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(54) **ENDPOINT FOR ELECTROCHEMICAL PROCESSING**

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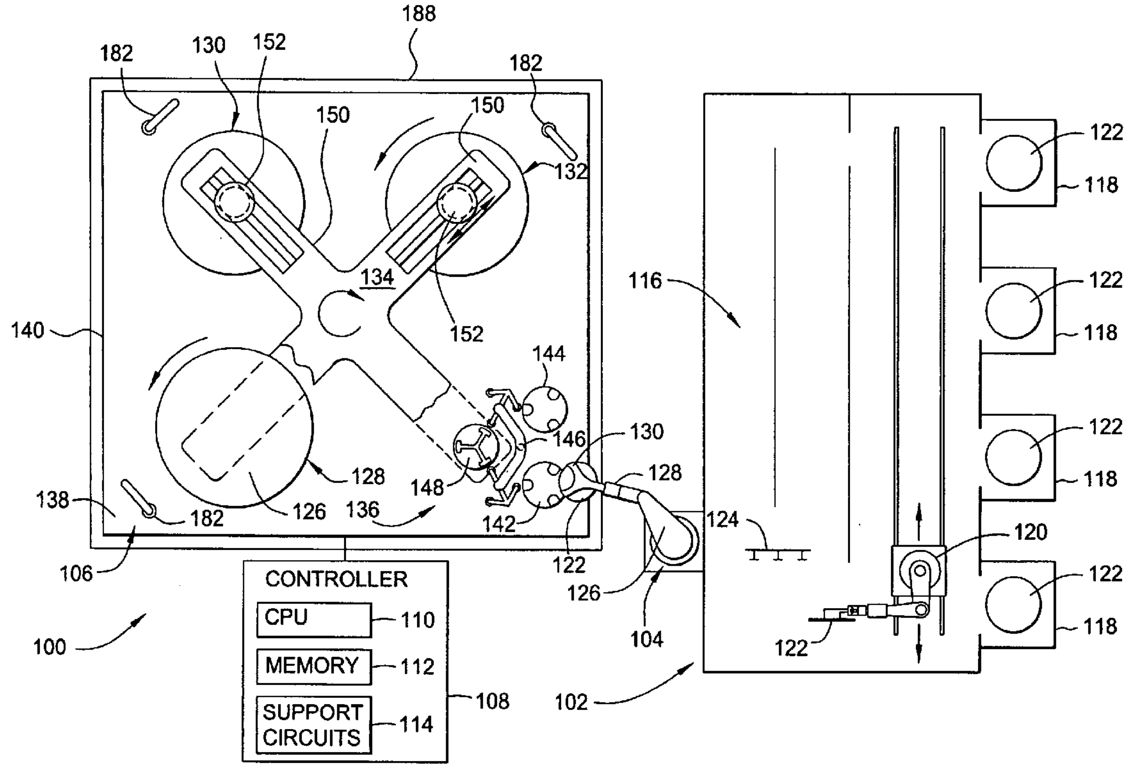
(52) **U.S. Cl.** **205/640**

(57) **ABSTRACT**

A method and apparatus for electrochemically processing a substrate is provided. In one embodiment, a method for electrochemically processing a substrate includes the steps of establishing an electrically-conductive path through an electrolyte between an exposed layer of barrier material on the substrate and an electrode, electrochemically removing a portion of the exposed layer during a first electrochemical processing step in a barrier processing station, detecting an endpoint of the first electrochemical processing step at or just prior to breakthrough of the exposed layer of barrier material, electrochemically processing the exposed layer of barrier material in a second electrochemical processing step in the barrier processing station, and detecting an endpoint of the second electrochemical processing step.



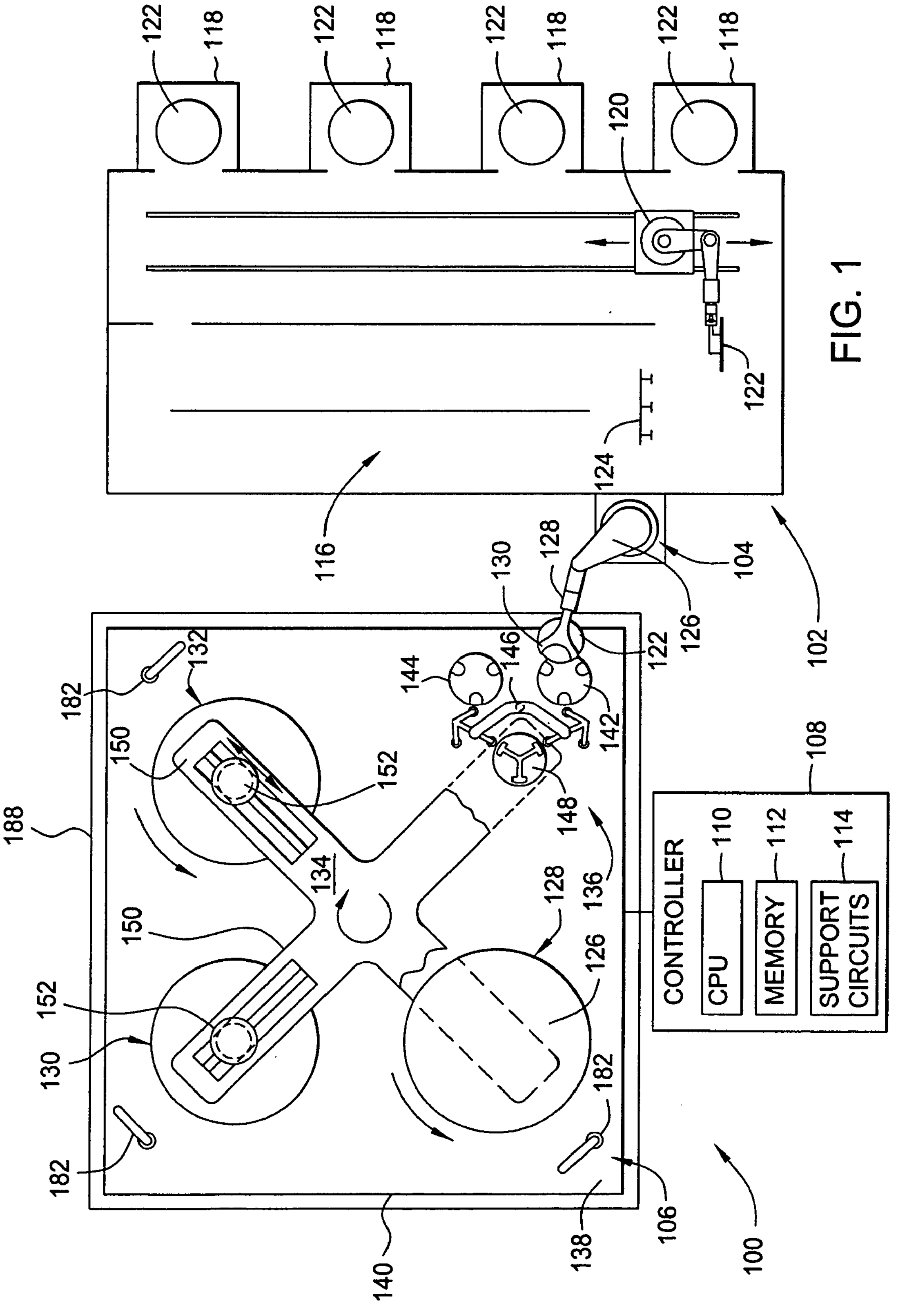

122
118
122
118
122
118
122
118
120
122
124
116
104
126
102
128
130
122
188
182
132
150
152
144
146
142
148
134
136
128
150
152
130
126
182
182
140
138
106
100
108
CONTROLLER
110
CPU
112
MEMORY
114
SUPPORT CIRCUITS

FIG. 1

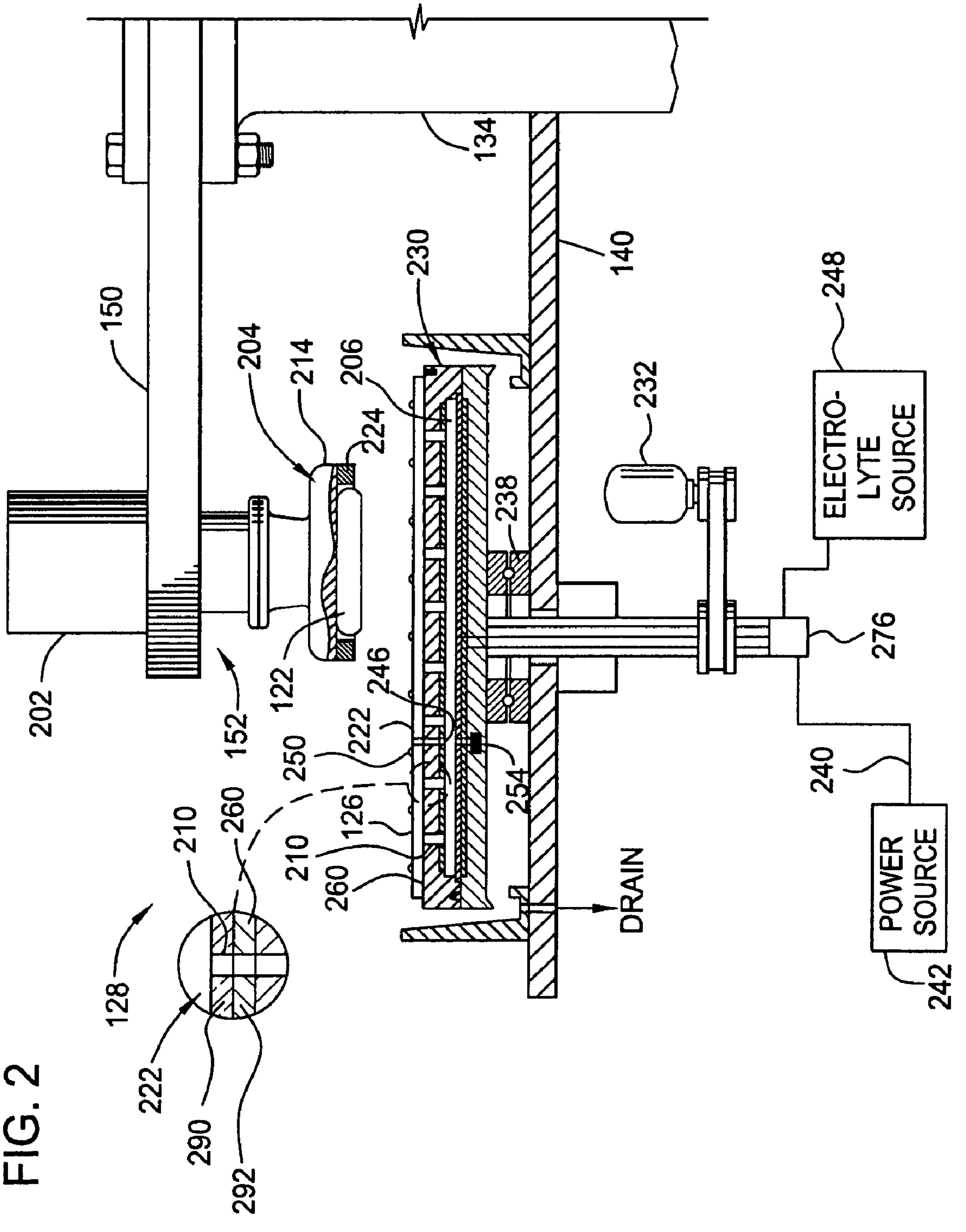

150
134
140
202
152
204
214
224
206
230
122
246
222
250
126
210
260
254
238
232
276
240
248
ELECTRO-LYTE SOURCE
POWER SOURCE
242
DRAIN
128
210
260
222
290
292

FIG. 2

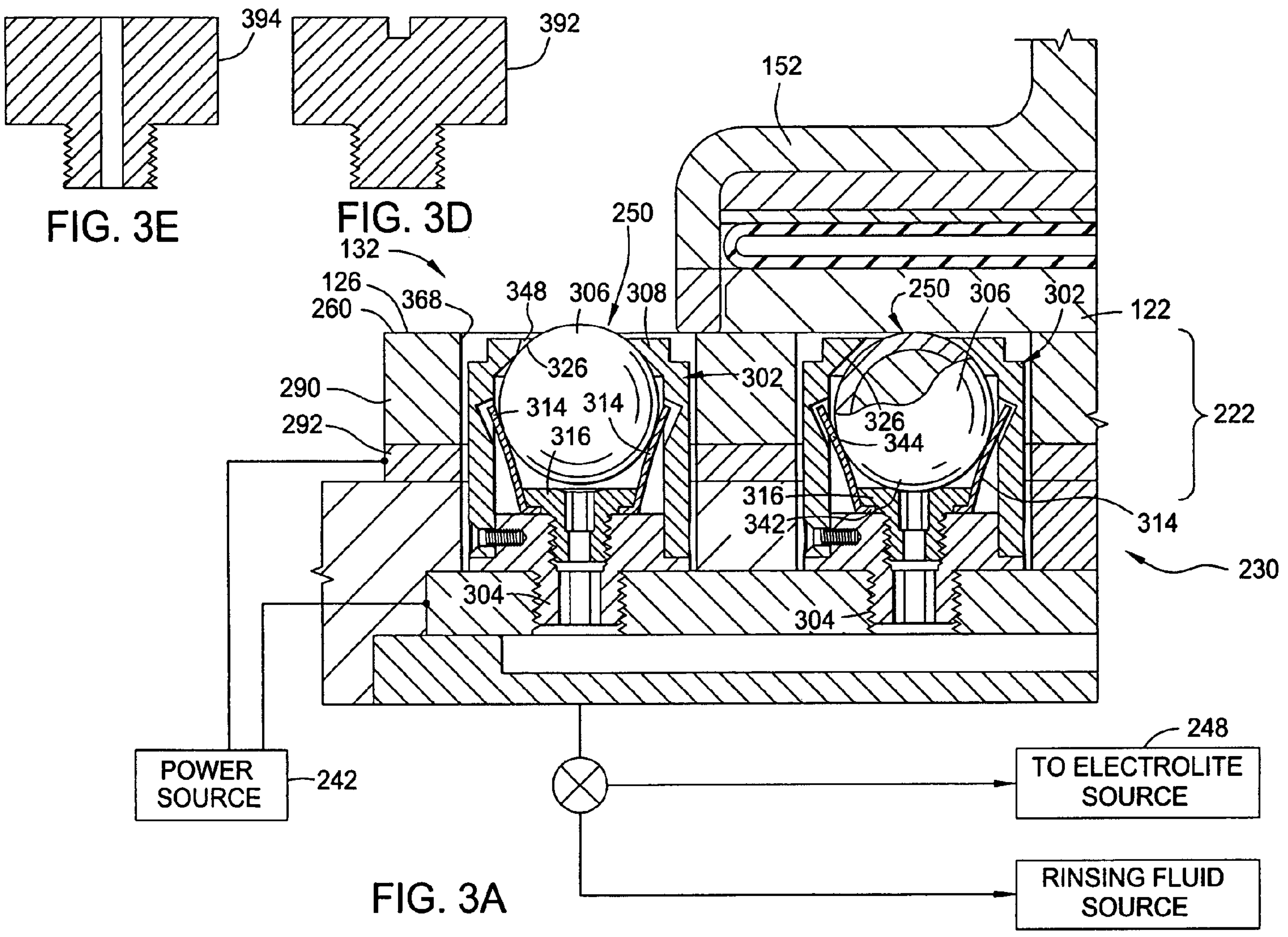


FIG. 3E

FIG. 3D

FIG. 3A

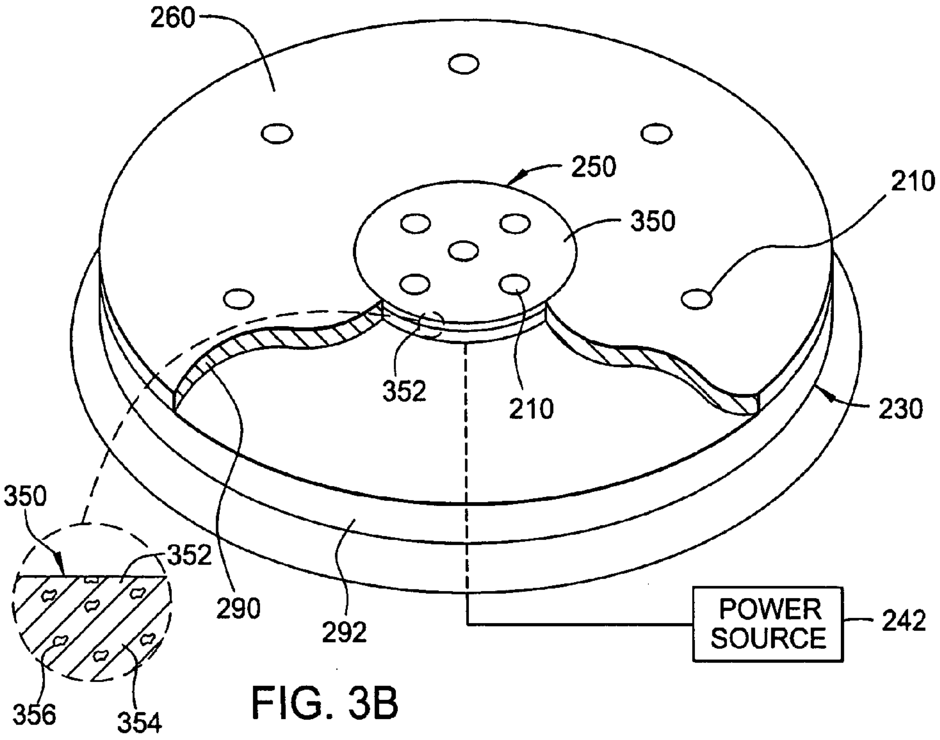

260
250
350
210
352
210
230
350
352
290
292
356
354
POWER SOURCE
242

FIG. 3B

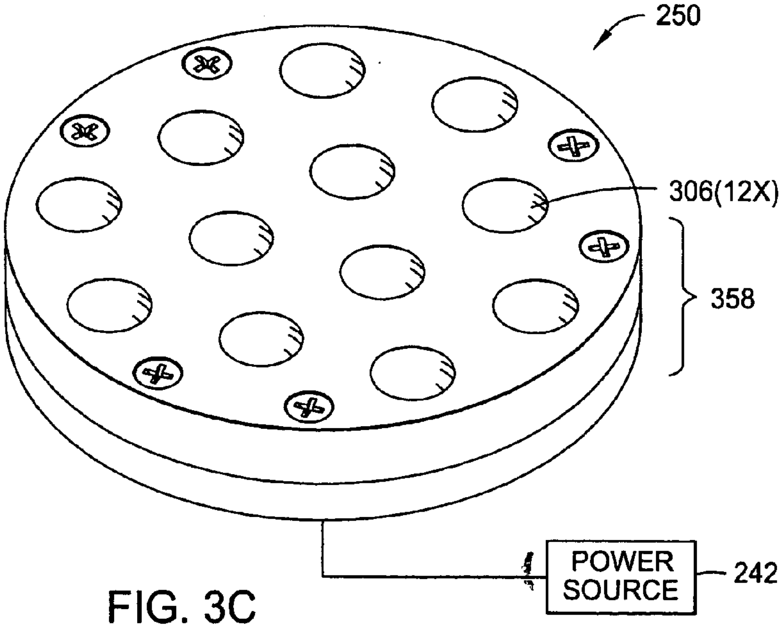

250
306(12X)
358
POWER SOURCE
242

FIG. 3C

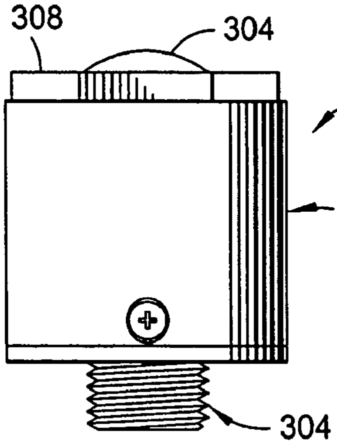


FIG. 4A

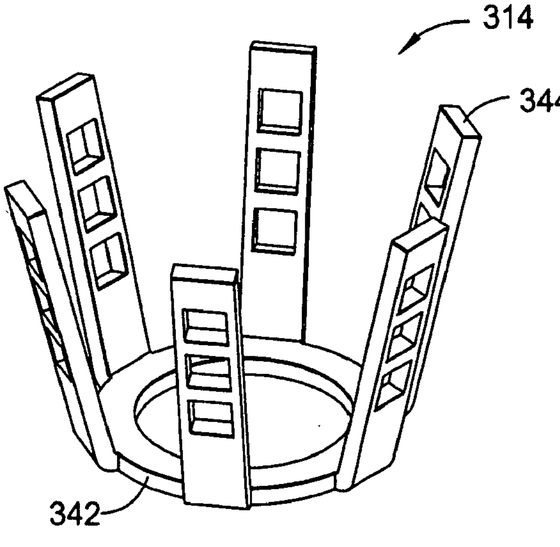


FIG. 5

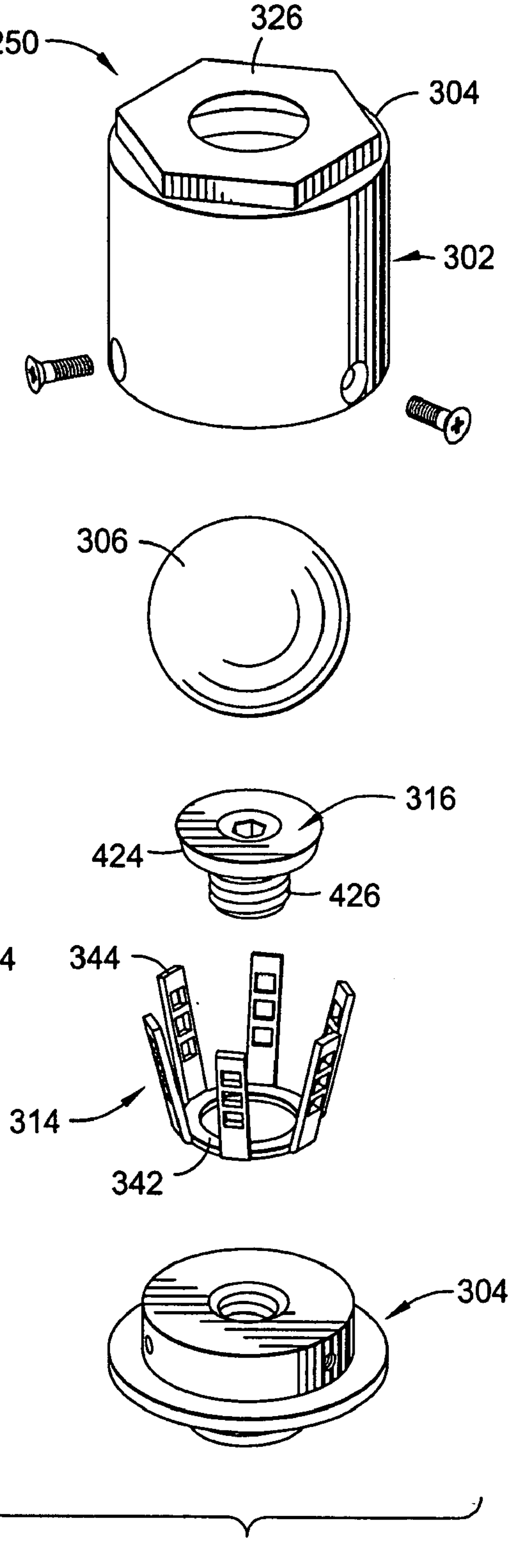


FIG. 4B

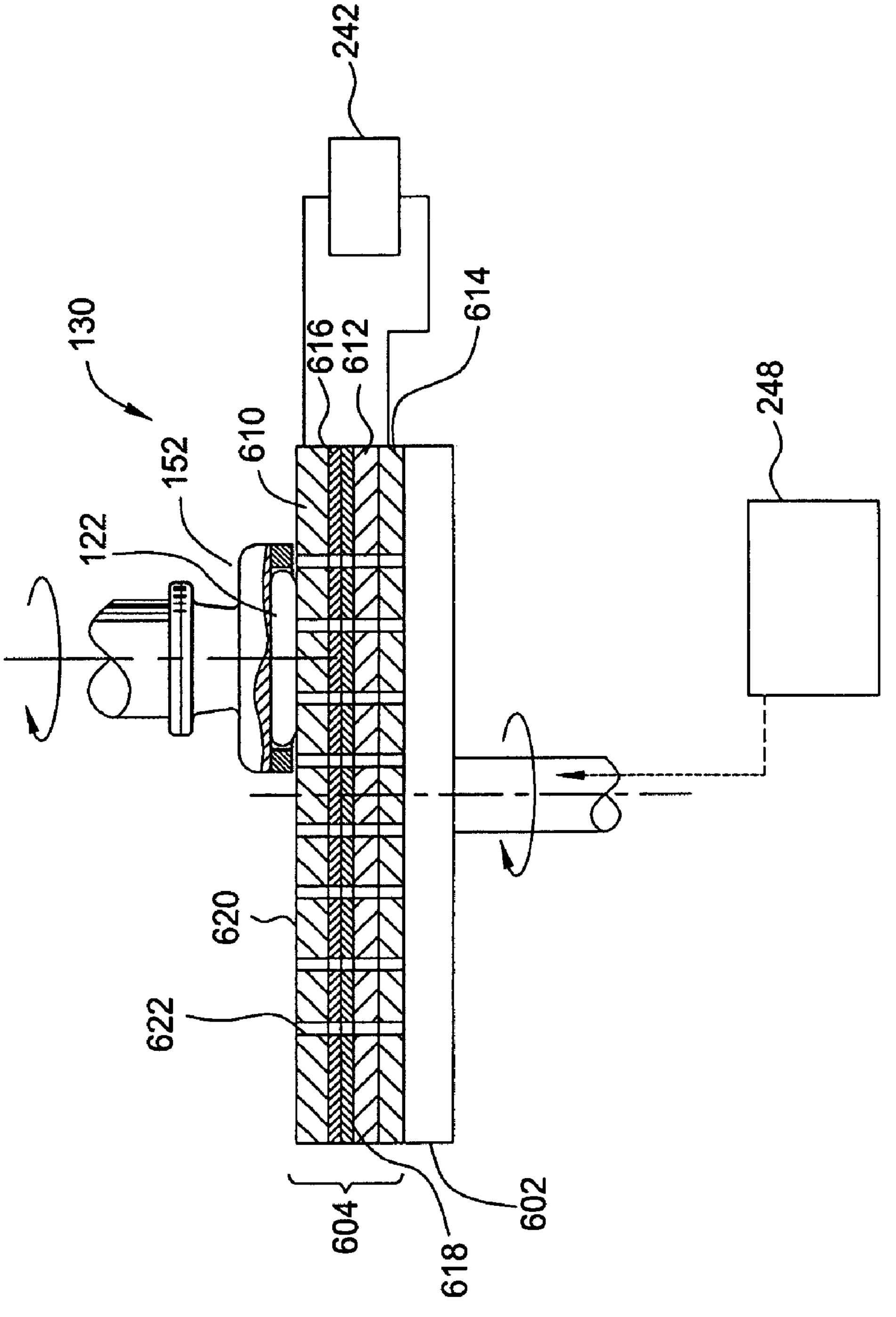
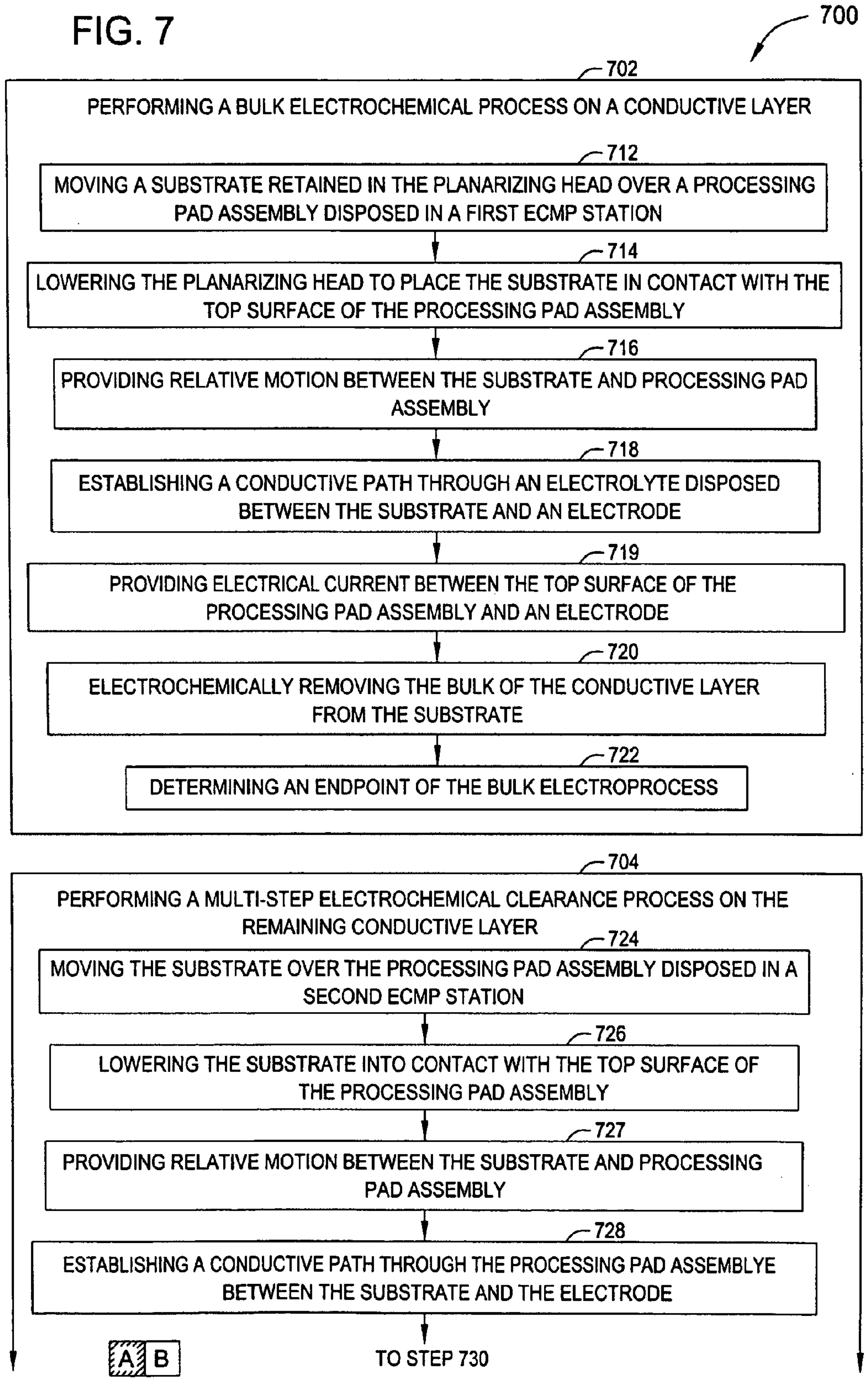
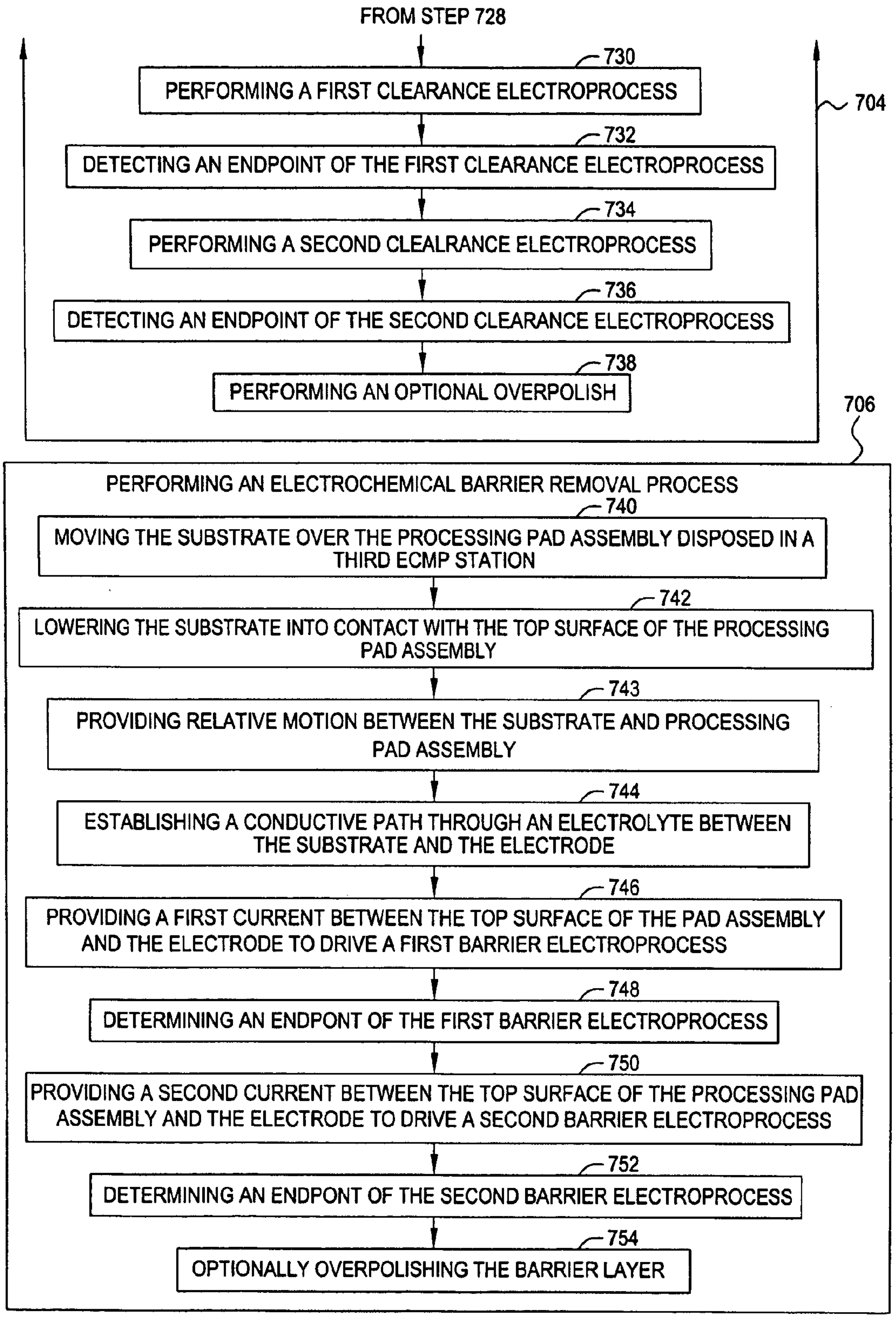


FIG. 6

FIG. 7


700
702
PERFORMING A BULK ELECTROCHEMICAL PROCESS ON A CONDUCTIVE LAYER
712
MOVING A SUBSTRATE RETAINED IN THE PLANARIZING HEAD OVER A PROCESSING PAD ASSEMBLY DISPOSED IN A FIRST ECMP STATION
714
LOWERING THE PLANARIZING HEAD TO PLACE THE SUBSTRATE IN CONTACT WITH THE TOP SURFACE OF THE PROCESSING PAD ASSEMBLY
716
PROVIDING RELATIVE MOTION BETWEEN THE SUBSTRATE AND PROCESSING PAD ASSEMBLY
718
ESTABLISHING A CONDUCTIVE PATH THROUGH AN ELECTROLYTE DISPOSED BETWEEN THE SUBSTRATE AND AN ELECTRODE
719
PROVIDING ELECTRICAL CURRENT BETWEEN THE TOP SURFACE OF THE PROCESSING PAD ASSEMBLY AND AN ELECTRODE
720
ELECTROCHEMICALLY REMOVING THE BULK OF THE CONDUCTIVE LAYER FROM THE SUBSTRATE
722
DETERMINING AN ENDPOINT OF THE BULK ELECTROPROCESS
704
PERFORMING A MULTI-STEP ELECTROCHEMICAL CLEARANCE PROCESS ON THE REMAINING CONDUCTIVE LAYER
724
MOVING THE SUBSTRATE OVER THE PROCESSING PAD ASSEMBLY DISPOSED IN A SECOND ECMP STATION
726
LOWERING THE SUBSTRATE INTO CONTACT WITH THE TOP SURFACE OF THE PROCESSING PAD ASSEMBLY
727
PROVIDING RELATIVE MOTION BETWEEN THE SUBSTRATE AND PROCESSING PAD ASSEMBLY
728
ESTABLISHING A CONDUCTIVE PATH THROUGH THE PROCESSING PAD ASSEMBLYE BETWEEN THE SUBSTRATE AND THE ELECTRODE
A B
TO STEP 730



A B

FIG. 7 (CONTINUED)

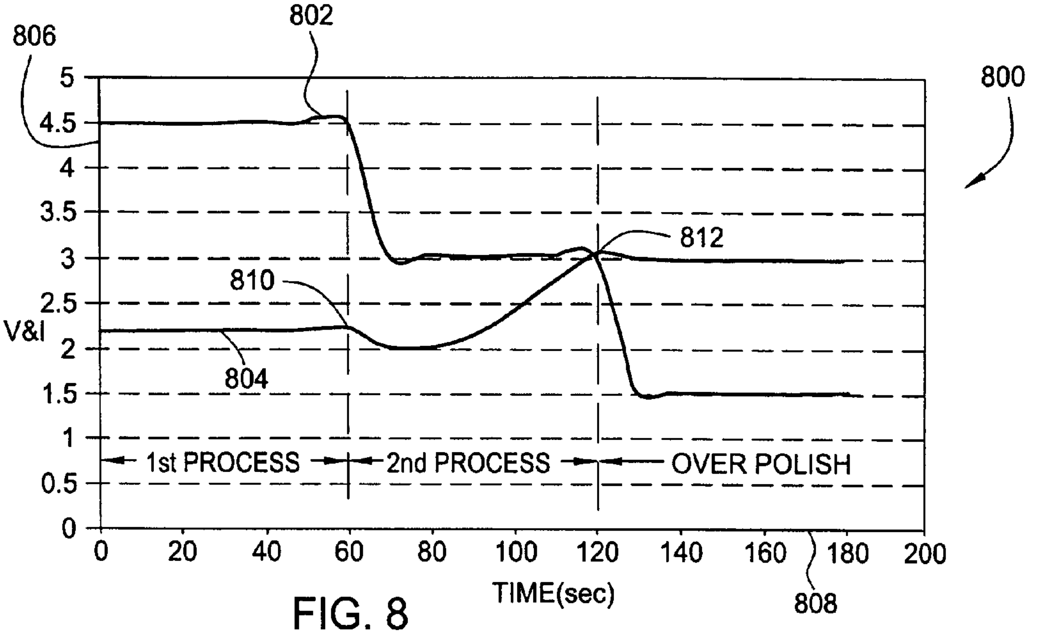

806
802
800
812
810
804
808
V&I
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
160
180
200
TIME(sec)
1st PROCESS
2nd PROCESS
OVER POLISH

FIG. 8

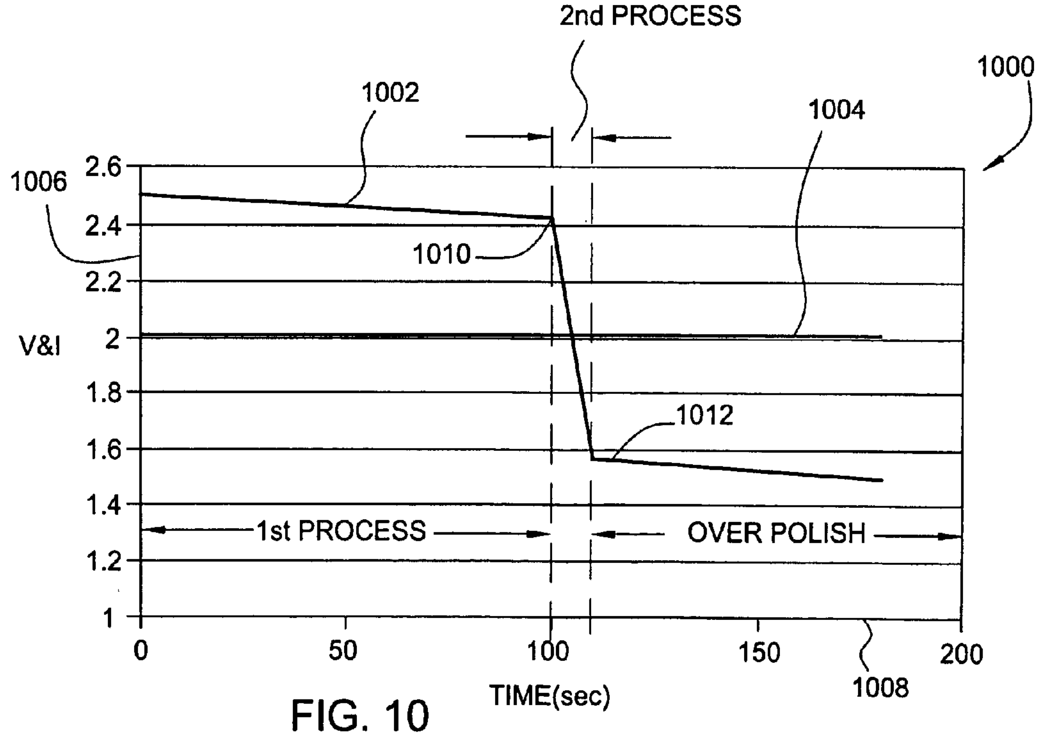

2nd PROCESS
1000
1002
1004
1006
1010
1012
1008
V&I
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0
50
100
150
200
TIME(sec)
1st PROCESS
OVER POLISH

FIG. 10

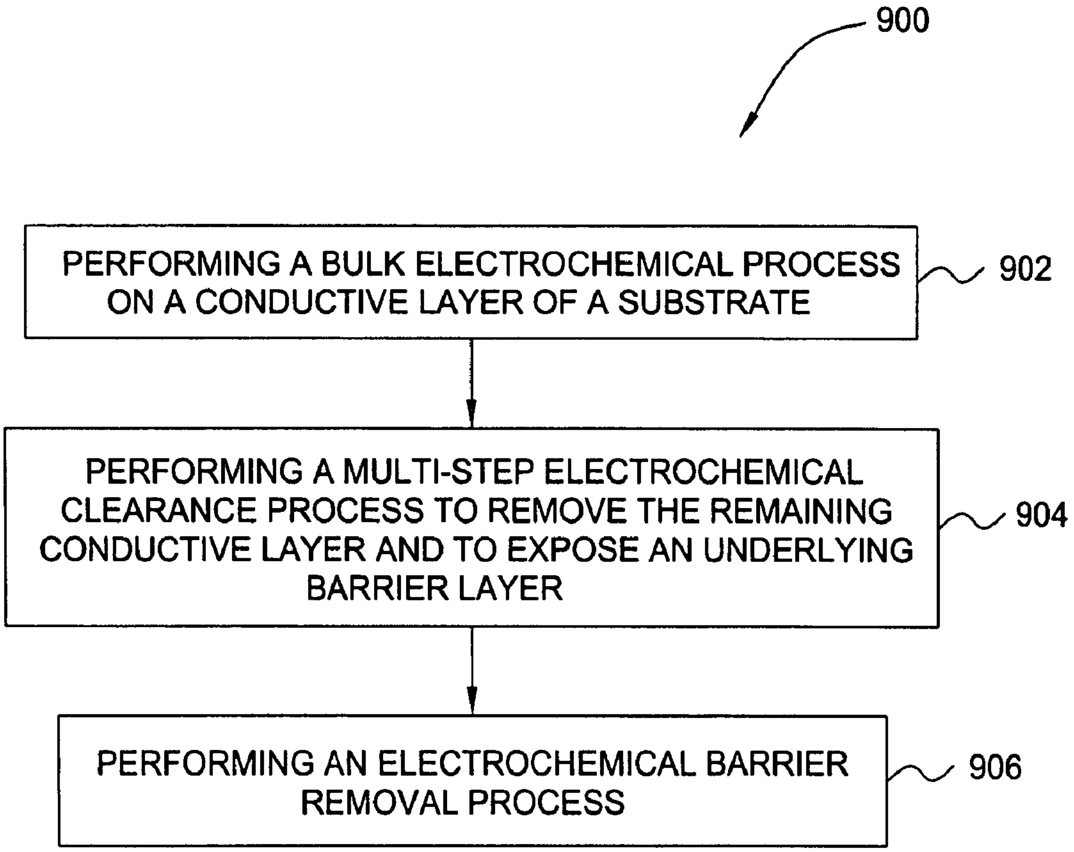

900
PERFORMING A BULK ELECTROCHEMICAL PROCESS ON A CONDUCTIVE LAYER OF A SUBSTRATE
902
PERFORMING A MULTI-STEP ELECTROCHEMICAL CLEARANCE PROCESS TO REMOVE THE REMAINING CONDUCTIVE LAYER AND TO EXPOSE AN UNDERLYING BARRIER LAYER
904
PERFORMING AN ELECTROCHEMICAL BARRIER REMOVAL PROCESS
906

FIG. 9

ENDPOINT FOR ELECTROCHEMICAL PROCESSING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of co-pending U.S. patent application Ser. No. 10/056,316 (Attorney Docket No. 6339), filed Jan. 22, 2002, entitled ENDPOINT DETECTION FOR ELECTRO CHEMICAL MECHANICAL POLISHING AND ELECTROPOLISHING PROCESSES, which is herein incorporated by reference in its entirety.

[0002] This application is related to U.S. patent application Ser. No. ______ (Attorney Docket No. 7187P2), filed ______, by Antoine Manens, entitled END POINT COMPENSATION IN ELECTROPROCESSING, which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0003] 1. Field of the Invention

[0004] Embodiments of the present invention generally relate to a method for endpoint detection for electrochemical processing.

[0005] 2. Description of the Related Art

[0006] Electrochemical mechanical planarizing (ECMP) is a technique used to remove conductive materials from a substrate surface by electrochemical dissolution while concurrently polishing the substrate with reduced mechanical abrasion compared to conventional planarization processes. ECMP systems may generally be adapted for deposition of conductive material on the substrate by reversing the polarity of the bias. Electrochemical dissolution is performed by applying a bias between a cathode and a substrate surface to remove conductive materials from the substrate surface into a surrounding electrolyte. Typically, the bias is applied to the substrate surface by a conductive polishing pad on which the substrate is processed. A mechanical component of the polishing process is performed by providing relative motion between the substrate and the conductive polishing pad that enhances the removal of the conductive material from the substrate.

[0007] Since the removal rate of the conductive film being processed may not be uniform across the diameter of the substrate, another film underlying this conductive can be exposed through the polished film. For example, during processing of a copper layer, the underlying barrier layer may be exposed when the remaining copper layer is about 2000-1000 Å thick. As the copper layer (or other conductive film being processed) no longer completely covers the original deposited area, remaining copper is removed rapidly as more and more of the underlying barrier layer is exposed. With further processing to remove residual copper from the substrate, the copper lines in the trenches in the exposed area tend to dish, and the exposed barrier layer maybe polished together with the oxide underneath, leading to erosion. The same holds true for ECMP of tungsten and other metals.

[0008] Moreover, as systems for electroprocessing copper generally rely on conventional chemical mechanical processing for barrier removal, such systems are complex, and require disparate utilities and share few common components between electroprocessing and conventional processing stations. Thus, it would be advantageous to have a system capable of removing barrier materials, such as tantalum, tantalum nitride, titanium and the like, through an electrochemical process.

[0009] Thus, there is a need for an improved method and apparatus for electrochemical processing of copper, tungsten and other conductive materials.

SUMMARY OF THE INVENTION

[0010] Embodiments of the invention generally provide a method for processing a substrate in an electrochemical mechanical planarizing system. In one embodiment, the method includes the steps of establishing an electrically-conductive path through an electrolyte between an exposed layer of barrier material on the substrate and an electrode, electrochemically removing a portion of the exposed layer during a first electrochemical processing step in a barrier processing station, detecting an endpoint of the first electrochemical processing step at or just prior to breakthrough of the exposed layer of barrier material, electrochemically processing the exposed layer of barrier material in a second electrochemical processing step in the barrier processing station, and detecting an endpoint of the second electrochemical processing step.

[0011] In another embodiment, a method for electrochemically processing a substrate includes removing a conductive layer having a barrier layer disposed thereunder at a first processing station of a system and electrochemically removing the barrier layer at a second processing station of the system. The system may include a processing station disposed between the first and second processing stations for residual removal of the conductive layer using a multi-step removal process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited embodiments of the invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0013] **FIG. 1** is a plan view of an electrochemical mechanical planarizing system;

[0014] **FIG. 2** is a sectional view of one embodiment of a first electrochemical mechanical planarizing (ECMP) station of the system of **FIG. 1**;

[0015] **FIG. 3A** is a partial sectional view of the first ECMP station through two contact assemblies;

[0016] FIGS. **3B**-C are sectional views of alternative embodiments of contact assemblies;

[0017] **FIG. 3D**-E are sectional views of plugs;

[0018] **FIGS. 4A and 4B** are side, exploded and sectional views of one embodiment of a contact assembly;

[0019] **FIG. 5** is one embodiment of a contact element;

[0020] **FIG. 6** is a vertical sectional view of another embodiment of an ECMP;

[0021] **FIG. 7** is a flow diagram of one embodiment of a method for electroprocessing conductive material;

[0022] **FIG. 8** is a graph of voltage and current plots for an exemplary electroprocess;

[0023] **FIG. 9** is a flow diagram of another embodiment of a method for electroprocessing conductive material; and

[0024] **FIG. 10** is a graph of current and voltage plots for an exemplary electroprocess.

[0025] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

DETAILED DESCRIPTION

[0026] Embodiments for a system and method for removal of conductive and barrier materials from a substrate are provided. Although the embodiments disclosed below focus primarily on removing material from, e.g., planarizing, a substrate, it is contemplated that the teachings disclosed herein may be used to electroplate a substrate by reversing the polarity of an electrical bias applied between the substrate and an electrode of the system.

[0027] Apparatus

[0028] **FIG. 1** is a plan view of one embodiment of a planarization system **100** having an apparatus for electrochemically processing a substrate. The exemplary system **100** generally comprises a factory interface **102**, a loading robot **104**, and a planarizing module **106**. The loading robot **104** is disposed proximate the factory interface **102** and the planarizing module **106** to facilitate the transfer of substrates **122** therebetween.

[0029] A controller **108** is provided to facilitate control and integration of the modules of the system **100**. The controller **108** comprises a central processing unit (CPU) **110**, a memory **112**, and support circuits **114**. The controller **108** is coupled to the various components of the system **100** to facilitate control of, for example, the planarizing, cleaning, and transfer processes.

[0030] The factory interface **102** generally includes a cleaning module **116** and one or more wafer cassettes **118**. An interface robot **120** is employed to transfer substrates **122** between the wafer cassettes **118**, the cleaning module **116** and an input module **124**. The input module **124** is positioned to facilitate transfer of substrates **122** between the planarizing module **106** and the factory interface **102** by grippers, for example vacuum grippers or mechanical clamps.

[0031] The planarizing module **106** includes at least a first electrochemical mechanical planarizing (ECMP) station **128**, disposed in an environmentally controlled enclosure **188**. Examples of planarizing modules **106** that can be adapted to benefit from the invention include MIRRA®, MIRRA MESA™, REFLEXION®, REFLEXION® LK, and REFLEXION LK Ecmp™ Chemical Mechanical Planarizing Systems, all available from Applied Materials, Inc. of Santa Clara, Calif. Other planarizing modules, including those that use processing pads, planarizing webs, or a combination thereof, and those that move a substrate relative to a planarizing surface in a rotational, linear or other planar motion may also be adapted to benefit from the invention.

[0032] In the embodiment depicted in **FIG. 1**, the planarizing module **106** includes the first ECMP station **128**, a second ECMP station **130** and a third ECMP station **132**. Bulk removal of conductive material disposed on the substrate **122** may be performed through an electrochemical dissolution process at the first ECMP station **128**. After the bulk material removal at the first ECMP station **128**, the remaining conductive material is removed from the substrate at the second ECMP station **130** through a multi-step electrochemical mechanical process, wherein part of the multi-step process is configured to remove residual conductive material. It is contemplated that more than one ECMP station may be utilized to perform the multi-step removal process after the bulk removal process performed at a different station. Alternatively, each of the first and second ECMP stations **128, 130** may be utilized to perform both the bulk and multi-step conductive material removal on a single station. It is also contemplated that all ECMP stations (for example 3 stations of the module **106** depicted in **FIG. 1**) may be configured to process the conductive layer with a two step removal process.

[0033] The exemplary planarizing module **106** also includes a transfer station **136** and a carousel **134** that are disposed on an upper or first side **138** of a machine base **140**. In one embodiment, the transfer station **136** includes an input buffer station **142**, an output buffer station **144**, a transfer robot **146**, and a load cup assembly **148**. The input buffer station **142** receives substrates from the factory interface **102** by means of the loading robot **104**. The loading robot **104** is also utilized to return polished substrates from the output buffer station **144** to the factory interface **102**. The transfer robot **146** is utilized to move substrates between the buffer stations **142, 144** and the load cup assembly **148**.

[0034] In one embodiment, the transfer robot **146** includes two gripper assemblies, each having pneumatic gripper fingers that hold the substrate by the substrate's edge. The transfer robot **146** may simultaneously transfer a substrate to be processed from the input buffer station **142** to the load cup assembly **148** while transferring a processed substrate from the load cup assembly **148** to the output buffer station **144**. An example of a transfer station that may be used to advantage is described in U.S. Pat. No. 6,156,124, issued Dec. 5, 2000 to Tobin, which is herein incorporated by reference in its entirety.

[0035] The carousel **134** is centrally disposed on the base **140**. The carousel **134** typically includes a plurality of arms **150**, each supporting a planarizing head assembly **152**. Two of the arms **150** depicted in **FIG. 1** are shown in phantom such that the transfer station **136** and a planarizing surface **126** of the first ECMP station **128** may be seen. The carousel **134** is indexable such that the planarizing head assemblies **152** may be moved between the planarizing stations **128, 130, 132** and the transfer station **136**. One carousel that may be utilized to advantage is described in U.S. Pat. No. 5,804,507, issued Sep. 8, 1998 to Perlov, et al., which is hereby incorporated by reference in its entirety.

[0036] A conditioning device **182** is disposed on the base **140** adjacent each of the planarizing stations **128, 130, 132**.

The conditioning device **182** periodically conditions the planarizing material disposed in the stations **128**, **130**,**132** to maintain uniform planarizing results.

[**0037**] **FIG. 2** depicts a sectional view of one of the planarizing head assemblies **152** positioned over one embodiment of the first ECMP station **128**. The second and third ECMP stations **130**, **132** may be similarly configured. The planarizing head assembly **152** generally comprises a drive system **202** coupled to a planarizing head **204**. The drive system **202** generally provides at least rotational motion to the planarizing head **204**. The planarizing head **204** additionally may be actuated toward the first ECMP station **128** such that the substrate **122** retained in the planarizing head **204** may be disposed against the planarizing surface **126** of the first ECMP station **128** during processing. The drive system **202** is coupled to the controller **108** that provides a signal to the drive system **202** for controlling the rotational speed and direction of the planarizing head **204**.

[**0038**] In one embodiment, the planarizing head may be a TITAN HEAD™ or TITAN PROFILER™ wafer carrier manufactured by Applied Materials, Inc. Generally, the planarizing head **204** comprises a housing **214** and retaining ring **224** that defines a center recess in which the substrate **122** is retained. The retaining ring **224** circumscribes the substrate **122** disposed within the planarizing head **204** to prevent the substrate from slipping out from under the planarizing head **204** while processing. The retaining ring **224** can be made of plastic materials such as PPS, PEEK, and the like, or conductive materials such as stainless steel, Cu, Au, Pd, and the like, or some combination thereof. It is further contemplated that a conductive retaining ring **224** may be electrically biased to control the electric field during ECMP. Conductive or biased retaining rings tend to slow the polishing rate proximate the edge of the substrate. It is contemplated that other planarizing heads may be utilized.

[**0039**] The first ECMP station **128** generally includes a platen assembly **230** that is rotationally disposed on the base **140**. The platen assembly **230** is supported above the base **140** by a bearing **238** so that the platen assembly **230** may be rotated relative to the base **140**. An area of the base **140** circumscribed by the bearing **238** is open and provides a conduit for the electrical, mechanical, pneumatic, control signals and connections communicating with the platen assembly **230**.

[**0040**] Conventional bearings, rotary unions and slip rings, collectively referred to as rotary coupler **276**, are provided such that electrical, mechanical, fluid, pneumatic, control signals and connections may be coupled between the base **140** and the rotating platen assembly **230**. The platen assembly **230** is typically coupled to a motor **232** that provides the rotational motion to the platen assembly **230**. The motor **232** is coupled to the controller **108** that provides a signal for controlling for the rotational speed and direction of the platen assembly **230**.

[**0041**] A top surface **260** of the platen assembly **230** supports a processing pad assembly **222** thereon. The processing pad assembly may be retained to the platen assembly **230** by magnetic attraction, vacuum, clamps, adhesives and the like.

[**0042**] A plenum **206** is defined in the platen assembly **230** to facilitate uniform distribution of electrolyte to the planarizing surface **126**. A plurality of passages, described in greater detail below, are formed in the platen assembly **230** to allow electrolyte, provided to the plenum **206** from an electrolyte source **248**, to flow uniformly though the platen assembly **230** and into contact with the substrate **122** during processing. It is contemplated that different electrolyte compositions may be provided during different stages of processing.

[**0043**] The processing pad assembly **222** includes an electrode **292** and at least a planarizing portion **290**. The electrode **292** is typically comprised of a conductive material, such as stainless steel, copper, aluminum, gold, silver and tungsten, among others. The electrode **292** may be solid, impermeable to electrolyte, permeable to electrolyte or perforated. At least one contact assembly **250** extends above the processing pad assembly **222** and is adapted to electrically couple the substrate being processing on the processing pad assembly **222** to the power source **242**. The electrode **292** is also coupled to the power source **242** so that an electrical potential may be established between the substrate and electrode **292**.

[**0044**] A meter **244** is provided to detect a metric indicative of the electrochemical process. The meter **244** may be coupled or positioned between the power source **242** and at least one of the electrode **292** or contact assembly **250**. The meter **244** may also be integral to the power source **242**. In one embodiment, the meter **244** is configured to provide the controller **108** with a metric indicative of processing, such a charge, current and/or voltage. This metric may be utilized by the controller **108** to adjust the processing parameters in-situ or to facilitate endpoint or other process stage detection.

[**0045**] A window **246** is provided through the pad assembly **222** and/or platen assembly **230**, and is configured to allow a sensor **254**, positioned below the pad assembly **222**, to sense a metric indicative of polishing performance. For example, the sensor **704** may be an eddy current sensor or an interferometer, among other sensors. The metric, provided by the sensor **254** to the controller **108**, provides information that may be utilized for processing profile adjustment in-situ, endpoint detection or detection of another point in the electrochemical process. In one embodiment, the sensor **254** an interferometer capable of generating a collimated light beam, which during processing, is directed at and impinges on a side of the substrate **122** that is being polished. The interference between reflected signals is indicative of the thickness of the conductive layer of material being processed. One sensor that may be utilized to advantage is described in U.S. Pat. No. 5,893,796, issued Apr. 13, 1999, to Birang, et al., which is hereby incorporated by reference in its entirety.

[**0046**] Embodiments of the processing pad assembly **222** suitable for removal of conductive material from the substrate **122** may generally include a planarizing surface **126** that is substantially dielectric. Other embodiments of the processing pad assembly **222** suitable for removal of conductive material from the substrate **122** may generally include a planarizing surface **126** that is substantially conductive. At least one contact assembly **250** is provided to couple the substrate to the power source **242** so that the substrate may be biased relative to the electrode **292** during processing. Apertures **210**, formed through the planarizing layer **290**, allow the electrolyte to establish a conductive path between the substrate **112** and electrode **292**.

[**0047**] In one embodiment, the planarizing portion **290** of the processing pad assembly **222** is a dielectric, such as polyurethane. Examples of processing pad assemblies that may be adapted to benefit from the invention are described in U.S. patent application Ser. No. 10/455,941, filed Jun. 6, 2003 by Y. Hu et al. (entitled "CONDUCTIVE PLANARIZING ARTICLE FOR ELECTROCHEMICAL MECHANICAL PLANARIZING") and U.S. patent application Ser. No. 10/455,895, filed Jun. 6, 2003 by Y. Hu et al. (entitled "CONDUCTIVE PLANARIZING ARTICLE FOR ELECTROCHEMICAL MECHANICAL PLANARIZING"), both of which are hereby incorporated by reference in their entireties.

[**0048**] **FIG. 3A** is a partial sectional view of the first ECMP station **128** through two contact assemblies **250**, and FIGS. 4A-C are side, exploded and sectional views of one of the contact assemblies **250** shown in **FIGS. 3A**. The platen assembly **230** includes at least one contact assembly **250** projecting therefrom and coupled to the power source **242** that is adapted to bias a surface of the substrate **122** during processing. The contact assemblies **250** may be coupled to the platen assembly **230**, part of the processing pad assembly **222**, or a separate element. Although two contact assemblies **250** are shown in **FIG. 3A**, any number of contact assemblies may be utilized and may be distributed in any number of configurations relative to the centerline of the platen assembly **230**.

[**0049**] The contact assemblies **250** are generally electrically coupled to the power source **242** through the platen assembly **230** and are movable to extend at least partially through respective apertures **368** formed in the processing pad assembly **222**. The positions of the contact assemblies **250** may be chosen to have a predetermined configuration across the platen assembly **230**. For predefined processes, individual contact assemblies **250** may be repositioned in different apertures **368**, while apertures not containing contact assemblies may be plugged with a stopper **392** or filled with a nozzle **394** (as shown in FIGS. 3D-E) that allows flow of electrolyte from the plenum **206** to the substrate. One contact assembly that may be adapted to benefit from the invention is described in U.S. patent application Ser. No. 10/445,239, filed May 23, 2003, by Butterfield, et a., and is hereby incorporated by reference in its entirety.

[**0050**] Although the embodiments of the contact assembly **250** described below with respect to **FIG. 3A** depicts a rolling ball contact, the contact assembly **250** may alternatively comprise a structure or assembly having a conductive upper layer or surface suitable for electrically biasing the substrate **122** during processing. For example, as depicted in **FIG. 3B**, the contact assembly **250** may include a pad structure **350** having an upper layer **352** made from a conductive material or a conductive composite (i.e., the conductive elements are dispersed integrally with or comprise the material comprising the upper surface), such as a polymer matrix **354** having conductive particles **356** dispersed therein or a conductive coated fabric, among others. The pad structure **350** may include one or more of the apertures **210** formed therethrough for electrolyte delivery to the upper surface of the pad assembly. Other examples of suitable contact assemblies are described in U.S. Provisional Patent Application Ser. No. 60/516,680, filed Nov. 3, 2003, by Hu, et al., which is hereby incorporated by reference in its entirety.

[**0051**] In one embodiment, each of the contact assemblies **250** includes a hollow housing **302**, an adapter **304**, a ball **306**, a contact element **314** and a clamp bushing **316**. The ball **306** has a conductive outer surface and is movably disposed in the housing **302**. The ball **306** may be disposed in a first position having at least a portion of the ball **306** extending above the planarizing surface **126** and at least a second position where the ball **306** is substantially flush with the planarizing surface **126**. It is also contemplated that the ball **306** may move completely below the planarizing surface **126**. The ball **306** is generally suitable for electrically coupling the substrate **122** to the power source **242**. It is contemplated that a plurality of balls **306** for biasing the substrate may be disposed in a single housing **358** as depicted in **FIG. 3C**.

[**0052**] The power source **242** generally provides a positive electrical bias to the ball **306** during processing. Between planarizing substrates, the power source **242** may optionally apply a negative bias to the ball **306** to minimize attack on the ball **306** by process chemistries.

[**0053**] The housing **302** is configured to provide a conduit for the flow of electrolyte from the source **248** to the substrate **122** during processing. The housing **302** is fabricated from a dielectric material compatible with process chemistries. A seat **326** formed in the housing **302** prevents the ball **306** from passing out of the first end **308** of the housing **302**. The seat **326** optionally may include one or more grooves **348** formed therein that allow fluid flow to exit the housing **302** between the ball **306** and seat **326**. Maintaining fluid flow past the ball **306** may minimize the propensity of process chemistries to attack the ball **306**.

[**0054**] The contact element **314** is coupled between the clamp bushing **316** and the adapter **304**. The contact element **314** is generally configured to electrically connect the adapter **304** and ball **306** substantially or completely through the range of ball positions within the housing **302**. In one embodiment, the contact element **314** may be configured as a spring form.

[**0055**] In the embodiment depicted in **FIGS. 3 and** 4A-C and detailed in **FIG. 5**, the contact element **314** includes an annular base **342** having a plurality of flexures **344** extending therefrom in a polar array. The flexure **344** is generally fabricated from a resilient and conductive material suitable for use with process chemistries. In one embodiment, the flexure **344** is fabricated from gold plated beryllium copper.

[**0056**] Returning to FIGS. 3A and 4A-B, the clamp bushing **316** includes a flared head **424** having a threaded post **422** extending therefrom. The clamp bushing **316** may be fabricated from either a dielectric or conductive material, or a combination thereof, and in one embodiment, is fabricated from the same material as the housing **302**. The flared head **424** maintains the flexures **344** at an acute angle relative to the centerline of the contact assembly **250** so that the flexures **344** of the contact elements **314** are positioned to spread around the surface of the ball **306** to prevent bending, binding and/or damage to the flexures **344** during assembly of the contact assembly **250** and through the range of motion of the ball **306**.

[0057] The ball **306** may be solid or hollow and is typically fabricated from a conductive material. For example, the ball **306** may be fabricated from a metal, conductive polymer or a polymeric material filled with conductive material, such as metals, conductive carbon or graphite, among other conductive materials. Alternatively, the ball **306** may be formed from a solid or hollow core that is coated with a conductive material. The core may be non-conductive and at least partially coated with a conductive covering.

[0058] The ball **306** is generally actuated toward the planarizing surface **126** by at least one of spring, buoyant or flow forces. In the embodiment depicted in **FIG. 3**, flow through the passages formed through the adapter **304** and clamp bushing **316** and the platen assembly **230** from the electrolyte source **248** urge the ball **306** into contact with the substrate during processing.

[0059] **FIG. 6** is a sectional view of one embodiment of the second ECMP station **130**. The first and third ECMP stations **128**, **132** may be configured similarly. The second ECMP station **130** generally includes a platen **602** that supports a fully conductive processing pad assembly **604**. The platen **602** may be configured similar to the platen assembly **230** described above to deliver electrolyte through the processing pad assembly **604**, or the platen **602** may have a fluid delivery arm **606** disposed adjacent thereto configured to supply electrolyte to a planarizing surface of the processing pad assembly **604**. The platen assembly **602** includes at least one of a meter **244** or sensor **254** (shown in **FIG. 2**) to facilitate endpoint detection.

[0060] In one embodiment, the processing pad assembly **604** includes interposed pad **612** sandwiched between a conductive pad **610** and an electrode **614**. The conductive pad **610** is substantially conductive across its top processing surface and is generally made from a conductive material or a conductive composite (i.e., the conductive elements are dispersed integrally with or comprise the material comprising the planarizing surface), such as a polymer matrix having conductive particles dispersed therein or a conductive coated fabric, among others. The conductive pad **610**, the interposed pad **612**, and the electrode **614** may be fabricated into a single, replaceable assembly. The processing pad assembly **604** is generally permeable or perforated to allow electrolyte to pass between the electrode **614** and top surface **620** of the conductive pad **610**. In the embodiment depicted in **FIG. 6**, the processing pad assembly **604** is perforated by apertures **622** to allow electrolyte to flow therethrough. In one embodiment, the conductive pad **610** is comprised of a conductive material disposed on a polymer matrix disposed on a conductive fiber, for example, tin particles in a polymer matrix disposed on a woven copper coated polymer. The conductive pad **610** may also be utilized for the contact assembly **250** in the embodiment of **FIG. 3C**.

[0061] A conductive foil **616** may additionally be disposed between the conductive pad **610** and the subpad **612**. The foil **616** is coupled to a power source **242** and provides uniform distribution of voltage applied by the source **242** across the conductive pad **610**. In embodiments not including the conductive foil **616**, the conductive pad **610** may be coupled directly, for example, via a terminal integral to the pad **610**, to the power source **242**. Additionally, the pad assembly **604** may include an interposed pad **618**, which, along with the foil **616**, provides mechanical strength to the overlying conductive pad **610**. Examples of suitable pad assemblies are described in the previously incorporated U.S. patent application Ser. Nos. 10/455,941 and 10/455,895.

[0062] Multi-Step Polishing Method

[0063] **FIG. 7** depicts one embodiment of a method **700** for electroprocessing conductive material, such as copper, tungsten, tantalum, tantalum nitride, titanium, titanium nitride, and the like, that may be practice on the system **100** described above. The method **700** may also be practiced on other electroprocessing systems. The method **700** is generally stored in the memory **112** of the controller **108**, typically as a software routine. The software routine may also be stored and/or executed by a second CPU (not shown) that is remotely located from the hardware being controlled by the CPU **110**.

[0064] Although the process of the present invention is discussed as being implemented as a software routine, some of the method steps that are disclosed therein may be performed in hardware as well as by the software controller. As such, the invention may be implemented in software as executed upon a computer system, in hardware as an application specific integrated circuit or other type of hardware implementation, or a combination of software and hardware.

[0065] The method **700** begins at step **702** by performing a bulk electrochemical process on the conductive layer, for example, copper, formed on the substrate **122**. In one embodiment, the bulk process step **702** is at the first ECMP station **128**. The bulk process step **702** generally is terminated when the conductive layer is about 2000 to about 1000 Å thick.

[0066] Next, a multi-step electrochemical clearance step **704** is performed to remove the remaining copper material to expose an underlying barrier layer, typically tantalum, tantalum nitride, titanium, titanium nitride and the like. The clearance step **704** may be performed on the first ECMP station **128**, or one of the other ECMP stations **130**, **132**.

[0067] Following the clearance step **704**, an electrochemical barrier removal step **706** is performed. Typically, the electrochemical barrier removal step **706** is performed on the third ECMP station **132**, but may alternatively be performed one of the other ECMP stations **128**, **130**.

[0068] In one embodiment, the bulk processing step **702** begins at step **712** by moving the substrate **122** retained in the planarizing head **204** over the processing pad assembly **222** disposed in the first ECMP station **128**. Although the pad assembly of **FIGS. 2**, **3A**, **4A**-C and **5**, are utilized in one embodiment it is contemplated that pad and contact assemblies as described in FIGS. 3B-C and **6** may alternatively be utilized. At step **714**, the planarizing head **204** is lowered toward the platen assembly **230** to place the substrate **122** in contact with the top surface of the pad assembly **222**. In one embodiment, the substrate **122** is urged against the pad assembly **222** with a force less than about 2 pounds per square inch (psi).

[0069] At step **716**, relative motion is provided between the substrate **122** and processing pad assembly **222**. In one embodiment, the planarizing head **204** is rotated at less than about 50 revolutions per minute, while the pad assembly **222** is rotated at least about 50 revolutions per minute.

[**0070**] At step **718**, electrolyte is supplied to the processing pad assembly **222** to establish a conductive path therethrough between the substrate **122** and the electrode **222**. At step **719**, current is provided from the power source **242** and runs between the top surface of the pad assembly **222** and the electrode **294**. In one embodiment, the current is held at a constant magnitude in the range of about 4 to about 5 amperes. Steps **716**, **718** and **719** are performed at substantially the same time.

[**0071**] In embodiments where tungsten is being processed, the current is about three times that utilized in copper processing to obtain the same removal rates. For example, step **719** may provide about 12 to about 15 amperes to remove a tungsten conductive layer.

[**0072**] The top surface of the pad assembly **222** is in contact with the substrate **122** and allows the current to be coupled thereto. The electrolyte filling the apertures **210** between the electrode **292** and the substrate **122** provides a conductive path between the power source **242** and substrate **122** to drive an electrochemical mechanical planarizing process that results in the removal of conductive material, such as copper, disposed on the surface of the substrate **122**, by an anodic dissolution method at step **720**. The process of step **720** generally has a removal rate of about 6000 Å/min.

[**0073**] At step **722**, an endpoint of the bulk electroprocess is determined. The endpoint may be determined using a first metric of processing provided by the meter **244**. The meter **244** may provide charge, voltage or current information utilized to determine the remaining thickness of the conductive material (e.g., the copper layer) on the substrate. In another embodiment, interferometer techniques, utilizing the sensor **254** may be utilized. The remaining thickness may be directly measured or calculated by subtracting the amount of material removed from a predetermined starting film thickness. In one embodiment, the endpoint is determined by comparing the charge removed from the substrate to a target charge amount for a predetermined area of the substrate. Examples of endpoint techniques that may be utilized are described in U.S. patent application Ser. No. 10/056,316, filed Jan. 22, 2002, and U.S. patent application Ser. No. 10/456,851, filed Jun. 6, 2002, both of which are hereby incorporated by reference in their entireties.

[**0074**] The step **722** is configured to detect the endpoint of the process prior to the breakthrough of the copper layer. In one embodiment, the remaining copper layer at step **722** has a thickness between about 1000 to about 2000 Å.

[**0075**] One embodiment of the clearance processing step **704** is now discussed with additional reference to a graph **800** of current and voltage traces **802**, **804** depicted in **FIG. 8**. Amplitude is plotted on the y-axis **806** and time is plotted on the x-axis **808**.

[**0076**] The clearance processing step **704** begins at step **724** by moving the substrate **122** retained in the planarizing head **204** over the processing pad assembly **604** disposed in the second ECMP station **130**. At step **726**, the planarizing head **204** is lowered toward the platen assembly **602** to place the substrate **122** in contact with the top surface of the pad assembly **604**. Although the pad assembly of **FIG. 6** is utilized in one embodiment it is contemplated that pad and contact assemblies as described in FIGS. **2**, **3**A-C, **4**A-C and **5** may alternatively be utilized. In one embodiment, the substrate **122** is urged against the pad assembly **604** with a force less than about 2 pounds per square inch (psi). At step **728**, electrolyte is supplied to the processing pad assembly **604** to establish a conductive path therethrough between the substrate **122** and the electrode **614**.

[**0077**] At a first clearance process step **730**, a first current is provided from the power source **242** and runs between the top surface of the pad assembly **604** and the electrode **614**. In one embodiment, the current (as illustrated by the current trace **802**) is held at a constant magnitude in the range of about 5 to about 4 amperes and passes through the electrolyte filling the apertures **622** between the electrode **614** and the substrate **122** to drive an electrochemical mechanical planarizing process. The process of step **730** generally has a removal rate of about similar to step **722**.

[**0078**] At step **732**, an endpoint of the electroprocess step **730** is determined. The endpoint may be determined using a first metric of processing provided by the meter **244** or by the sensor **254**. In one embodiment, the endpoint is determined by detecting a first discontinuity **810** in voltage sensed by the meter **244**. The first discontinuity **810** appears when the underlying layer begins to break through the conductive layer (e.g., copper layer). As the underlying layer has a different resistivity than the copper layer, the resistance across the processing cell (i.e., from the conductive portion of the substrate to the electrode **292**) changes as the area of copper layer relative to the exposed area of the underlying layer changes.

[**0079**] Utilizing current (or voltage) for endpoint detection is particularly useful in tungsten removal processes as the close reflexivity between tungsten and underlying titanium nitride materials makes convention optical detection difficult.

[**0080**] In response to the endpoint detection at step **732**, a second clearance process step **734** is performed to remove the residual copper layer. At step **734**, a second current is provided from the power source **242**. The current is held at a constant magnitude less than the current of step **730** and passes through the electrolyte filling the apertures **620** between the electrode **614** and the substrate **122** to drive an electrochemical mechanical planarizing process. For example, current may be provided in the range of about 1.5 to about 4.5 amperes. The process of step **734** generally has a removal rate of about 500 to about 1500 Å/min. In tungsten processes, the current may be in the range of about 4.5 to about 13.5 amperes to obtain removal rates of 500-2000 Å/min.

[**0081**] At step **736**, an endpoint of the electroprocess step **734** is determined. The endpoint may be determined using a second metric of processing provided by the meter **244** or by the sensor **254**. In one embodiment, the endpoint is determined by detecting a second discontinuity **812** in voltage sensed by the meter **244**. The discontinuity **812** appears when the underlying barrier layer is fully exposed and copper layer that remains substantially in the features formed in the substrate **122** (e.g., copper lines and vias).

[**0082**] Optionally, a third clearance process step **738** may be performed to remove any remaining debris from the conductive layer. The third clearance process step **738** is typically a timed process, and is performed at the same or reduced current levels relative to the second clearance process step **732**. In one embodiment, the third clearance process step **738** (also referred to as an overpolish step) has a duration of about 15 to about 30 seconds. During the step **738**, the current may be lowered to less than the current level for the previous processing step, for example, to about 0.5-3 amperes.

[**0083**] The electrochemical barrier removal step **706** begins at step **740** by moving the substrate **122** retained in the planarizing head **204** over the processing pad assembly **604** disposed in the third ECMP station **132**. At step **742**, the planarizing head **204** is lowered toward the platen assembly **602** to place the substrate **122** in contact with the top surface of the pad assembly **604**. Although the pad assembly of **FIG. 6** is utilized in one embodiment it is contemplated that pad and contact assemblies as described in FIGS. **2**, **3**A-C, **4**A-C and **5** may alternatively be utilized. In one embodiment, the substrate **122** is urged against the pad assembly **604** with a force less than about **2** pounds per square inch (psi). At step **744**, electrolyte is supplied to the processing pad assembly **604** to establish a conductive path therethrough between the substrate **122** and the electrode **614**. The electrolyte utilized for barrier removal may be different than the electrolyte utilized for copper removal.

[**0084**] In one embodiment, electrolyte composition provided at the third ECMP station **132** includes phosphoric or sulfuric acid and a catalyst. The electrolyte may be adapted to prevent or inhibit oxide formation on the barrier layer. The catalyst is selected to activate the Ti or other barrier layer to react selectively with a complexing agent so that the barrier layer may be removed and/or dissolved easily with minimal or no removal of copper or tungsten. The electrolyte composition may additionally include pH adjusters and clelating agents, such as amino acids, organic amines and phthalic acid or other organic carbolic acids, picolinic acid or its derivatives. The electrolyte may optionally contain abrasives. Abrasives may be desirable to remove a portion of the underlying oxide layer.

[**0085**] At a first barrier process step **746**, a first current is provided from the power source **242** and runs between the top surface of the pad assembly **604** and the electrode **614**. In one embodiment, the current is held at a constant magnitude in the range of about 1.5 to about 6 amperes and passes through the electrolyte filling the apertures **620** between the electrode **614** and the substrate **122** to drive an electrochemical mechanical planarizing process. The process of step **746** generally has a removal rate of about 500-2000 Å/min.

[**0086**] At step **748**, an endpoint of the electroprocess step **746** is determined. The endpoint may be determined using a first metric of processing provided by the meter **244** or by the sensor **254**. The current and voltage traces of the electrochemical barrier removal step **706** are similar is form to the traces depicted in **FIG. 8**, and as such, have been omitted for brevity. In one embodiment, the endpoint of step **748** is determined by detecting a first discontinuity in voltage sensed by the meter **244**. The first discontinuity appears when the underlying layer (typically an oxide) begins to breakthrough the barrier layer. As the underlying oxide layer has a different resistivity than the barrier layer, the change in resistance across the processing cell is indicative of the breakthrough of the barrier layer.

[**0087**] In response to the endpoint detection at step **748**, a second clearance process step **750** is performed to remove the residual copper layer. At step **748**, a second current is provided from the power source **242**. The current is held at a constant magnitude less than the current of step **746** and passes through the electrolyte filling the apertures **620** between the electrode **614** and the substrate **122** to drive an electrochemical mechanical planarizing process. For example, in one embodiment, current may be provided in the range of about 3.5 to about 2.5 amperes The process of step **748** generally has a removal rate of about 1000 Å/min.

[**0088**] At step **752**, an endpoint of the electroprocess step **750** is determined. The endpoint may be determined using a second metric of processing provided by the meter **244** or by the sensor **254**. In one embodiment, the endpoint is determined by detecting a second discontinuity in voltage sensed by the meter **244**. The second discontinuity appears when the oxide layer is fully exposed.

[**0089**] Optionally, a third clearance process step **754** may be performed to remove any remaining debris from the barrier layer. The third clearance process step **754** is typically a timed process, and is performed at the same or reduced current levels relative to the second clearance process step **746**. In one embodiment, the third clearance process step **754** (also referred to as an overpolish step) has a duration of about 15 to about 30 seconds.

[**0090**] **FIG. 9** is a flow diagram of another embodiment of a method **900** for electrochemical processing. The method **900** is substantially similar to the method **800** described above, except wherein the electrochemical process is driven by a constant voltage provided by the power source **242** as depicted in a graph **1000** of current and voltage traces **1002**, **1004** shown in **FIG. 10**. Amplitude is plotted on the y-axis **1006** and time is plotted on the x-axis **1008**

[**0091**] In one embodiment, the method **900** begins at step **902** by performing a bulk electrochemical process on the conductive layer, for example, a copper layer, formed on the substrate **112**. The bulk process step **902** generally is terminated when the conductively layer is about 2000 to about 1000 Å thick.

[**0092**] Next, a multi-step electrochemical clearance step **904** is performed to remove the remaining copper material to expose an underlying barrier layer. The clearance step **904** may be performed on the first ECMP station **128**, or one of the other ECMP stations **130**, **132**. Following the clearance step **904**, an electrochemical barrier removal step **906** is performed. Typically, the electrochemical barrier removal step **906** is performed on the third ECMP station **132**, but may alternatively be performed one of the other ECMP stations **128**, **130**.

[**0093**] In one embodiment, the bulk processing step **902** is substantially similar to the bulk processing step **702** described above. The bulk processing step **702** utilizes substantially constant voltage provided from the power source **242** to drive the electrochemical process. In one embodiment, the voltage is held at a substantially constant magnitude in the range of about 1 to about 4 volts. The endpoint of the bulk electroprocess is determined as discussed above, for example, by summation of charge removed from the conductive layer, among other methods for endpoint detection. It should be noted that during the first processing step illustrated on the left portion of trace **1002**, the current decreases as the conductive layer thins. This is particularly measurable when removing tungsten, and thus, the slope of the trace may be utilized to determine removal rates or the remaining thickness of the conductive layer. Thickness versus current change information may be empirically found or calculated and stored in a database accessible to the controller **108** of use in endpoint detection, removal profile control or other process control.

[**0094**] The clearance processing step **904** is now performed. The clearance processing step **904** is similar to the step **904** described above, except that the electrochemical process is driven at a constant voltage. In one embodiment, the voltage is constant over both the bulk and clearance processing steps **902**, **904**. In another embodiment, the voltage driving the clearance processing step **904** may be less than the preceding processing step.

[**0095**] A first endpoint of the processing step **904** is identified by detecting a first discontinuity **1010** in the current trace **1002** as monitored by the meter **244**. The first endpoint may alternatively be determined by other methods. The detection of the first discontinuity **1010** signifies the breakthrough of the copper layer.

[**0096**] A second endpoint of the processing step **904** is identified by detecting a second discontinuity **1012** in the current trace **1002**. The second endpoint may be identified by alternative methods. The second discontinuity identifies clearance of the copper layer. Optionally, a timed overpolish step may be performed during the clearance processing step **904** after detection of the second endpoint as identified by the second discontinuity **1012**.

[**0097**] The electrochemical barrier removal step **906** is substantially similar to the barrier removal step **706** described above, except that the electrochemical process is driven at a substantially constant voltage. The voltage is generally held at a substantially constant magnitude equal to or less than the voltage utilized for the steps **902**, **904**. In one embodiment, the voltage is held at a substantially constant magnitude less than about 3 volts for at least the bulk portion of barrier removal. The voltage may optionally be reduced for the residual removal portion of the barrier removal process.

[**0098**] Thus, the present invention provides an improved apparatus and method for electrochemically planarizing a substrate. The apparatus advantageously facilitates efficient bulk and residual copper and barrier materials removal from a substrate. It is contemplated that a method and apparatus as described by the teachings herein, may be utilized to deposit materials onto a substrate by reversing the polarity of the bias applied to the electrode and the substrate.

[**0099**] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method for electroprocessing a substrate, comprising:

establishing an electrically-conductive path through an electrolyte between an exposed layer of barrier material on the substrate and an electrode;

electrochemically removing a portion of the exposed layer during a first electrochemical processing step in a barrier processing station;

detecting an endpoint of the first electrochemical processing step at or just prior to breakthrough of the exposed layer of barrier material;

electrochemically processing the exposed layer of barrier material in a second electrochemical processing step in the barrier processing station; and

detecting an endpoint of the second electrochemical processing step.

2. The method of claim 1, wherein the step of establishing a conductive path further comprises:

flowing electrolyte from below the electrode and through a processing pad assembly into contact with the substrate.

3. The method of claim 1 comprising:

contacting the barrier material on the substrate with a processing pad assembly; and

moving the substrate relative to the pad assembly in a polishing motion;

4. The method of claim 1, wherein the second electrochemical processing step further comprises:

detecting a first endpoint;

processing the substrate at a slower rate; and

detecting a second endpoint indicative of residual barrier material being cleared from the substrate.

5. The method of claim 4, wherein the second electrochemical processing step further comprises:

overpolishing the substrate after detection of the second endpoint.

6. The method of claim 4, wherein the step of detecting the first endpoint further comprises:

detecting a first discontinuity in a potential difference between the substrate and the electrode.

7. The method of claim 6, wherein the step of detecting the second endpoint further comprises:

detecting a second discontinuity in a potential difference between the substrate and the electrode.

8. The method of claim 4, wherein the step of detecting the first endpoint further comprises:

detecting a first discontinuity in a current passing between the substrate and the electrode.

9. The method of claim 8, wherein the step of detecting the second endpoint further comprises:

detecting a second discontinuity in the current passing between the substrate and the electrode.

10. The method of claim 5, wherein the over polish step has a duration of 15 to 35 seconds.

11. The method of claim 1, wherein the barrier processing station is disposed within an enclosure of a processing system.

12. The method of claim 11 further comprising:

removing, within the processing system, a conductive layer disposed over the barrier layer.

13. The method of claim 12 further comprising:

electrochemically processing the conductive layer.

14. The method of claim 13 further comprising:

transferring the substrate between a first electrochemical processing station to the barrier processing station.

15. The method of claim 1 further comprising:

determining a remaining thickness of the barrier layer from a change in current between the substrate and the electrode.

16. A method of electrochemically processing a substrate having an exposed conductive layer and an underlying barrier layer, comprising:

establishing an electrically-conductive path through an electrolyte between the exposed layer of conductive material on the substrate and an electrode;

electrochemically removing a portion of the exposed layer during a first electrochemical processing step in a first processing station;

detecting an endpoint of the first electrochemical processing step at or just prior to breakthrough of the exposed layer of conductive material;

electrochemically processing the exposed layer of conductive material in a second electrochemical processing step;

detecting an endpoint of the second electrochemical processing step;

transferring the substrate to a barrier removal station; and

electrochemically processing the barrier layer.

17. The method of claim 16, wherein the second electrochemical processing step is performed in the first processing station.

18. The method of claim 16 further comprising:

transferring the substrate to a second processing station where the second electrochemical processing step is performed.

19. The method of claim 16, wherein the step of establishing a conductive path further comprises:

flowing electrolyte from below the electrode and through a processing pad assembly into contact with the substrate.

20. The method of claim 17, wherein the second electrochemical processing step further comprises:

detecting a first endpoint;

processing the substrate at a slower rate; and

detecting a second endpoint indicative of residual conductive material being cleared from the substrate.

21. The method of claim 20, wherein the second electrochemical processing step further comprises:

overpolishing the substrate after detection of the second endpoint.

22. The method of claim 20, wherein the step of detecting the first endpoint further comprises:

detecting a first discontinuity in a potential difference between the substrate and the electrode.

23. The method of claim 22, wherein the step of detecting the second endpoint further comprises:

detecting a second discontinuity in a potential difference between the substrate and the electrode.

24. The method of claim 20, wherein the step of detecting the first endpoint further comprises:

detecting a first discontinuity in a current passing between the substrate and the electrode.

25. The method of claim 24, wherein the step of detecting the second endpoint further comprises:

detecting a second discontinuity in the current passing between the substrate and the electrode.

26. The method of claim 21, wherein the over polish step has a duration of 15 to 35 seconds.

27. The method of claim 16, wherein the barrier electrochemical processing step further comprises:

detecting a first endpoint;

processing the substrate at a slower rate; and

detecting a second endpoint indicative of barrier material being cleared from the substrate.

28. The method of claim 27, wherein the barrier electrochemical processing step further comprises:

overpolishing the substrate after detection of the second endpoint.

29. The method of claim 28, wherein the step of detecting the first endpoint further comprises:

detecting a first discontinuity in a potential difference between the substrate and the electrode.

30. The method of claim 27, wherein the step of detecting the second endpoint further comprises:

detecting a second discontinuity in a potential difference between the substrate and the electrode.

31. The method of claim 27, wherein the step of detecting the first endpoint further comprises:

detecting a first discontinuity in a current passing between the substrate and the electrode.

32. The method of claim 27, wherein the step of detecting the second endpoint further comprises:

detecting a second discontinuity in the current passing between the substrate and the electrode.

33. The method of claim 28, wherein the over polish step has a duration of 15 to 35 seconds.

34. The method of claim 16 comprising:

contacting an exposed layer of conductive material on the substrate with a polishing pad; and

moving the substrate relative to the pad in a polishing motion.

35. The method of claim 15 further comprising:

determining a thickness remaining of the conductive material from a change in current.

36. A method of electrochemically processing a substrate having an exposed conductive layer and an underlying barrier layer, comprising:

disposing the substrate on a processing pad assembly in a first processing station of a processing system;

establishing an electrically-conductive path through an electrolyte between the exposed layer of conductive material on the substrate and an electrode;

providing a polishing motion between the processing pad assembly and the substrate in contact therewith;

electrochemically removing a portion of the exposed layer during a first electrochemical processing step in the first processing station;

detecting an endpoint of the first electrochemical processing step at or just prior to breakthrough of the exposed layer of conductive material;

electrochemically processing the exposed layer of conductive material in a second electrochemical processing step;

detecting an endpoint of the second electrochemical processing step;

transferring the substrate to a barrier removal station;

establishing an electrically-conductive path through an electrolyte between the barrier layer and an electrode disposed in the barrier removal station;

electrochemically removing a portion of the barrier layer during a first electrochemical barrier processing step in a barrier processing station;

detecting an endpoint of the first electrochemical barrier processing step at or just prior to breakthrough of barrier material;

electrochemically processing the barrier material in a second electrochemical barrier processing step in the barrier processing station; and

detecting an endpoint of the second electrochemical processing step.

37. The method of claim 36, wherein the step of detecting at least two of endpoints of the barrier and conductive material processing steps further comprises:

detecting discontinuities in a potential difference between the substrate and the electrode.

38. The method of claim 36, wherein the step of detecting at least two of endpoints of the barrier and copper processing steps further comprises:

detecting discontinuities in current measured between the substrate and the electrode.

39. The method of claim 36 further comprising:

determining a thickness remaining of the conductive material from a change in current.

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