic substrate **110**.

[0060] **FIGS. 8B-8C** illustrate electrodes **820** (shown as first electrodes **820***a* and second electrodes **820***b*) arranged concentrically in accordance with still further embodiments of the invention. In one embodiment shown in **FIG. 8B**, the first electrode **820***a* can be positioned concentrically around the second electrode **820***b*, and a dielectric material **829** can be disposed between the first electrode **820***a* and the second electrode **820***b*. The first electrode **820***a* can define a complete 360° arc around the second electrode **820***b*, as shown in **FIG. 8B**, or alternatively, the first electrode **820***a* can define an arc of less than 360°.

[0061] In another embodiment, shown in **FIG. 8C**, the first electrode **820***a* can be concentrically disposed between two second electrodes **820***b*, with the dielectric material **829** disposed between neighboring electrodes **820**. In one aspect of this embodiment, current can be supplied to each of the second electrodes **820***b* with no phase shifting. Alternatively, the current supplied to one second electrode **820***b* can be phase-shifted relative to the current supplied to the other second electrode **820***b*. In a further aspect of the embodiment, the current supplied to each second electrode **820***b* can differ in characteristics other than phase, for example, amplitude.

[0062] One feature of the electrodes **820** described above with respect to **FIGS. 8B-8C** is that the first electrode **820***a* can shield the second electrode(s) **820***b* from interference from other current sources. For example, the first electrode **820***a* can be coupled to ground to shield the second electrodes **820***b*. An advantage of this arrangement is that the current applied to the substrate **110** (**FIG. 7**) via the electrodes **820** can be more accurately controlled.

[0063] **FIG. 9** schematically illustrates an apparatus **560** for chemically, mechanically and/or electrolytically processing the microelectronic substrate **110** in accordance with an embodiment of the invention. In one aspect of this embodiment, the apparatus **560** has a support table **580** with a top-panel **581** at a workstation where an operative portion "W" of a polishing pad **582** is positioned. The top-panel **581** is generally a rigid plate to provide a flat, solid surface to which a particular section of the polishing pad **582** may be secured during material removal processes.

[0064] The apparatus **560** can also have a plurality of rollers to guide, position and hold the polishing pad **582** over the top-panel **581**. The rollers can include a supply roller **583**, first and second idler rollers **584***a* and **584***b*, first and second guide rollers **585***a* and **585***b*, and a take-up roller **586**. The supply roller **583** carries an unused or pre-operative portion of the polishing pad **582**, and the take-up roller **583** carries a used or post-operative portion of the polishing pad **582**. Additionally, the first idler roller **584***a* and the first guide roller **585***a* can stretch the polishing pad **582** over the top-panel **581** to hold the polishing pad **582** stationary during operation. A motor (not shown) drives at least one of the supply roller **583** and the take-up roller **586** to sequentially advance the polishing pad **582** across the top-panel **581**. Accordingly, clean pre-operative sections of the polishing pad **582** may be quickly substituted for used sections to provide a consistent surface for polishing and/or cleaning the substrate **110**.

[0065] The apparatus **560** can also have a carrier assembly **590** that controls and protects the substrate **110** during the material removal processes. The carrier assembly **590** can include a substrate holder **592** to pick up, hold and release the substrate **110** at appropriate stages of the material removal process. The carrier assembly **590** can also have a support gantry **594** carrying a drive assembly **595** that can translate along the gantry **594**. The drive assembly **595** can have an actuator **596**, a drive shaft **597** coupled to the actuator **596**, and an arm **598** projecting from the drive shaft **597**. The arm **598** carries the substrate holder **592** via a terminal shaft **599** such that the drive assembly **595** orbits the substrate holder **592** about an axis E-E (as indicated by arrow "R_1"). The terminal shaft **599** may also rotate the substrate holder **592** about its central axis F-F (as indicated by arrow "R_2").

[0066] In one embodiment, the polishing pad **582** and a planarizing solution **587** define at least a portion of a material removal medium that mechanically and/or chemically-mechanically removes material from the surface of the substrate **110**. The polishing pad **582** used in the apparatus **560** can be a fixed-abrasive polishing pad having abrasive particles that are fixedly bonded to a suspension medium. Accordingly, the planarizing solution **587** can be a "clean solution" without abrasive particles because the abrasive particles are fixedly distributed across a polishing surface **588** of the polishing pad **582**. In other applications, the polishing pad **582** may be a non-abrasive pad without abrasive particles, and the planarizing solution **587** can be a slurry with abrasive particles and chemicals to remove material from the substrate **110**.

[**0067**] To remove material from the substrate **110** with the apparatus **560**, the carrier assembly **590** presses the face **113** of the substrate **110** against the polishing surface **588** of the polishing pad **582** in the presence of the planarizing solution **587**. The drive assembly **595** then orbits the substrate holder **592** about the axis E-E and optionally rotates the substrate holder **592** about the axis F-F to translate the substrate **110** across the planarizing surface **588**. As a result, the abrasive particles and/or the chemicals in the material removal medium remove material from the surface of the substrate **110** in a chemical and/or chemical-mechanical planarization (CMP) process. Accordingly, in one embodiment, the polishing pad **582** can smooth the substrate **110** by removing rough features projecting from the conductive layer **111** of the substrate **110**.

[**0068**] In a further aspect of this embodiment, the apparatus **560** can include an electrolyte supply vessel **530** that delivers an electrolyte to the planarizing surface **588** of the polishing pad **582** with a conduit **537**, as described in greater detail with reference to **FIG. 10**. The apparatus **560** can further include a current supply **521** coupled to the support table **580** and/or the top-panel **581** to supply an electrical current to electrodes positioned in the support table **580** and/or the top-panel **581**. Accordingly, the apparatus **560** can electrolytically remove material from the conductive layer **111** in a manner similar to that described above with reference to **FIGS. 1-8C**.

[**0069**] In one aspect of an embodiment of the apparatus **560** described above with reference to **FIG. 9**, material can be sequentially removed from the conductive layer **111** of the substrate **110** first by an electrolytic process and then by a CMP process. For example, the electrolytic process can remove material from the conductive layer **111** in a manner that roughens the conductive layer **111**. After a selected period of electrolytic processing time has elapsed, the electrolytic processing operation can be halted and additional material can be removed via CMP processing. Alternatively, the electrolytic process and the CMP process can be conducted simultaneously. In either of these processing arrangements, one feature of an embodiment of the apparatus **560** described above with reference to **FIG. 9** is that the same apparatus **560** can planarize the substrate **110** via CMP and remove material from the substrate **110** via an electrolytic process. An advantage of this arrangement is that the substrate **110** need not be moved from one apparatus to another to undergo both CMP and electrolytic processing.

[**0070**] Another advantage of an embodiment of the apparatus **560** described above with reference to **FIG. 9** is that the processes, when used in conjunction with each other, are expected to remove material from the substrate **110** more quickly and accurately than some conventional processes. For example, as described above, the electrolytic process can remove relatively large amounts of material in a manner that roughens the microelectronic substrate **110**, and the planarizing process can remove material on a finer scale in a manner that smoothes and/or flattens the microelectronic substrate **110**.

[**0071**] **FIG. 10** is a partially exploded, partially schematic isometric view of a portion of the apparatus **560** described above with reference to **FIG. 9**. In one aspect of an embodiment shown in **FIG. 10**, the top-panel **581** houses a plurality of electrode pairs **570**, each of which includes a first electrode **520***a* and a second electrode **520***b*. The first electrodes **520***a* are coupled to a first lead **528***a* and the second electrodes **520***b* are coupled to a second lead **528***b*. The first and second leads **528***a* and **528***b* are coupled to the current source **521** (**FIG. 9**). In one aspect of this embodiment, the first electrode **520***a* can be separated from the second electrodes **520***b* by an electrode dielectric layer **529***a* that includes Teflon™ or another suitable dielectric material. The electrode dielectric layer **529***a* can accordingly control the volume and dielectric constant of the region between the first and second electrodes **520***a* and **520***b* to control electrical coupling between the electrodes.

[**0072**] The electrodes **520***a* and **520***b* can be electrically coupled to the microelectronic substrate **110** (**FIG. 9**) by the polishing pad **582**. In one aspect of this embodiment, the polishing pad **582** is saturated with an electrolyte **531** supplied by the supply conduits **537** through apertures **538** in the top-panel **581** just beneath the polishing pad **582**. Accordingly, the electrodes **520***a* and **520***b* are selected to be compatible with the electrolyte **531**. In an alternate arrangement, the electrolyte **531** can be supplied to the polishing pad **582** from above (for example, by disposing the electrolyte **531** in the planarizing liquid **587**) rather than through the top-panel **581**. Accordingly, the polishing pad **582** can include a pad dielectric layer **529***b* positioned between the polishing pad **582** and the electrodes **520***a* and **520***b*. When the pad dielectric layer **529***b* is in place, the electrodes **520***a* and **520***b* are isolated from physical contact with the electrolyte **531** and can accordingly be selected from materials that are not necessarily compatible with the electrolyte **531**.

[**0073**] In either embodiment, the electrodes **520***a* and **520***b* can be in fluid communication with each other and the conductive layer **111** via a common volume of electrolyte **531**. Each electrode **520***a*, **520***b* can be more directly electrically coupled to the conductive layer **111** (**FIG. 9**) than to the other electrode so that electrical current passes from one electrode through the conductive layer **111** to the other electrode.

[**0074**] In one aspect of an embodiment of the apparatus shown in **FIG. 10**, the electrodes **520***a* and **520***b* face toward the face surface **113** (**FIG. 9**) of the microelectronic substrate **110**, with the polishing pad **582** interposed between the electrodes **520***a* and **520***b* and the face surface **113**. As the microelectronic substrate **110** and the electrodes **520***a* and **520***b* move relative to each other, the electrodes can electrically couple to at least a substantial portion of the face surface **113**. Accordingly, the likelihood for forming electrically isolated "islands" in the conductive layer **111** (**FIG. 9**) at the face surface **113** can be reduced when compared to conventional devices. Alternatively, if the apparatus includes only two electrodes, each configured to face toward about one-half of the face surface **113** (in a manner generally similar to that described above with reference to electrode **220***g* of **FIG. 6**), then the electrodes can also electrically couple to at least a substantial portion of the face surface **113**.

[**0075**] In any of the embodiments described above with reference to **FIG. 10**, the polishing pad **582** can provide several additional advantages over some conventional electrolytic arrangements. For example, the polishing pad **582** can uniformly separate the electrodes **520***a* and **520***b* from the microelectronic substrate **110** (**FIG. 9**), which can increase the uniformity with which the electrolytic process removes material from the conductive layer **111** (**FIG. 9**). The polishing pad **582** can also have abrasive particles **589** for planarizing the microelectronic substrate **110** in the manner described above with reference to **FIG. 9**. Furthermore, the polishing pad **582** can filter carbon or other material that erodes from the electrodes **520***a* and **520***b* to prevent the electrode material from contacting the microelectronic substrate **110**. Still further, the polishing pad **582** can act as a sponge to retain the electrolyte **531** in close proximity to the microelectronic substrate **110**.

[0076] **FIG. 11** is a partially schematic, cross-sectional side elevational view of a rotary apparatus **660** for mechanically, chemically and/or electrolytically processing the microelectronic substrate **110** in accordance with another embodiment of the invention. In one aspect of this embodiment, the apparatus **660** has a generally circular platen or table **680**, a carrier assembly **690**, a polishing pad **682** positioned on the table **680**, and a planarizing liquid **687** on the polishing pad **682**. The polishing pad **682** can be a fixed abrasive polishing pad or, alternatively, the planarizing liquid **687** can be a slurry having a suspension of abrasive elements and the polishing pad **682** can be a non-abrasive pad. A drive assembly **695** rotates (arrow "G") and/or reciprocates (arrow "H") the platen **680** to move the polishing pad **682** during planarization.

[0077] The carrier assembly **690** controls and protects the microelectronic substrate **110** during the material removal process. The carrier assembly **690** typically has a substrate holder **692** with a pad **694** that holds the microelectronic substrate **110** via suction. A drive assembly **696** of the carrier assembly **690** typically rotates and/or translates the substrate holder **692** (arrows "I" and "J," respectively). Alternatively, the substrate holder **692** may include a weighted, free-floating disk (not shown) that slides over the polishing pad **682**.

[0078] To planarize the microelectronic substrate **110** with the apparatus **660** in one embodiment, the carrier assembly **690** presses the microelectronic substrate **110** against a polishing surface **688** of the polishing pad **682**. The platen **680** and/or the substrate holder **692** then move relative to one another to translate the microelectronic substrate **110** across the polishing surface **688**. As a result, the abrasive particles in the polishing pad **682** and/or the chemicals in the planarizing liquid **687** remove material from the surface of the microelectronic substrate **110**.

[0079] The apparatus **660** can also include a current source **621** coupled with leads **628***a* and **628***b* to one or more electrode pairs **670** (one of which is shown in **FIG. 11**). The electrode pairs **670** can be integrated with the platen **680** in generally the same manner with which the electrodes **520***a* and **520***b* (**FIG. 10**) are integrated with the top panel **581** (**FIG. 10**). Alternatively, the electrode pairs **670** can be integrated with the polishing pad **682**. In either embodiment, the electrode pairs **670** can include electrodes having shapes and configurations generally similar to any of those described above with reference to **FIGS. 3-10** to electrolytically remove conductive material from the microelectronic substrate **110**. The electrolytic process can be carried out before, during or after the CMP process, as described above with reference to **FIG. 9**.

[0080] **FIG. 12A** is a schematic circuit representation of some of the components described above with reference to **FIG. 10**. The circuit analogy can also apply to any of the arrangements described above with reference to **FIGS. 3-11** or below with reference to **FIGS. 13-18**. As shown schematically in **FIG. 12A**, the current source **521** is coupled to the first electrode **520***a* and the second electrode **520***b* with leads **528***a* and **528***b*, respectively. The electrodes **520***a* and **520***b* are coupled to the microelectronic substrate **110** with the electrolyte **531** in an arrangement that can be represented schematically by two sets of parallel capacitors and resistors. A third capacitor and resistor schematically indicates that the microelectronic substrate **110**"floats" relative to ground or another potential.

[0081] In one aspect of an embodiment shown in **FIG. 12A**, the current source **521** can be coupled to an amplitude modulator **522** that modulates the signal produced by the current source **521**, as is shown in **FIG. 12B**. Accordingly, the current source **521** can generate a high-frequency wave **804**, and the amplitude modulator **522** can superimpose a low-frequency wave **802** on the high-frequency wave **804**. For example, the high-frequency wave **804** can include a series of positive or negative voltage spikes contained within a square wave envelope defined by the low-frequency wave **802**. Each spike of the high-frequency wave **804** can have a relatively steep rise time slope to transfer charge through the dielectric to the electrolyte, and a more gradual fall time slope. The fall time slope can define a straight line, as indicated by high-frequency wave **804**, or a curved line, as indicated by high-frequency wave **804***a*. In other embodiments, the high-frequency wave **804** and the low-frequency wave **802** can have other shapes depending, for example, on the particular characteristics of the dielectric material and electrolyte adjacent to the electrodes **420**, the characteristics of the substrate **110**, and/or the target rate at which material is to be removed from the substrate **110**.

[0082] An advantage of this arrangement is that the high frequency signal can transmit the required electrical energy from the electrodes **520***a* and **520***b* to the microelectronic substrate **110**, while the low frequency superimposed signal can more effectively promote the electrochemical reaction between the electrolyte **531** and the conductive layer **111** of the microelectronic substrate **110**. Accordingly, any of the embodiments described above with reference to **FIGS. 3-11** can include an amplitude modulator in addition to a current source.

[0083] **FIG. 13** is a partially schematic, side elevational view of an apparatus **960** for electrically, chemically and/or mechanically removing at least some of a conductive material **111** from the substrate **110**. In one aspect of this embodiment, the apparatus **960** can include a support member **940** that supports the substrate **110** with the face surface **113** and the conductive layer **111** facing upwardly. In a further aspect of this embodiment, the support member **940** can include a substrate drive unit **941** that translates (as indicated by arrow "A") and/or rotates (as indicated by arrow "B") the support member **940** and the substrate **110**.

[0084] The apparatus **960** can further include a material removal medium **930** that removes at least part of the conductive material **111** from the substrate **110**. In one aspect of this embodiment, the material removal medium **930** can include first and second electrodes **920***a*, **920***b* supported by an electrode support **937** and coupled to an electrical potential source **921**, such as an alternating current source or a pulsed direct current source. The material removal medium **930** can further include a polishing pad **982** having a first portion **982***a* adjacent to the first electrode **920***a* and a second portion **982***b* adjacent to the second electrode **920***b*. The material removal medium **930** can move relative to the support member **940** (and the microelectronic substrate **110**) as indicated by arrows "H" and "G."

[**0085**] A fluid **931** can be disposed between the microelectronic substrate **110** and a polishing surface **988** of the polishing pad **982** to facilitate electrical and/or chemical-mechanical removal of the conductive material **111**. For example, the fluid **931** can include an electrolyte that electrically couples the first and second electrodes **920***a*, **920***b* to the conductive material **111** on at least a substantial portion of the face surface **113**, as was generally described above. The fluid **931** can also include chemicals and/or abrasive elements to chemically and/or mechanically remove at least some of the conductive material **111** from the substrate **110**. Alternatively, the polishing pad **982** (rather than the fluid **931**) can include abrasive elements. Accordingly, the combination of electrical and chemical-mechanical removal techniques in one embodiment of the apparatus **960** can provide the user with an increased level of control over the rate at which the conductive material **111** is removed from the substrate **110**, the amount of conductive material **111** removed, and/or the region of the microelectronic substrate **110** from which the conductive material **111** is removed.

[**0086**] **FIGS. 14A-14C** illustrate apparatuses configured to receive gases generated during the electrical and/or chemical-mechanical process described above and conduct the gases away from a region proximate to the microelectronic substrate **110** and/or the electrodes. For example, an apparatus **960***a* shown in **FIG. 14A** can include a material removal medium **930***a* having an electrode support **937** with first and second electrodes **920***c* and **920***d*. The material removal medium **930***a* can further include polishing pad portions **982** (shown as a first polishing pad portion **982***c* adjacent the first electrode **920***c*, and a second polishing pad portion **982***d* adjacent the second electrode **920***d*). In one aspect of this embodiment, the polishing pad portions **982***c*, **982***d* can be generally non-porous and can cover less than the entire downwardly facing surface area of each of the electrodes **920***c*, **920***d*. Accordingly, an exposed surface **927** of each of the electrodes **920***c*, **920***d* directly faces the substrate **110**. These exposed surfaces **927** can include channels **925** defined by channel surfaces **926** that can collect gas bubbles and conduct the gas bubbles away from the region proximate to the substrate **110** and/or the electrodes **920***c*, **920***d*.

[**0087**] In a further aspect of this embodiment, the electrodes **920***c*, **920***d* can be separated from each other by a gap **928**. The gap can reduce or eliminate direct electrical coupling between the two electrodes, so that the current instead flows from one electrode through the conductive material **111** of the microelectronic substrate **110** to the other electrode. Furthermore, the gap **928** can operate in addition to, or in lieu of the channels **925** to conduct gas bubbles away from the electrodes **920***c*, **920***d* and/or the microelectronic substrate **110**. In still a further aspect of this embodiment, the electrode support **937** can rotate (as indicated by arrow "G") at a rate sufficient to move the gas bubbles radially outwardly by centrifugal force.

[**0088**] Another feature of the apparatus **960***a* shown in **FIG. 14A** is that the type and placement of the polishing pad portions **982***c*, **982***d* can control the electrical coupling between the electrodes **920***c*, **920***d* and the microelectronic substrate **110**. For example, the polishing pad portions **982***c*, **982***d* can be generally non-porous so that only the exposed portions of the electrodes **920***c*, **920***d* are electrically coupled to the substrate **110** via the fluid **931**. Alternatively, the polishing pad portions **982***c*, **982***d* can be porous or partially porous to allow some electrical coupling between the electrodes **920***c*, **920***d* and the substrate **110** in regions where the polishing pad portions **982***c*, **982***d* are interposed between the microelectronic substrate **110** and the electrodes. The degree of coupling through the polishing pad portions **982***c*, **982***d* can be less than the degree of electrical coupling between the exposed portions of the electrodes and the microelectronic substrate **110**. Further examples of arrangements for controlling the electrical coupling between the electrodes and the microelectronic substrate **110** are described below with reference to **FIGS. 17A-18**.

[**0089**] **FIG. 14B** illustrates an apparatus **960***b* that includes a material removal medium **930***b* having first and second electrodes **920***e*, **920***f* and corresponding first and second polishing pad portions **982***e*, **982***f* Each of the polishing pad portions **982***e*, **982***f* is porous and accordingly includes pores **983** and passages **984** extending from the pores **983** upwardly to the electrodes **920***e*, **920***f* The electrodes **920***e*, **920***f* can include downwardly facing channels **925***a* in fluid communication with the passages **984**. Accordingly, the passages **984** can allow gas bubbles to rise from the microelectronic substrate **110** through the polishing pad portions **982** to the channels **925***a*, where the gas is collected and removed. When the passages **984** are filled with the fluid **931**, the passages **984** can also provide an electrical link between the electrodes **920***e*, **920***f* and the microelectronic substrate **110**. The fluid **931** can either be provided directly on the surface of the microelectronic substrate **110** and then wick up through the pores **983**, or alternatively, the fluid **931** can be pumped through the passages **984** from above, as will be described in greater detail below with reference to **FIG. 15**.

[**0090**] **FIG. 14C** illustrates an apparatus **960***c* having a material removal medium **930***c* that includes first and second electrodes **920***g*, **920***h* and corresponding first and second polishing pad portions **982***g* and **982***h*. In one aspect of this embodiment, the polishing pad portions **982***g*, **982***h* can be porous to conduct gas bubbles away from the microelectronic substrate **110**, as described above with references to **FIG. 14B**. In another aspect of this embodiment, the electrodes **920***g*, **920***h* can include downwardly facing channels **925***b* positioned to collect the gas bubbles and inclined to conduct the gas bubbles away from the electrodes **920***g*, **920***h*. The material removal medium **930** can include an electrode support **937***c* having canted lower surfaces **938** to orient the passages **925***b* at a selected inclination angle. In one aspect of this embodiment, a downwardly facing surface **927** of each of the electrodes **920***g*, **920***h* is also inclined. The inclination angle can be shallow to reduce the difference in separation distance between the microelectronic substrate **110** and the electrodes at the center of the material removal medium **930***c* relative to the separation distance at the outer periphery of the material removal medium **930***c*. Alternatively, the inclination angle can be steeper to deliberately reduce the electrical coupling between the electrodes **920***g*, **920***h* and the microelectronic substrate **110** at the periphery of the material removal medium **930** and thereby control the electrical coupling between the electrodes and the microelectronic substrate. In still a further alternate embodiment, the channels **925***b* can be inclined upwardly (as shown in **FIG. 14C**), although a lower surface **927***c* of the electrodes **920***g*, **920***h* is horizontal, as indicated in dashed lines in **FIG. 14C**.

[0091] **FIG. 15** is a partially schematic, side-elevational view of an apparatus **1060** having a material removal medium **1030** that can controllably exert pressure on the microelectronic substrate **110** while recycling a portion of the process fluid and removing gas from a region proximate to the microelectronic substrate **110**. For example, in one aspect of this embodiment, the material removal medium **1030** can include a pressurized housing **1038** that supports a pliable polishing pad **1082** against the microelectronic substrate **110**. The housing **1038** can also support first and second electrodes **1020***a* and **1020***b* proximate to the polishing pad **1082**. In one aspect of this embodiment, the apparatus **1060** can further include a pressure conduit **1097** connected between a pressure source **1096** and the housing **1038**. When a pressurized fluid (such as air or another gas) is introduced into the housing **1038** via the pressure conduit **1097**, it can exert a downward force on the polishing pad **1082** that can increase the rate at which material is removed from the microelectronic substrate **110**. In a further aspect of this embodiment, the pressure applied to the polishing pad **1082** can be uniform over the entire extent of the polishing pad, as illustrated in **FIG. 15**. Alternatively, fluid at different pressures can be applied to different portions of the polishing pad **1082** to further control the mechanical removal of material from the microelectronic substrate **110**.

[0092] In another aspect of an embodiment of the apparatus **1060** shown in **FIG. 15**, the electrodes **1020***a*, **1020***b* can be separated from the polishing pad **1082** to define a passage **1091**. The passage **1091** can be coupled via a fluid supply conduit **1090** to a pump **1095** that supplies process fluid **1031** to the material removal medium **1030**. In still a further aspect of this embodiment, the fluid **1031** can split into two streams, one of which "weeps" through the perforations **1084** in the polishing pad **1082**, and one of which passes adjacent to the electrodes **1020***a*, **1020***b*. The fluid stream flowing adjacent to the electrodes **1020***a*, **1020***b* can cool the electrodes **1020***a*, **1020***b*. This fluid stream can also entrain and remove gas bubbles that accumulate against the downwardly facing surfaces of the electrodes **1020***a*, **1020***b*, and/or gas bubbles that may rise through the perforated polishing pad **1082**. The fluid passing adjacent to the electrodes **1020***a*, **1020***b* can be collected in a return conduit **1092** and withdrawn from the housing **1038**. In one aspect of this embodiment, a vacuum source **1093** can increase the rate at which the fluid **1031** is withdrawn from the housing **1038**. The fluid can be treated in a recycling device **1094** that can withdraw entrained gas from the fluid **1031** and/or provide makeup fluid before returning the fluid **1031** to the pump **1095** for another cycle.

[0093] One feature of an embodiment of the apparatus described above with reference to **FIG. 15** is that the pressure source **1096** can control the mechanical pressure applied by the polishing pad **1082** to the microelectronic substrate **110** and the fluid **1031** while the electrodes **1020***a*, **1020***b* control an electrochemical interaction with the conductive material **111** of the microelectronic substrate **110** with the electrodes **1020***a*, **1020***b*. In one aspect of this embodiment, the pressure applied to the polishing pad **1082** can be independent of the flow rate of the fluid **1031**. Alternatively, the fluid supply conduit **1090** can pressurize the housing **1038** while at the same time supplying fluid to the polishing pad **1082** and the region between the polishing pad **1082** and the electrodes **1020***a*, **1020***b*. Accordingly, the pressure conduit **1097** and the pressure source **1096** can be eliminated in this embodiment. In either embodiment, an advantage of this arrangement is that by controlling both the mechanical pressure on the substrate **110** and the electrochemical coupling with the substrate **110**, the apparatus **1060** can control the rate and manner with which the conductive material **111** is removed more precisely than can some conventional devices.

[0094] **FIG. 16** is a partially schematic, side elevational view of an apparatus **1160** for removing conductive material **111** from the microelectronic substrate **110** in accordance with another embodiment of the invention. In one aspect of this embodiment, the apparatus **1160** can include a substrate support **1110** that supports the microelectronic substrate **110** with the conductive material **111** facing downwardly against a polishing pad **1182**. A processing fluid **1131** is disposed on the polishing pad **1182** to promote removing material from the microelectronic substrate **110**, as described above.

[0095] In one aspect of this embodiment, the apparatus **1160** can further include pairs of first and second electrodes **1120***a*, **1120***b* positioned beneath, and/or integrated with the polishing pad **1182**. Each electrode **1120***a*, **1120***b* can have a surface **1127** facing toward the microelectronic substrate **110** and can be adjacent to a divider **1128** that electrically isolates the first electrode **1120***a* from the second electrode **1120***b*. The apparatus **1160** can further include a conduit **1138** that provides the processing fluid **1131** to the polishing pad **1182** where it can travel upwardly through pores or passages (not shown in **FIG. 16**) in the polishing pad **1182** to a polishing surface **1188**. The polishing surface **1188** can include channels **1189** that allow gas bubbles to collect and move laterally during processing, thereby limiting the time during which the bubbles will collect against the microelectronic substrate **110** where they can reduce the efficiency of the electrical and/or chemical-mechanical material removal processes.

[0096] In a further aspect of this embodiment, the apparatus **1160** can include an ultrasonic energy emitter **1112** in fluid communication with the material removal fluid **1131**. The ultrasonic energy emitter **1112** can transmit ultrasonic energy into the fluid **1131**, which can increase the rate and/or efficiency with which gas bubbles are removed from the region proximate to the microelectronic substrate **110**.

[0097] **FIGS. 17A-17E** illustrate apparatuses that include material removal media having spatially varying electrical characteristics in accordance with further embodiments of the invention. **FIG. 17A** illustrates a material removal medium **1230***a* that includes an electrode support **1237** supporting a first electrode **1220***a* and a second electrode **1220***b* proximate to the microelectronic substrate **110**. The material removal medium **1230***a* can further include a polishing pad **1282***a* disposed adjacent to the electrodes **1220***a*, **1220***b*. In one aspect of this embodiment, the polishing pad **1282***a* can include a plurality of regions **1284***a*-**1284***d*, one or more of which has electrical characteristics different than those of a neighboring region. The regions **1284***b*-**1284***d* can be disposed annularly about the region **1284***a* in one embodiment, or alternatively, the regions can have other patterns or arrangements in other embodiments. In any of these embodiments, adjacent regions **1284***a*-**1284***d* can have different dielectric constants and/or conductivities to spatially vary the degree of electrical coupling between the electrodes **1220***a*, **1220***b* and the microelectronic substrate **110**. Accordingly, the impedance of the circuit or circuits formed by the electrodes **1220***a*, **1220***b* and the conductive material **111** can vary over the surface of the microelectronic substrate **110**, providing a variation in the rate at which material is electrically removed from the conductive material **111**. Alternatively, the spatially varying electrical characteristics can correct for factors (such as varying relative velocity between the substrate **110** and the polishing pad **1282***a*) that would otherwise result in a spatially non-uniform material removal rate.

[0098] **FIG. 17B** illustrates a material removal medium **1230***b* having a porous polishing pad **1282***b* in accordance with another embodiment of the invention. In one aspect of this embodiment, the polishing pad **1282***b* can include pores **1283** and passages **1284** that provide fluid communication for a processing fluid **1231** to electrically couple the electrodes **1220***a* and **1220***b* to the conductive material **111** of the microelectronic substrate **110**. In a further aspect of this embodiment, the porosity of the polishing pad **1282***b* can vary in a continuous manner from one region to another. For example, the porosity can decrease in a radial outward direction. In other embodiments, the porosity can change in other manners to provide a different level of electrical coupling over different portions of the microelectronic substrate **110**.

[0099] **FIG. 17C** illustrates a material removal medium **1230***c* that includes a polishing pad **1282***c* having three concentric regions **1285***a*-**1285***c*, each with a different but constant porosity. In one aspect of this embodiment, the porosity of the polishing pad **1282***c* can decrease in a radial, outward direction, and in other embodiments, the porosity can change in other manners. In still further embodiments, the polishing pad **1282** can have more or fewer than three distinct regions.

[0100] **FIG. 17D** illustrates a material removal medium **1230***d* having a polishing pad **1282***d* with porous and nonporous regions. For example, the polishing pad **1282***d* can include a porous region **1286***a* toward the center of the material removal medium **1230***d*, and a nonporous region **1286***b* positioned concentrically about the porous region **1286***a*. Accordingly, the electrodes **1220***a*, **1220***b* can be electrically coupled with the microelectronic substrate **110** only in the central region of the material removal medium **1230***d*, while the polishing pad **1282***d* can mechanically remove material over the entire contact area between the material removal medium **1230***d* and the substrate **110**. In an alternative arrangement, shown in **FIG. 17E**, a material removal medium **1230***e* includes a polishing pad **1282***e* having uniform porosity. The polishing pad **1282***e* can be attached to a mask **1287** that precludes or at least limits electrical coupling between the electrodes **1220***a*, **1220***b* and the microelectronic substrate **110** in regions where the mask **1287** is interposed between the microelectronic substrate **110** and the polishing pad **1282***e*.

[0101] **FIG. 18** is a partially schematic, side-elevational view of an apparatus **1360** having a material removal medium **1330** that controls electrical coupling to the microelectronic substrate **110** by disposing different electrolytic fluids over different portions of the microelectronic substrate **110**. Accordingly, the material removal medium **1330** can include first, second and third electrolyte supply conduits **1338***a*-**1338***c* coupled to corresponding concentric regions **1382***a*-**1382***c* of the polishing pad **1382**. The concentric regions **1382***a*-**1382***c* can be separated by nonpermeable barriers **1328**. Within each region **1382***a*-**1382***c* are positioned first and second electrodes **1320***a*, **1320***b* that are electrically coupled to the conductive material **111** of the microelectronic substrate **110** via an electrolytic fluid **1331** in the pores of the polishing pad **1382**.

[0102] In one aspect of this embodiment, a first electrolytic fluid supplied to the first supply conduit **1338***a* can be different than a second electrolytic fluid supplied to the second conduit **1338***b*, and both the first and second electrolytic fluids can be different than a third electrolytic fluid supplied to the third supply conduit **1338***c*. For example, the first, second, and third electrolytic fluids can have different chemical compositions and/or different concentrations of the same chemical agent or agents. In either embodiment, the impedance of an electrical circuit that includes the first region **1382***a* and the conductive material **111** can be different than the impedance of an electrical circuit that includes the second region **1382***b* and the conductive material **111**. Accordingly, the degree to which the electrodes **1320***a*, **1320***b* are electrically coupled to the microelectronic substrate **110** can vary over the face of the microelectronic substrate **110**, providing control over the rate at which material are electrically removed from the microelectronic substrate.

[0103] From the foregoing, it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. For example, some or all of the techniques described above in the context of a web-format apparatus (such as the one shown in **FIG. 9**) can be applied was well to a rotary apparatus. The rate at which material is removed from the microelectronic substrate can be controlled by controlling characteristics of the electrical signal applied to the microelectronic substrate, the electrolytic fluid adjacent to the microelectronic substrate, and/or the polishing pad in contact with the microelectronic substrate. For example, characteristics of the electrical current can include current, voltage, waveform and/or frequency. Characteristics of the electrolytic fluid can include chemical composition, pH, and/or ionic strength. Characteristics of the polishing pad can include the pad configuration (such as shape, porosity, hardness, etc.). The rate at which material is removed can also be controlled by controlling the relative velocity and/or normal force between the polishing pad and the microelectronic substrate. Accordingly, the invention is not limited except as by the appended claims.

1-64. (Canceled)

65. An apparatus for removing conductive material from a microelectronic substrate, comprising:

a support member configured to support a microelectronic substrate; and

a material removal medium proximate to the support member, the material removal medium including a first electrode and a second electrode positioned to be spaced apart from the microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the first and second electrodes being coupleable to a source of varying electrical current, the material removal medium further including a gas removal surface positioned to remove gas from a region proximate to the microelectronic substrate and/or at least one of the first and second electrodes during operation.

66. The apparatus of claim 65 wherein the microelectronic substrate has a face surface and an edge surface, and wherein the material removal medium includes a polishing surface disposed between the face surface and both the first and second electrodes during operation.

67. The apparatus of claim 65, further comprising a housing supporting the material removal medium, the housing being coupleable to a source of pressurized fluid, and wherein the material removal medium includes a polishing pad having a first surface facing inwardly toward an interior of the housing and a second surface engaged with the microelectronic substrate during operation, the second surface being biased against the microelectronic substrate when the housing is coupled to the source of pressurized fluid during operation.

68. The apparatus of claim 65, further comprising a housing supporting the material removal medium, the housing being coupleable to a source of pressurizing fluid, and wherein the material removal medium includes a polishing pad having a first surface facing inwardly toward an interior of the housing and a second surface engaged with the microelectronic substrate during operation, the second surface being biased against the microelectronic substrate when the housing is coupled to the source of pressurizing fluid during operation, at least a portion of the first surface of the polishing pad being spaced apart from the first electrode to define a fluid passage, the fluid passage having an entrance coupleable to a source of electrolytic fluid, the fluid passage further having an exit.

69. The apparatus of claim 68, further comprising a vacuum source coupled to the exit of the fluid passage.

70. The apparatus of claim 65 wherein the material removal medium includes a polishing pad having a polishing surface positioned to engage the microelectronic substrate when the support member supports the microelectronic substrate.

71. The apparatus of claim 65 wherein the substrate support member is positioned to support the microelectronic substrate from below and the material removal medium is positioned above the substrate support.

72. The apparatus of claim 65 wherein at least one of the substrate support member and the material removal medium is rotatable at a rate sufficient to direct the gas radially outwardly and away from the microelectronic substrate.

73. The apparatus of claim 65, further comprising the microelectronic substrate.

74. The apparatus of claim 65, further comprising a liquid electrolyte disposed adjacent to the material removal medium.

75. The apparatus of claim 65 wherein the gas removal surface is one of a plurality of gas removal surfaces positioned to define a gas removal channel.

76. The apparatus of claim 65 wherein the material removal medium includes a medium support member supporting the first and second electrodes, and wherein the first and second electrodes each have a surface facing downwardly toward the microelectronic substrate during operation, and wherein the planarizing medium further includes a polishing pad positioned adjacent to at least one of the first and second electrodes and having the polishing surface facing downwardly and engaged with the microelectronic substrate during operation, the first and second electrodes being spaced apart from each other with the gas removal surface positioned above the microelectronic substrate during operation to collect the gas from the region proximate to the microelectronic substrate.

77. The apparatus of claim 65 wherein the first and second electrodes each have a surface facing downwardly toward the microelectronic substrate during operation, and wherein the gas removal surface is recessed into at least one of the downwardly facing surfaces.

78. The apparatus of claim 65 wherein the first and second electrodes each have a surface facing downwardly toward the microelectronic substrate during operation, and wherein at least one of the downwardly facing surfaces is non-horizontal to conduct gas away from the region proximate to the microelectronic substrate.

79. The apparatus of claim 65 wherein the material removal medium includes a porous polishing pad having a polishing surface with pores facing toward the microelectronic substrate during operation, and wherein the gas removal surface is in fluid communication with at least one of the pores to conduct gas away from the region.

80. An apparatus for removing conductive material from a microelectronic substrate, comprising:

a support member configured to support a microelectronic substrate;

a material removal medium proximate to the support member, the material removal medium including a first electrode and a second electrode each positioned to be spaced apart from the microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the first and second electrodes being coupleable to a source of varying electrical current; and

an ultrasonic energy emitter positioned proximate to the material removal medium to remove gas from a region proximate to the microelectronic substrate and/or at least one of the first and second electrodes during operation.

81. The apparatus of claim 80 wherein the ultrasonic energy emitter is positioned to contact an electrolytic fluid when the electrolytic fluid is disposed between the microelectronic substrate and at least one of the first and second electrodes.

82. The apparatus of claim 80 wherein the material removal medium further includes a gas removal surface positioned to remove the gas from the region proximate to the microelectronic substrate and/or at least one of the first and second electrodes during operation.

83. The apparatus of claim 80 wherein the material removal medium includes a polishing pad having a polishing surface positioned to engage the microelectronic substrate when the support member supports the microelectronic substrate.

84. An apparatus for removing conductive material from a microelectronic substrate, comprising:

a substrate support member configured to support a microelectronic substrate;

a material removal medium proximate to the substrate support member and having a polishing surface positioned to engage the microelectronic substrate when the microelectronic substrate is supported by the substrate support member, at least one of the material removal medium and the substrate support member being movable relative to the other, the material removal medium further having a first electrode at least proximate to the polishing surface and a second electrode at least proximate to the polishing surface and spaced apart from the first electrode, at least one of the first and second electrodes being coupleable to a source of varying electrical current, at least one of the substrate support member and the planarizing medium having a gas removal surface positioned to receive and remove gas from a region proximate to the microelectronic substrate during operation.

85. The apparatus of claim 84 wherein the microelectronic substrate has a face surface and an edge surface, and wherein the material removal medium includes a polishing surface disposed between the face surface and both the first and second electrodes during operation.

86. The apparatus of claim 84, further comprising the source of varying electrical current, and wherein the source coupled to at least one of the electrodes to transmit to the at least one electrode alternating current and/or pulsed direct current.

87. The apparatus of claim 84 wherein the substrate support is positioned to support the microelectronic substrate from below and the polishing surface is positioned to engage an upward facing surface of the microelectronic substrate.

88. The apparatus of claim 84, further comprising the microelectronic substrate.

89. The apparatus of claim 84 wherein the polishing surface has pores facing toward the microelectronic substrate during operation, and wherein the gas removal surface is in fluid communication with at least one of the pores to conduct gas away from the region proximate to the microelectronic substrate.

90. The apparatus of claim 84, further comprising a housing supporting the material removal medium, the housing being coupleable to a source of pressurizing fluid, and wherein the material removal medium includes a polishing pad having a first surface facing inwardly toward an interior of the housing and a second surface engaged with the microelectronic substrate during operation, the second surface being biased against the microelectronic substrate when the housing is coupled to the source of pressurizing fluid during operation, at least a portion of the first surface of the polishing pad being spaced apart from the first electrode to define a fluid passage, the fluid passage having an entrance coupleable to a source of electrolytic fluid and an exit, the fluid passage being positioned to entrain gas from at least one of first electrode and the first surface of the polishing pad.

91. An apparatus for removing conductive material from a face surface of a microelectronic substrate, comprising:

a substrate support member configured to support a microelectronic substrate; and

a material removal medium positioned proximate to the substrate support member, the material removal medium having a medium support member and first and second electrodes supported by the medium support member, both the first and second electrodes facing toward the face surface of the microelectronic substrate during operation, the material removal medium further including a polishing pad at least proximate to the first and second electrodes and engaged with the microelectronic substrate when the substrate support member support the microelectronic substrate.

92. The apparatus of claim 91 wherein the polishing pad is interposed between at least a portion of the electrode surfaces and the microelectronic substrate during operation.

93. The apparatus of claim 91 wherein the polishing pad depends from at least one of the least electrodes.

94. The apparatus of claim 91 wherein the material removal medium further includes a gas removal surface positioned to receive and remove gas from a region proximate to the microelectronic substrate during operation.

95. The apparatus of claim 91 wherein the material removal medium has first and second regions positioned to be electrically coupled to the microelectronic substrate, the first region having a first electrical characteristic, the second region having a second electrical characteristic different than the first electrical characteristic.

96. An apparatus for removing conductive material from a microelectronic substrate, comprising:

a support member configured to support a microelectronic substrate; and

a material removal medium proximate to the support member and having a polishing surface positioned to engage the microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the material removal medium and the support member being movable relative to the other, the material removal medium having a first region with a first electrical characteristic and a second region with a second electrical characteristic different than the first electrical characteristic, the first region being aligned with a first portion of the microelectronic substrate and the second region being aligned with a second portion of the microelectronic substrate when the polishing surface is engaged with the microelectronic substrate, the material removal medium further including a first electrode proximate to the polishing surface and a second electrode proximate to the polishing surface, at least one of the first and second electrodes being coupleable to a source of varying electrical current.

97. The apparatus of claim 96 wherein the material removal medium includes a polishing pad having the polishing surface, further wherein the polishing pad has a first dielectric constant in the first region and a second dielectric constant in the second region, the first dielectric constant being different than the second dielectric constant.

98. The apparatus of claim 96 wherein the material removal medium includes a polishing pad having the polishing surface, the polishing pad being generally porous in the first region and generally non-porous in the second region.

99. The apparatus of claim 96 wherein the material removal medium includes a polishing pad having the polishing surface, the polishing pad having a first porosity in the first region and a second porosity different than the first porosity in the second region.

100. The apparatus of claim 96 wherein the material removal medium includes a generally porous polishing pad having the polishing surface, and wherein the material removal medium further includes a generally non-porous blocking material adjacent to the polishing pad in the first region to block pores of the polishing pad in the first region.

101. An apparatus for removing conductive material from a microelectronic substrate, comprising:

a support member configured to support a microelectronic substrate; and

a material removal medium proximate to the support member and having a first region with a first electrical characteristic and a second region with a second electrical characteristic different than the first electrical characteristic, the first region being aligned with a first portion of the microelectronic substrate and the second region being aligned with a second portion of the microelectronic substrate when the support member supports the microelectronic substrate, the material removal medium further including a first electrode and a second electrode at least proximate to the microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the first and second electrodes being coupleable to a source of varying electrical current.

102. The apparatus of claim 101 wherein the material removal medium further includes a polishing pad having a polishing surface positioned to engage the microelectronic substrate during operation.

103. The apparatus of claim 101 wherein the material removal medium includes a polishing pad having a polishing surface positioned to engage the microelectronic substrate during operation, further wherein the polishing pad has a first dielectric constant in the first region and a second dielectric constant in the second region, the first dielectric constant being different than the second dielectric constant.

104. The apparatus of claim 101 wherein the material removal medium includes a polishing pad having a polishing surface positioned to engage the microelectronic substrate during operation, the polishing pad being generally porous in the first region and generally non-porous in the second region.

105. The apparatus of claim 101 wherein the material removal medium includes a polishing pad having a polishing surface positioned to engage the microelectronic substrate during operation, the polishing pad having a first porosity in the first region and a second porosity different than the first porosity in the second region.

106. The apparatus of claim 101 wherein the material removal medium includes a generally porous polishing pad having a polishing surface positioned to engage the microelectronic substrate during operation, and wherein the material removal medium further includes a generally non-porous blocking material adjacent to the polishing pad in the first region to block pores of the polishing pad in the first region.

107. The apparatus of claim 101 wherein the material removal medium includes a first electrolytic fluid in the first region and a second electrolytic fluid in the second region, the second electrolytic fluid being different than the first electrolytic fluid.

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