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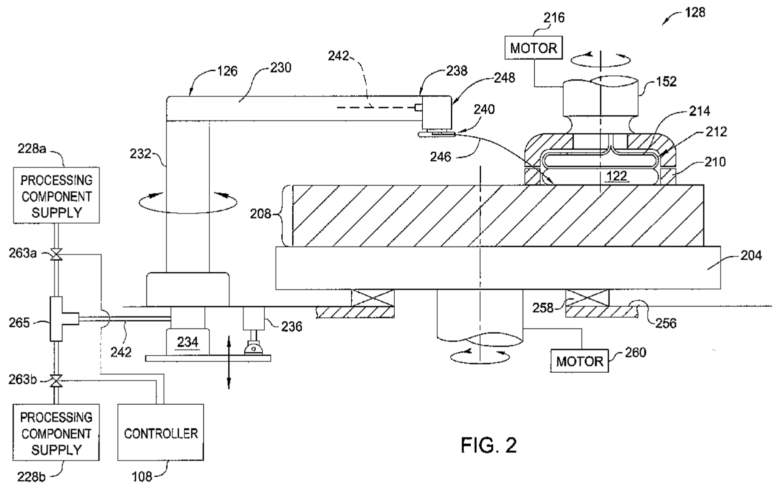


FIG. 2

(57) **Abstract**: Embodiments described herein provide a method for polishing a substrate surface. The methods generally include storing processing components in multiple storage units during processing, and combining the processing components to create a slurry while flowing the processing components to a polishing pad. A substrate is polished using the slurry, and the thickness of a material layer disposed on the substrate is determined. The flow rate of one or more processing components is then adjusted to affect the rate of removal of the material layer disposed on the substrate.

TWO-LINE MIXING OF CHEMICAL AND ABRASIVE PARTICLES WITH ENDPOINT CONTROL FOR CHEMICAL MECHANICAL POLISHING

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments described herein generally relate to a method for chemical mechanical polishing.

Description of the Related Art

[0002] Chemical mechanical planarization, or chemical mechanical polishing (CMP), is a common technique used to planarize substrates. CMP utilizes two modes to planarize substrates. One mode is a chemical reaction using a chemical composition, typically a slurry or other fluid medium, for removal of material from substrates, and the other is mechanical force. In conventional CMP techniques, a substrate carrier or polishing head is mounted on a carrier assembly and positioned in contact with a polishing pad in a CMP apparatus. The carrier assembly provides a controllable pressure to the substrate urging the substrate against the polishing pad. The pad is moved relative to the substrate by an external driving force. Thus, the CMP apparatus affects a polishing or rubbing movement between the substrate surface and the polishing pad, while dispensing a polishing composition to encompass both chemical and mechanical activities.

[0003] Increased substrate throughput using CMP is highly desirable. However attempts to increase substrate throughput by increasing the pressure applied to the substrate surface can lead to a decrease in planarization efficiency and a corresponding increase in hollow metal and corrosion defects. Planarization efficiency is defined as a reduction of the step height of a deposited material. In the CMP process, planarization efficiency is a function of both pressure and platen speed applied between the substrate surface polishing pad. The higher the pressure, the higher the polishing rate and the poorer the planarization efficiency. Whereas a lower polishing rate leads to better planarization efficiency but also leads to a decrease in throughput.

[0004] Thus, there is a need for an improved method and apparatus for chemical mechanical processing of materials which increases substrate throughput while maintaining improved planarization efficiency.

SUMMARY OF THE INVENTION

[0005] Embodiments described herein provide a method for polishing a substrate surface. The methods generally include storing multiple processing components in multiple storage units during processing, and combining the processing components to create a slurry while flowing the processing components to a polishing pad. A substrate is polished using the slurry, and the thickness of a material layer disposed on the substrate is determined. The flow rate of one or more processing components is then adjusted to affect the rate of removal of the material layer disposed on the substrate.

[0006] In one embodiment, a method for processing a semiconductor substrate surface includes storing a first processing component in a first storage unit during processing, and storing a second processing component in a second storage unit during processing. The first processing component and second processing component are combined while flowing to a polishing pad. A substrate is polished with the polishing pad to remove at least a portion of a material layer disposed thereon. The thickness or uniformity of the material layer disposed on the substrate is measured, and the flow rate of the first processing component or the second processing component is adjusted in response to the measured thickness or uniformity of the material layer to affect the polishing rate of the material layer.

[0007] In another embodiment, a method for processing a semiconductor substrate surface includes flowing a polishing slurry to a polishing pad. The polishing slurry includes a first processing component stored in a first storage unit and a polishing abrasive stored in a second storage unit. The polishing slurry is used to polish a substrate and remove at least a portion of a material layer disposed thereon. The thickness or uniformity of the material layer disposed on the substrate is measured, and the flow rate of the first processing component or the flow rate of the polishing abrasive is adjusted in response to the measured thickness or uniformity of the material layer to affect the polishing rate.

[0008] In another embodiment, a method for processing a semiconductor substrate surface includes storing two or more processing components separately during processing, and combining the two or more processing components during processing to form a polishing slurry. The polishing slurry flows to the polishing pad, and a substrate is polished with the polishing pad to remove at least a portion of a material layer disposed on a substrate. The thickness or uniformity of the material layer disposed on the substrate is measured, and the flow rate of at least one of the two or more processing components is adjusted in response to the measured thickness or uniformity of the material layer to affect the polishing rate of the material layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of 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.

[0010] Figure 1 is a schematic view of a chemical mechanical planarizing system;

[0011] Figure 2 is a schematic sectional view of a processing station of Figure 1;

[0012] Figures 3A-C are schematic views of two-line interconnects;

[0013] Figures 4A-B are plots comparing the thickness of a material layer disposed on a substrate and the amount of time the material layer has been polished;

[0014] Figures 5 is a flow diagram of one embodiment for a method of chemical mechanical polishing a substrate;

[0015] Figure 6 is a plot comparing polishing removal rate for a polishing slurry with the amount of hydrogen peroxide in the polishing slurry;

[0016] Figure 7 is a plot comparing polishing removal rate for a polishing slurry with the amount of corrosion inhibitor in the polishing slurry; and

[0017] Figure 8 is a plot comparing polishing removal rate of a copper layer with down force applied to a polishing pad.

[0018] To facilitate understanding, identical reference numerals have been used, wherever possible, to designate identical elements that are common to the figures. It is contemplated that elements and/or process steps of one embodiment may be beneficially incorporated in other embodiments without additional recitation.

DETAILED DESCRIPTION

[0019] Embodiments described herein provide a method for polishing a substrate surface. Copper and barrier CMP often require different slurries that are individually optimized to promote polishing rate and provide colloidal stability. Once a slurry formulation is fixed, it can be difficult to tune the process flexibility at different processing steps. For example, bulk material removal, material clearing, barrier and dielectric polishing may all require distinct slurry formulations. Two-line mixing of process components combined with endpoint detection provides process flexibility and minimizes the cost for high polishing rates by using cheap bulk raw materials.

[0020] The methods described herein generally include storing processing components in multiple storage units during processing, and combining the processing components to create a slurry while flowing the processing components to a polishing pad. A substrate is polished using the slurry, and the thickness of a material layer disposed on the substrate is determined. The flow rate of one or more processing components is then adjusted to affect the rate of removal of the material layer disposed on the substrate.

[0021] Embodiments described herein are especially advantageous in through-silicon via (TSV) applications. Embodiments of the methods described herein are also suitable for CMP applications on standard substrates. TSV applications include electrical connections passing completely through a silicon substrate, such as in 3D packages and 3D integrated circuits. TSV applications commonly include multiple integrated circuits disposed on one another. For example, a 3D integrated circuit may include multiple silicon substrates stacked vertically on one another. The stacking of multiple substrates often results in a relatively thick layer of metal or dielectric material that may need to be polished or removed. In one embodiment, a layer of material disposed on a substrate is within a range from about 2 micrometers to about 10 micrometers. For example, about 8 micrometers. In another embodiment, a dielectric layer having a thickness within a range from about 1 micrometer to about 3 micrometers is disposed on a metal layer having a thickness within a range from about 2 micrometers to about 8 micrometers.

[0022] The ability to control the flow rate of multiple processing components to the polishing pad allows a high removal rate of material disposed on a substrate at the beginning of the polishing process. The ability to affect the flow rate of processing components to increase the polishing rate is especially advantageous for low k materials that have a maximum down force pressure that may be applied due to damage that may occur. Additionally, the ability to affect the flow rate of processing components allows for adjustment and/or selectivity when multiple films, such as metal and dielectric films, are polished at different stages.

[0023] For example, a relatively high polishing rate is desired when the thickness of the material is within a range from about 4,000 angstroms to about 8 micrometers. As the thickness of material disposed on a substrate decreases, the removal rate can be adjusted to prevent dishing. In one embodiment, the removal rate is decreased by decreasing the flow rate of a processing component which includes a polishing abrasive.

[0024] Additionally, the ability the ability to control the flow rate of processing components to the polishing pad is advantageous when multiple films or layers are deposited on a substrate. For example, for TSV applications in which a dielectric layer is disposed on a bulk metal layer of a substrate, it may be desirable to polish the layers at different polishing rates, or by using a different combination of processing components.

[0025] Embodiments described herein will be described below in reference to a planarizing process and composition that can be carried out using chemical mechanical polishing process equipment, such as MIRRA®, MIRRA MESA®, REFLEXION®, REFLEXION LK™, and REFLEXION LK ECMP™ chemical mechanical planarizing systems, available from Applied Materials, Inc. of Santa Clara, California. Embodiments described herein may also be practiced on overhead circular track polishing systems. 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 embodiments described herein. In addition, any system enabling chemical mechanical polishing using the methods or compositions described herein can be used advantageously. The following apparatus description is illustrative and should not be construed or interpreted as limiting the scope of the embodiments described herein.

[0026] Figure 1 is a schematic view of a chemical mechanical planarizing system. Chemical mechanical planarizing system 100 generally comprises a factory interface 102, a loading robot 104, and a planarizing module 106. The loading robot 104 is disposed to facilitate the transfer of substrates 122 between the factory interface 102 and the planarizing module 106.

[0027] 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 the planarizing, cleaning, and transfer processes.

[0028] The factory interface 102 generally includes a metrology module 190, a cleaning module 116 and one or more substrate cassettes 118. An interface robot 120 is employed to transfer substrates 122 between the substrate 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.

[0029] The metrology module 190 may be a non-destructive measuring device suitable for providing a metric indicative of the thickness profile of a substrate. The metrology module 190 may include eddy current sensors, an interferometer, a capacitance sensor and other suitable devices. Examples of suitable metrology modules include ISCAN^{TM} and IMAP^{TM} substrate metrology modules, available from Applied Materials, Inc. The metrology module 190 provides the metric to the controller 108 wherein a target removal profile is determined for the specific thickness profile measured from a substrate.

[0030] The planarizing module 106 includes at least a first chemical mechanical planarizing (CMP) station 128, disposed in an environmentally controlled enclosure 188. In the embodiment depicted in Figure 1, the planarizing module 106 includes the first CMP station 128, a second CMP station 130 and a third CMP station 132. Bulk removal of material disposed on a substrate 122 may be performed through a chemical mechanical polishing process at the first CMP station 128. In one embodiment, the bulk removal of material may be a multi-step process. After the bulk material removal at the first CMP station 128, the remaining material or residual material may be cleared from the substrate at the second CMP station 130 in a single-step or multi-step chemical mechanical polishing process, wherein part of the multi-step process is configured to remove residual material disposed on a substrate. The third CMP station 132 may be used to polish a barrier layer. In one embodiment, both the bulk material removal and residual material removal may be performed at a single station. In such an embodiment, only two platens may be necessary. Alternatively, more than one CMP station may be utilized to perform the multi-step removal process after the bulk removal process performed at a different station.

[0031] In the embodiment of Figure 1, the planarizing module 106 also includes a transfer station 136 and a carousel 134 that are disposed on an upper or first side 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.

[0032] The transfer robot 146 includes two gripper assemblies, each having pneumatic gripper fingers that hold a substrate by a 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.

[0033] The carousel 134 is centrally disposed over the base 140. The carousel 134 typically includes a plurality of arms 150, each supporting a carrier head assembly 152. Two of the arms 150 depicted in Figure 1 are shown in phantom such that the transfer station 136 and a planarizing surface 129 of the first CMP station 128 may be seen. The carousel 134 is indexable such that the carrier head assemblies 152 may be moved between the CMP stations 128, 130, and 132 and the transfer station 136. A conditioning device 182 is disposed on the base 140 adjacent each of the CMP stations 128, 130, and 132. The conditioning device 182 periodically conditions the planarizing material disposed in the CMP stations 128, 130, and 132 to maintain uniform planarizing results.

[0034] A clear window 170 is included in the polishing pad 208 (*See* Figure 2) and is positioned such that it passes beneath substrate 122 during a portion of the platen's rotation, regardless of the translational position of the carrier head. The clear window 170 may be used for metrology devices, for example, an eddy current sensor may be placed below the clear window 170. In certain embodiments the window 170 and related sensing methods may be used for an endpoint detection or profile detection process.

[0035] During the polishing process, a real-time profile control (RTPC) model of the substrate may be developed. The thickness of a conductive material may be measured at different regions on the substrate. For example, the thickness of a metal layer at different regions on a substrate may be monitored to ensure that processing is proceeding uniformly across the substrate. Thickness information for regions of the substrate (which collectively may be referred to as a "profile" of the substrate) may then be used to adjust processing parameters in real time to obtain desired cross-substrate uniformity. For example, in a chemical mechanical polishing process, the thickness of a material layer at different regions on the substrate may be monitored, and detected thickness or non-uniformities may cause the CMP system to adjust polishing parameters in real time. Such profile control may be referred to as real time profile control (RTPC). The measurements taken during RTPC may be used for endpoint detection of a process.

[0036] In one embodiment, the polishing parameter adjusted includes the flow rate of one or more processing components. RTPC may be used to control the remaining material profile by adjusting the flow rates of one or more processing components during polishing. In one embodiment, the flow rate of one or more processing components is adjusted in response to a measurement of a material layer thickness as determined during the RTPC process. Examples of suitable RTPC techniques and apparatus are described in U.S. Patent No. 7,229,340, to *Hanawa et al.* entitled

METHOD AND APPARATUS FOR MONITORING A METAL LAYER DURING CHEMICAL MECHANICAL POLISHING and U.S. Patent Application Serial No. 10/633,276, entitled EDDY CURRENT SYSTEM FOR IN-SITU PROFILE MEASUREMENT, filed July 31, 2003, now issued as US Patent No. 7,112,960.

[0037] In one embodiment the endpoint may be determined using spectrum based endpoint detecting techniques. Spectrum based endpoint techniques include obtaining spectra from different zones on a substrate during different times in a polishing sequence, matching the spectra with indexes in a library and using the indexes to determine a polishing rate for each of the different zones from the indexes. In another embodiment, the endpoint may be determined using a first metric of processing provided by a meter. The meter may provide charge, voltage or current information utilized to determine the remaining thickness of a conductive material (*e.g.*, copper layer) on a substrate. In another embodiment, optical techniques, such as an interferometer utilizing a sensor 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 a substrate to a target charge amount for a predetermined area of a substrate. Examples of endpoint techniques that may be utilized are described in U.S. Patent No. 7,226,339, entitled SPECTRUM BASED ENDPOINTING FOR CHEMICAL MECHANICAL POLISHING, issued June 5, 2007 to *Benvegnu et al.*, U.S. Patent Application Serial No. 11/748,825, entitled SUBSTRATE THICKNESS MEASURING DURING POLISHING, filed May 15, 2007, now published as US 2007/0224915, and U.S. Patent No. 6,924,641, to *Hanawa et al.*, entitled METHOD AND APPARATUS FOR MONITORING A METAL LAYER DURING CHEMICAL MECHANICAL POLISHING.

[0038] Figure 2 is a schematic sectional view of one embodiment of the first CMP station 128 that includes the fluid delivery arm assembly 126. Referring to Figure 1, the first CMP station 128 includes the carrier head assembly 152 and a platen 204. The carrier head assembly 152 generally retains a substrate 122 against a polishing pad 208 disposed on the platen 204. At least one of a carrier head assembly 152 or platen 204 is rotated or otherwise moved to provide relative motion between a substrate 122 and the polishing pad 208. In the embodiment depicted in Figure 2, the carrier head assembly 152 is coupled to an actuator or motor 216 that provides at least rotational motion to a substrate 122. The motor 216 may also oscillate the carrier head assembly 152, such that a substrate 122 is moved laterally back and forth across the surface of the polishing pad 208.

[0039] The polishing pad 208 may comprise a conventional material such as a foamed polymer disposed on the platen 204 as a pad. In one embodiment, the conventional polishing material is foamed polyurethane. In one embodiment, the pad is an IC1010 polyurethane pad, available from Rodel Inc., of Newark, Del. IC1010 polyurethane pads typically have a thickness of about 2.05 mm and a compressibility of about 2.01%. Other pads that can be used include IC1000 pads with and without an additional compressible bottom layer underneath the IC1000 pad, IC1010 pads with an additional compressible bottom layer underneath the IC1010 pad, and polishing pads available from other manufacturers. The compositions described herein are placed on the surface of the pad to contribute to the chemical mechanical polishing of a substrate.

[0040] In one embodiment, the carrier head assembly 152 includes a retaining ring 210 circumscribing a substrate receiving pocket 212. A bladder 214 is disposed in the substrate receiving pocket 212 and may be evacuated to chuck a substrate to the carrier head assembly 152 and pressurized to control the downward force of a substrate 122 when pressed against the polishing pad 208. In one embodiment, the carrier head may be a multi-zone carrier head. One suitable carrier head assembly 152 is a TITAN HEAD^{TM} carrier head available from Applied Materials, Inc., located in Santa Clara, California. Other examples of carrier heads that may be adapted to benefit from the embodiments described herein are described in United States Patent No. 6,159,079, issued December 12, 2001, and United States Patent No. 6,764,389, issued July 29, 2004.

[0041] In the embodiment of Figure 2, the platen 204 is supported on a base 256 by bearings 258 that facilitate rotation of the platen 204. A motor 260 is coupled to the platen 204 and rotates the platen 204 such that the polishing pad 208 is moved relative to the carrier head assembly 152.

[0042] The fluid delivery arm assembly 126 is utilized to deliver one or more processing components from first and second processing component supplies 228a and 228b to a top or working surface of the polishing pad 208. Processing component supplies 228a and 228b include individual storage units that contain separate processing components. The processing components from processing components supplies 228a and 228b can be combined to create a polishing slurry. In one embodiment, first processing component supply 228a includes a first storage unit which stores a first processing component during a CMP process, and second processing component supply 228b includes a second storage unit which stores a second processing component during a CMP process.

[0043] In the embodiment depicted in Figure 2, the fluid delivery arm assembly 126 includes an arm 230 extending from a stanchion 232. A motor 234 is provided to control the rotation of the arm 230 about a center line of the stanchion 232. An adjustment mechanism 236 may be provided to control the elevation of a distal end 238 of the arm 230 relative to the working surface of the polishing pad 208. The adjustment mechanism 236 may be an actuator coupled to at least one of the arm 230 or the stanchion 232 for controlling the elevation of the distal end 238 of the arm 230 relative to the platen 204. Some examples of suitable fluid delivery arms which may be adapted to benefit from the embodiments described herein are described in United States Patent Application Serial No. 11/298,643, filed December 8, 2005, entitled METHOD AND APPARATUS FOR PLANARIZING A SUBSTRATE WITH LOW FLUID CONSUMPTION; now published as US 2007/0131562, U.S. Patent Application Serial No. 09/921,588, entitled MULTIPORT POLISHING FLUID DELIVERY SYSTEM, filed August 2, 2001, now published as US 2003/0027505; U.S. Patent Application Serial No. 10/428,914, entitled SLURRY DELIVERY ARM, filed May 2, 2003, now issued as U.S. Patent No. 6,939,210; U.S. Patent Application

Serial No. 10/131,638, entitled FLEXIBLE POLISHING FLUID DELVERY SYSTEM, filed April 22, 2002, now issued as U.S. Patent No. 7,086,933.

[0044] The separation of processing component supplies 228a and 228b allows for processing components with relatively short shelf lives to be stored separately prior to processing. Storage of certain components of a polishing slurry together may adversely effect properties such as colloidal properties, chemical stability, or pH range of the polishing slurry. For example, separation of these components until immediately prior to processing extends the shelf life from days to months.

[0045] The nozzle assembly 248 is disposed at the distal end of the arm 230. The nozzle assembly 248 is coupled to the processing component supplies 228a and 228b by a tube 242 routed through the fluid delivery arm assembly 226. The nozzle assembly 248 includes a nozzle 240 that may be selectively adjusted relative to the arm, such that the fluid exiting the nozzle 240 may be selectively directed to a specific area of the polishing pad 208.

[0046] Tube 242 couples the processing component supplies 228a and 228b to the nozzle assembly 248. Processing component supplies 228a and 228b provide individual processing components through interconnect 265 to tube 242. Valves 263a and 263b are disposed between processing component supplies 228a and 228b, respectively, allowing precise control of processing components to tube 242. The valves 263a and 263b are connected to controller 108 allowing for real-time automated control of processing component flow rates through the valves 263a and 263b.

[0047] In one embodiment, the nozzle 240 is configured to generate a spray of processing components. In another embodiment, the nozzle 240 is adapted to provide a stream of processing components. In another embodiment, the nozzle 240 is configured to provide a stream and/or spray of processing components at a rate between about 20 to about 120 ml/second to the polishing surface. In one embodiment, processing components are delivered to the polishing surface at a rate within a range from about 200 ml/minute to about 500 ml/minute.

[0048] Figures 3A-C are schematic views of two-line interconnects 365a-c. Figures 3A and 3B show embodiments of different two-line interconnects 365a and 365b which may be utilized to combine a first processing component form a first processing component supply 228a and a second processing component from a second processing component supply 228b while inflow to polishing pad 208. The flow rates of the first processing component and a second processing component are individually controlled by valves 363a and 363b, respectively (not shown in Figures 3B or 3C). Valves 363a and 363b are coupled to controller 108 (not shown in Figures 3B or 3C) to provide real-time flow rate control.

[0049] Figure 3C is a schematic view of a two-line interconnect 365c. The two-line interconnect 365c has inlets 367a and 367b coupled to a first processing component supply 228a and a second processing component supply 228b. The inlets 367a and 367b are off-centered so that a first processing component and a second processing component create a helical or spiral flow in the two-line interconnect 365c. The helical or spiral flow induces mixing to create a uniform composition when the first processing component and the second processing component combine for delivery to the polishing pad.

[0050] Additionally, two-line interconnects 365a-c may include more than two input lines. For example, three, four, five or more processing components can be combined in an interconnect; each component flowing from a different storage unit. Additionally or alternatively, an interconnect may provide an input for a polishing pad rinsing fluid as well.

[0051] Processing components suitable for use with CMP system 100 generally include one or more of: acids, oxidizers, corrosion inhibitors, pH buffers, polishing abrasives and combinations thereof. For example, a first processing component including an acid, an oxidizer, a corrosion inhibitor and a pH buffer may be stored in a first processing component storage unit, and second processing component including a polishing abrasive may be stored in a second processing component storage unit. The processing components are combined during processing to create a polishing slurry, which is delivered to polishing pad 208.

[0052] Suitable acids for a polishing slurry include organic or inorganic acids. For example: dilute organic acids including acetic acid, citric acid, oxalic acid, malic acid, tartaric acid, derivatives thereof and combinations thereof; or dilute inorganic acids including HNO_3, HCl, H_2S0_4, boric acid, fluoroboric, derivatives thereof and combinations thereof. Additionally, a combination of one or more organic acids and one or more inorganic may be used.

[0053] Suitable oxidizers for a polishing slurry include hydrogen peroxide, monopersulfate compounds (*e.g.*, ammonium persulfate), peracetic acid, derivatives thereof and combinations thereof. Suitable corrosion inhibitors for a polishing slurry include aromatic organic compounds, for example benzotriazole and its derivatives (*e.g.*, 5-chlorobenzotriazole, 5-methylbenzotriazole, 5-nitrobenzotriazole), triazole and its derivatives (*e.g.*, 1,2,4-triazole-3-thiol; 1,2,3-triazole[4,5-b]pyridine), 5-aminotetrazole, triazine, derivatives thereof and combinations thereof.

[0054] Suitable pH buffers for a polishing slurry include a mixture of a weak acid and its conjugate base, or a mixture of a weak base and its conjugate acid. For example, a pH buffer may include acetate, citrate, phosphate, ammonium, and their respective conjugate bases.

[0055] Suitable polishing abrasive compounds for a polishing slurry include alumina, ceria, copper oxide, iron oxide, nickel oxide, manganese oxide, silica, silicon nitride, silicon carbide, tin oxide, titania, titanium carbide, tungsten oxide, yttrium oxide, zirconia, derivatives thereof and combinations thereof. For the polishing abrasive particles to obtain a high removal rate without causing excessive scratching or surface defects, it is preferred that polishing abrasive particles have a mean average diameter within a range from about 10 nanometers to about 1 micrometer. In one embodiment, the mean average diameter is within a range from about 50 nanometers to about 500 nanometers. In one embodiment, the maximum diameter of the polishing abrasive particles is less than about 10 micrometers.

[0056] The processing components described above may be stored as concentrated solutions or diluted solutions. In one embodiment, prior to applying the processing components to the polishing pad 208 as a polishing slurry, the processing components combine to create a polishing slurry that has a formulation wherein the acid is within a range from about 2 grams per liter to about 40 grams per liter; the oxidizer is within a range from about 4 grams per liter to about 80 grams per liter; the corrosion inhibitor is within a range from about 0.3 grams per liter to about 5 grams per liter; the pH buffer is within a range from 0 grams per liter to about 100 grams per liter; and the polishing abrasive is within a range from about 0.1 grams per liter to about 50 grams per liter. In one embodiment, the pH of the polishing slurry is within a range from about 2 to about 5, or from about 8 to about 11.

[0057] Figures 4A-B are plots comparing the thickness of a material layer disposed on a substrate and the amount of time the material layer has been polished. The plots illustrate how adjusting the flow rate of one or more processing components can affect the removal rate of a material layer disposed on a substrate. The polishing of the substrate of Figure 4A was done using two processing components which were combined during processing to create a polishing slurry. The first processing component included an acid, a pH buffer, an oxidizer and a corrosion inhibitor. The second processing component included a polishing abrasive. The polishing of a substrate in Figure 4B was done using three processing components which were combined during processing to create a polishing slurry. The first processing fluid included an acid, an oxidizer, and a pH buffer. The second processing fluid included a corrosion inhibitor. The third processing fluid included a polishing abrasive.

[0058] The flow rates of the processing components are adjusted in response to a measurement of the thickness or uniformity of a material layer disposed on a substrate. In one embodiment, the thickness or uniformity of a material layer is determined by endpoint detection, such as those described above. The endpoint may be detected using detection systems such as the iScan™ thickness monitor and the FullScan™ optical endpoint system, both of which are available from Applied Materials, Inc. of Santa Clara, California.

[0059] Referring back to Figure 4A, a plot of the thickness of the material layer versus time is displayed. Point A represents the initial thickness of the material layer disposed on a substrate. Between points A and B, removal of the material layer occurs at a rate of about 3.7 micrometers per minute. Using varied concentrations of the polishing slurry described above, removal rates as great as about 6 micrometers per minute or less can be obtained. For example, the removal rate may be about 4 micrometers or less per minute, or about 1.5 micrometers or less per minute. The removal rate between points A and B is linear, and no change in the flow rate of the processing fluids occurred (*e.g.*, the flow rates of the processing fluids remained constant during the first 120 seconds).

[0060] At point B, the thickness of the material layer disposed on a substrate was determined to be 6000 angstroms using endpoint detection. The removal rate was decreased to about 2000 angstroms per minute by reducing the flow rate of the polishing abrasive processing component. Additionally, it is to be noted that thickness measurements can occur between points A and B, but no change in the flow rate of processing components need occur until a predetermined thickness of a layer is reached. Additionally or alternatively, the removal rate between points A and B can be increased in response to layer thickness measurements by increasing the flow rate of the polishing abrasive processing component, or decreasing the flow rate of a processing component which includes a corrosion inhibitor.

[0061] At point C, the thickness of the layer disposed on a substrate was determined to be 2000 angstroms using endpoint detection. The removal rate was decreased to about 1500 angstroms per minute by reducing the flow rate of the polishing abrasive processing component. At point D, the thickness was again determined using endpoint detection, and the removal rate was decreased by further reducing the flow rate of the polishing abrasive processing component to a final point E. In another embodiment, points B, C and D may not result in changes of the flow rate of a processing component, and a linear removal rate is observed between points B and E. In one embodiment, the flow rates of the processing components remain constant from the beginning of the polishing process until the thickness of the layer disposed on the substrate is within a range from about 4000 angstroms to less than about 2000 angstroms. In response to a measurement of the thickness of the layer disposed on the substrate, the flow rate of one or more processing components is adjusted, and the polishing process is completed.

[0062] Figure 4B represents the polishing of a material layer disposed on a substrate. The removal rate of the material layer in Figure 4B has a gradually decreasing removal rate as the material layer disposed on a substrate approaches a thickness of zero angstroms. The removal rate is relatively high at the beginning of the bulk layer removal step. In one embodiment, the removal rate is within a range from about 1.5 micrometers to about 4 micrometers per minute. As the bulk layer approaches a thickness within a range from about 2,000 angstroms to about 6,000 angstroms as detected during an RTPC process, the controller changes the flow rate of one or more processing components. RTPC allows the thickness of the layer disposed on the substrate to be continuously monitored during polishing, and the flow rates of one or more processing components are adjusted in response to the measurements.

[0063] In the embodiment of Figure 4B, a change in processing components began occurring when the thickness of a layer disposed on a substrate was about 6,000 angstroms. The graded removal rate of Figure 4B can obtained by gradually decreasing the flow rate of the polishing abrasive processing component, and/or gradually increasing the flow rate of the corrosion inhibitor processing component. In one embodiment, this is accomplished in conjunction with an RTPC process. In one embodiment, the flow rate of the a third processing component is increased or decreased to compensate for the change of the flow rate of another processing component in order to keep the total flow rate of the combined processing components constant. In another embodiment, the overall flow rate does not remain constant throughout processing.

[0064] Changes in the flow rate of one or more processing components allows for precise control over the removal rate of a material layer disposed on a substrate. For example, a high removal rate can be obtained at the beginning of the process by increasing or maintaining a relatively high flow rate to the polishing pad of a processing component which includes a polishing abrasive. As the thickness of a material layer disposed on a substrate decreases, the flow rate of the processing component which includes a polishing abrasive can be decreased, or the flow rate of a processing component which includes a corrosion inhibitor can be increased to reduce the removal rate, which generates a more uniform surface on a substrate and helps to prevent dishing. Additionally, since the removal rate is precisely controlled by the flow rate of processing components to the polishing pad in response to endpoint detection, both a bulk layer removal step and a clear step can be performed on a single platen without causing excessive dishing. In one embodiment, a layer of material having a thickness greater than 2 micrometers disposed on a substrate is polished on a single platen until a barrier layer is revealed. In another embodiment, a layer of copper having a thickness greater than 8,000 angstroms disposed on a substrate is polished on a single platen until a barrier layer is revealed.

[0065] Figure 5 depicts one embodiment of a method 500 for chemical mechanical polishing a substrate having an exposed material layer and an underlying barrier layer disposed thereon. Method 500 may be practiced on the system 100 described above. The method 500 may also be practiced on other chemical mechanical processing systems. The method 500 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.

[0066] Although embodiments described herein are discussed as being implemented as a software routine, some of the method steps that are disclosed herein may be performed in hardware as well as by the software controller. As such, the embodiments described herein 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.

[0067] The method 500 begins at step 502 by positioning a substrate comprising a material disposed over an underlying barrier material on a first platen containing a first polishing pad. The material layer may comprise tungsten, copper, combinations thereof, and the like. Alternatively, the material layer may comprise a dielectric material, for example, silicon oxide or silicon nitride. Additionally or alternatively, a dielectric layer may be disposed over the bulk copper layer. The material layer may be conductive or non-conductive. The barrier layer may comprise ruthenium, tantalum, tantalum nitride, titanium, titanium nitride, tungsten nitride, tungsten, combinations thereof, and the like. A dielectric layer, typically an oxide, generally underlies the barrier layer.

[0068] At step 502, a substrate 122 retained in the carrier head assembly 152 is moved over the polishing pad 208 disposed in the first CMP station 128. The carrier head assembly 152 is lowered toward the polishing pad 208 to place a substrate 122 in contact with the top surface of the polishing pad 208.

[0069] At step 504 a chemical mechanical polishing process is performed on the bulk material. At step 506, the substrate is polished on a first platen at a first removal rate to remove a bulk portion of the material. In one embodiment, the material layer is a copper layer having an initial thickness within a range from about 2 micrometers and about 10 micrometers. In another embodiment, the material layer is a copper layer having an initial thickness within a range from about 4 micrometers and about 7 micrometers. In another embodiment, the material layer is a copper layer having an initial thickness within a range from about 6,000 angstroms to about 8,000 angstroms. In one embodiment, the polishing step 506 may be performed at the first CMP station 128. A substrate 122 may be urged against the polishing pad 208 with a force of less than about 4 pounds per square inch (psi). In one embodiment, the force is less than about 2.5 psi. In another embodiment, the force is between about 1 psi and 2 psi, for example, about 1.8 psi.

[0070] At step 506, relative motion between a substrate 122 and polishing pad 208 is provided. In one embodiment, the carrier head assembly 152 is rotated at between about 50-100 revolutions per minute, for example, between about 30-60 revolutions per minute, while the polishing pad 208 is rotated at between about 50-100 revolutions per minute, for example, between about 7-35 revolutions per minute. In one embodiment, the process has a material layer removal rate of about 9000 Å/min. In another embodiment, the process has a material layer removal rate less than about 6 micrometers per minute, for example within a range from about 2 micrometers per minute to about 4 micrometers per minute.

[0071] A polishing slurry is supplied to the polishing pad 208. Suitable polishing slurry includes any combination of processing components including but not limited to an acid, a pH buffer, an oxidizer, a corrosion inhibitor and a polishing abrasive. Examples of suitable polishing compositions and methods for bulk chemical mechanical processes are described herein as well as in United States Patent Application Serial No. 11/839,048, entitled IMPROVED SELECTIVE CHEMISTRY FOR FIXED ABRASIVE CMP, filed August 15, 2007, now published as US 2008/0182413 and United States Patent Application Serial No. 11/356,352, entitled METHOD AND COMPOSITION FOR POLISHING A SUBSTRATE, now published as US2006/0169597. In certain embodiments, a substrate 122 contacts the polishing pad 208 after addition of the polishing slurry. In certain embodiments, a substrate 122 contacts the polishing pad 208 prior to the addition of the polishing slurry.

[0072] At step 508, the thickness of a material layer disposed on a substrate is measured using endpoint detection. In one embodiment, the endpoint of the bulk portion removal process occurs prior to breakthrough of the material layer. At step 510, the CPU compares the measured thickness of the material layer disposed on a substrate with a predetermined value. If the thickness of the layer is greater than the predetermined value, then method 500 returns to step 506 and continues to polish the substrate. However, if the measured thickness of the material layer disposed on a substrate is equal to or about equal to the predetermined value, then method 500 continues to step 512.

[0073] At step 512, the flow rate of one or more processing components are adjusted to decrease the removal rate of a material layer disposed on a substrate. In one embodiment the removal rate is decreased by decreasing the flow of a processing component which includes a polishing abrasive. In another embodiment, the removal rate is decreased by increasing the flow rate of a processing component which includes a corrosion inhibitor. In another embodiment, the removal rate is decreased by maintaining the flow rate of processing component including a polishing abrasive, and increasing the flow rate of another processing component such that the concentration of the polishing abrasive in the polishing slurry is decreased.

[0074] In the embodiment of Figure 5, adjustment of the flow rates of processing components occurs at the transition between a bulk layer removal and residual material removal. In another embodiment, the flow rates of processing components may be adjusted one or more times during the polishing process of the bulk material during step 504 or the polishing process of the residual material during step 514.

[0075] At step 514, a chemical mechanical polishing process is performed on the residual material. The residual material removal process comprises polishing a substrate on a second platen and determining an endpoint of that polishing process. At step 516, a substrate is polished on a second platen to remove any residual conductive material. Alternatively, steps 504 and 514 may occur on a single platen. In one embodiment, a substrate may be polished at a removal rate between about 1500-2500 Å/min, for example, about 2400 Å/min. Step 516 may be a single or multi-step chemical mechanical clearance process. The clearance step 516 may be performed on the second CMP station 130, or one of the other CMP stations 128, 132.

[0076] The clearance processing step 516 begins by moving a substrate 122 retained in the carrier head assembly 152 over the polishing pad disposed in the second CMP station 130. The carrier head assembly 152 is lowered toward the polishing pad to place a substrate 122 in contact with the top surface of the polishing pad. A substrate 122 is urged against the polishing pad with a force less than about 2 psi. In another embodiment, the force is less than or equal to about 0.3 psi.

[0077] Next, relative motion between a substrate 122 and polishing pad 208 is provided. Polishing slurry is supplied to the surface of the polishing pad 208. In one embodiment, the carrier head assembly 152 is rotated within a range from about 30 revolutions per minute to about 80 revolutions per minute, for example, about 50 revolutions per minute, while the polishing pad is rotated within a range from about 7 revolutions per minute to about 90 revolutions per minute, for example, about 53 revolutions per minute. The process of step 516 generally has a removal rate of about 1500 Å/min for tungsten and about 2000 Å/min for copper.

[0078] At step 518 an endpoint of the residual material removal is determined. The endpoint may be determined using FullScan™ or any of the other techniques discussed above. In one embodiment, for an electrochemical mechanical polishing process (Ecmp), the endpoint is determined by detecting a first discontinuity in current sensed by using a meter. The discontinuity appears when the underlying layer begins to break through the conductive layer (*e.g.*, the 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) changes as the area of conductive layer relative to the exposed area of the underlying layer changes, thereby causing a change in the current. In one embodiment, the thickness of a layer disposed on a substrate 122 is monitored in conjunction with RTPC to provide for continuous measurement of the thickness of the layer disposed on substrate 122. In one embodiment, the flow rate of one or more processing fluids is adjusted in response to step 518. In another embodiment, the flow rate of one or more processing fluids remains constant in response to step 518.

[0079] Optionally, in response to the endpoint detection, a second clearance process step may be performed to remove the residual material layer. A substrate 122 is pressed against the pad assembly with a pressure less than about 2 psi, and in another embodiment, a substrate 122 is pressed against the pad assembly with a pressure less than or equal to about 0.3 psi. The process of step generally has a removal rate of about 500 to about 2000 Å/min, for example, between about 500 to about 1200 Å/min for both copper and tungsten processes.

[0080] Optionally, at step 520, a third clearance process step or "overpolish" may be performed to remove any remaining debris from the material layer. The third clearance process step is typically a timed process, and is performed at a reduced pressure. In one embodiment, the third clearance process step (also referred to as an overpolish step) has a duration of about 10 to about 30 seconds.

[0081] Following the residual material removal step 514, a barrier polish may be performed. In one embodiment, the barrier polish may be performed on the third CMP station 132, but may alternatively be performed on one of the other CMP stations 128, 130.

[0082] The following examples are provided to illustrate the effect of adjusting the flow rates of processing components which are combined to create a polishing slurry. Figure 6 is a plot comparing polishing removal rate for a polishing slurry with the amount of hydrogen peroxide in the polishing slurry. A removal rate as high as 4.2 micrometers per minute is observed with the processing component combinations shown in Figure 6.

[0083] In Figure 6, a first flow rate of processing component which includes a polishing abrasive of colloidal silica is kept constant to maintain the polishing slurry at 6% polishing abrasive by mass. The amount of hydrogen peroxide present in the slurry is varied from 3% to 9% for three concentrations of ELECTRACLEAN^{TM} (EC) chemical. The ELECTRACLEAN^{TM} chemical includes ammonium citrate with a pH of about 3. In general, the removal rate of a material disposed on a substrate increases as the percent EC or percent hydrogen peroxide is increased. Generally, a change in the percent EC has a greater effect on the removal rate than does a change in amount of hydrogen peroxide.

[0084] Figure 7 is a plot comparing polishing removal rate of a polishing slurry with the amount of corrosion inhibitor in the polishing slurry. For two separate polishing processes, the amount of corrosion inhibitor in a polishing slurry was varied from zero percent to 0.40 percent. In the first polishing process, the down force (DF) applied to the polishing pad was about 1 (psi). In the second polishing process the down force applied was about 3 psi. As a general trend, the removal rate of a material disposed on a substrate decreases as the down force applied to a polishing pad decreases or as the amount of corrosion inhibitor present in the polishing slurry increases.

[0085] Figure 8 is a plot comparing polishing removal rate of a copper layer with down force applied to a polishing pad. In the embodiment of Figure 8, the composition of the polishing slurry remained constant. The polishing slurry of the embodiment of Figure 8 included an acid having a concentration within a range from about 2 grams per liter to about 40 grams per liter; an oxidizer having a concentration within a range from about 4 grams per liter to about 80 grams per liter; a corrosion inhibitor having a concentration within a range from about 0.3 grams per liter to about 5 grams per liter; a pH buffer having a concentration less than about 100 grams per liter; and a polishing abrasive having a concentration within a range from about 0.1 grams per liter to about 50 grams per liter. Generally, as the applied down force increases, the removal rate of material disposed on a substrate increases.

[0086] While the foregoing is directed to embodiments of the present 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.

We Claim:

1. A method for processing a semiconductor substrate surface, comprising:

combining a first polishing component from a first storage unit and a polishing abrasive from a second storage unit while flowing the polishing abrasive and the first polishing component to a polishing pad, the polishing abrasive selected from the group consisting of colloidal silica, alumina, and ceria;

polishing a substrate with the polishing pad to remove at least a portion of a material layer disposed thereon;

measuring the thickness or uniformity of the material layer disposed on the substrate; and

adjusting the flow rate of the polishing abrasive or the first polishing component in response to the measured thickness or uniformity of the material layer to affect the removal rate of the material layer.

2. The method of claim 1, wherein the substrate comprises a through-silicon via, and the first polishing component comprises an acid, a buffer, and an oxidizer.

3. The method of claim 2, further comprising combining a second polishing component from a third storage unit with the polishing abrasive and the first polishing component while flowing the polishing abrasive, the first polishing component, and the second polishing component to the polishing pad, wherein the second polishing component comprises a corrosion inhibitor.

4. The method of claim 1, wherein the flow rate of the first polishing component or the polishing abrasive is adjusted when the thickness of the material layer on the substrate is within a range from about 2,000 angstroms to about 4,000 angstroms.

5. The method of claim 4, wherein the material layer comprises copper, and the thickness of the material layer removed from the substrate is within a range from about 4 micrometers to about 7 micrometers.

6. The method of claim 1, wherein the polishing a substrate comprises incrementally reducing a polishing rate in response to the measured thickness of the material layer.

7. A method for processing a semiconductor substrate surface, comprising:

flowing a polishing slurry to a polishing pad, the polishing slurry comprising:

a polishing abrasive from a first storage unit; and

a polishing component from a second storage unit, the polishing component comprising an acid, an oxidizer, a corrosion inhibitor and a pH buffer;

polishing a substrate with the polishing pad at a first rate to remove at least a portion of a material layer disposed thereon;

measuring the thickness or uniformity of the material layer disposed on the substrate; and

adjusting the flow rate of the polishing abrasive in response to the measured thickness or uniformity of the material layer to affect the polishing rate.

8. The method of claim 7, wherein the measuring the thickness or uniformity of the material layer is performed by spectrum based endpoint detection, optical endpoint detection, or charge, voltage or current measurement endpoint detection.

9. The method of claim 8, wherein the rate of polishing the substrate decreases in response to the decreasing thickness of the material layer disposed on the substrate, and the material layer removed from the substrate has a thickness within a range from about 6 micrometers to about 8 micrometers.

10. The method of claim 7, wherein a bulk material removal step and a residual material clear step are performed on the same platen, and the material layer comprises a conductive material.

11. A method for processing a semiconductor substrate surface, comprising:

combining a polishing abrasive from a first storage unit and a polishing component from a second storage unit while flowing the polishing abrasive and the polishing component to a polishing pad, the polishing abrasive selected from the group consisting of colloidal silica, alumina, and ceria, and the polishing component comprising an acid, an oxidizer, a corrosion inhibitor and a pH buffer;

polishing a substrate comprising a through-silicon via with the polishing pad to remove at least a portion of a material layer disposed on a substrate;

measuring the thickness or uniformity of the material layer disposed on the substrate; and

reducing the flow rate of the polishing abrasive in response to the decreasing measured thickness of the material layer, wherein the flow rate of the polishing component or the polishing abrasive is adjusted when the thickness of the material layer on the substrate is within a range from about 2,000 angstroms to about 4,000 angstroms.

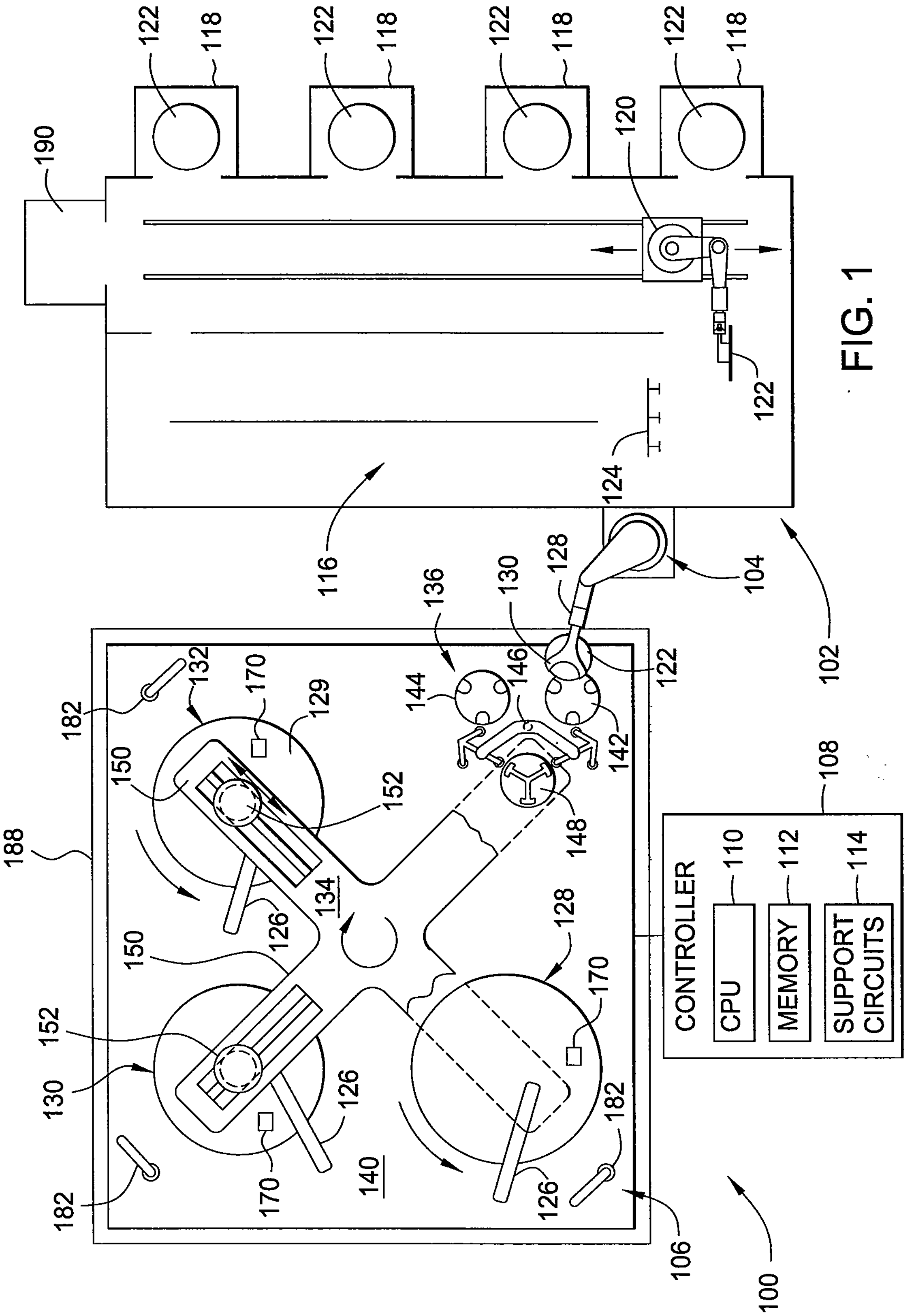
12. The method of claim 11, wherein the material layer comprises copper, and the thickness of the material layer removed from the substrate is within a range of about 4 micrometers to about 7 micrometers.

13. The method of claim 12, wherein the polishing component comprises a corrosion inhibitor, and further wherein the flow rate of the corrosion inhibitor is increased as the thickness of the material layer disposed on the substrate decreases.

14. The method of claim 13, wherein the measuring the thickness or uniformity of the material layer is performed by spectrum based endpoint detection, optical endpoint detection, or charge, voltage or current measurement endpoint detection.

15. The method of claim 11, wherein the combining the polishing abrasive and the polishing component is accomplished by creating a helical or spiraling flow path

within a single section of tubing to facilitate mixing of the polishing abrasive and the polishing component, and the polishing component comprises an acid, an oxidizer, a corrosion inhibitor and a pH buffer.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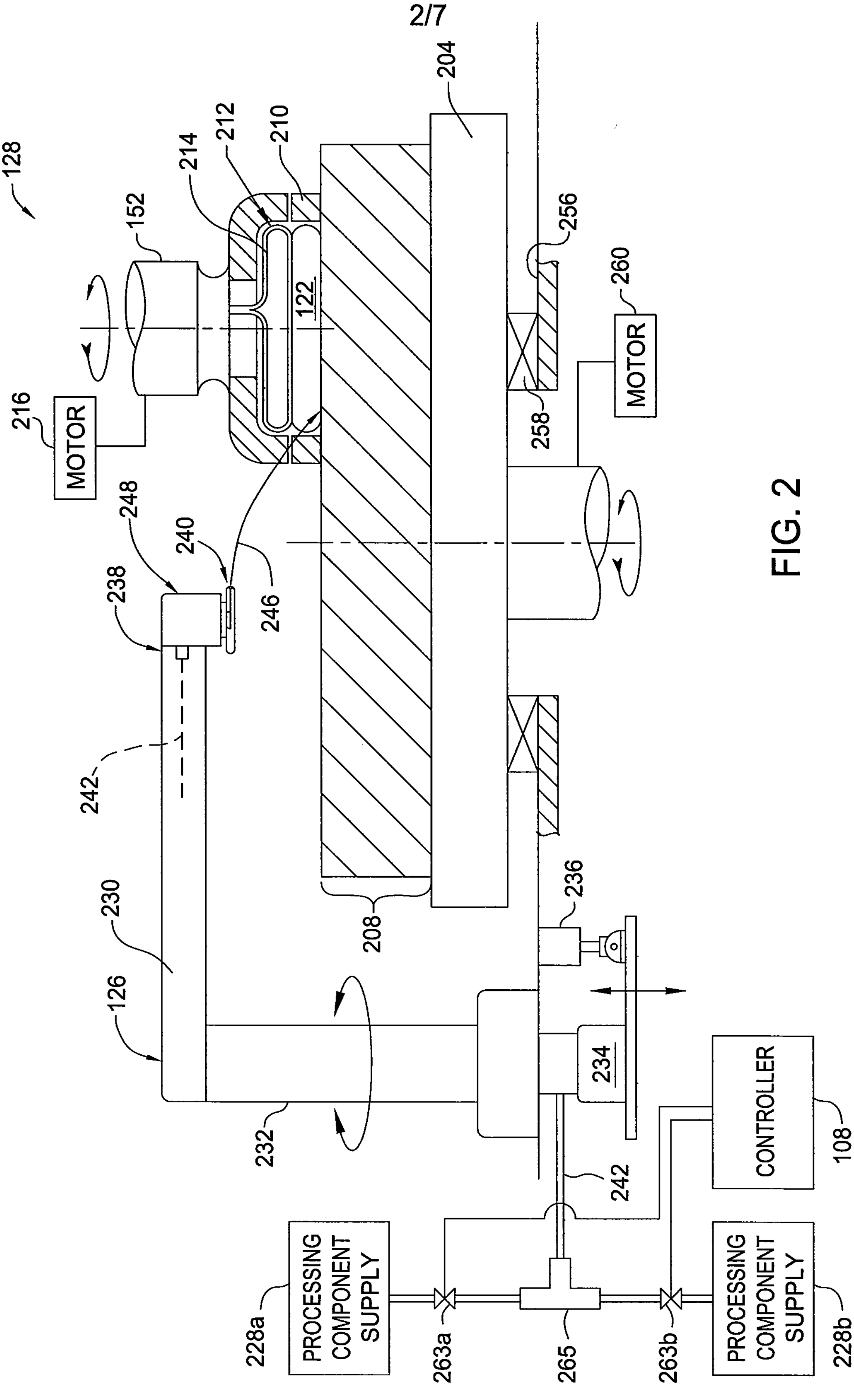
142
148
132
170
129
182
150
152
188
134
150
152
130
126
170
126
140
128
170
182
126
182
106
100
108
CONTROLLER
110
CPU
112
MEMORY
114
SUPPORT CIRCUITS

FIG. 1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152
214
212
210
204
216
MOTOR
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240
238
246
122
256
260
MOTOR
258
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230
126
208
236
234
232
242
CONTROLLER
108
PROCESSING COMPONENT SUPPLY
228a
263a
265
263b
PROCESSING COMPONENT SUPPLY
228b

FIG. 2

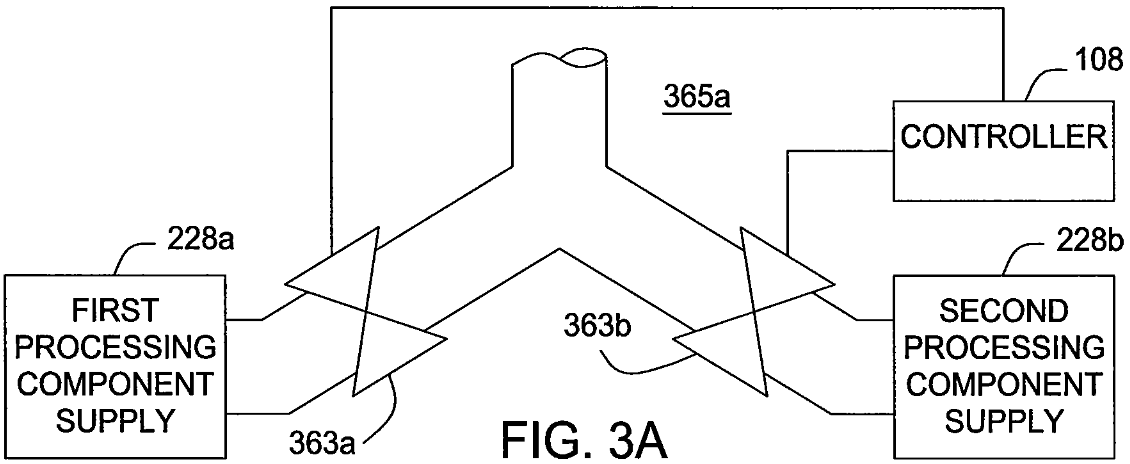


FIG. 3A

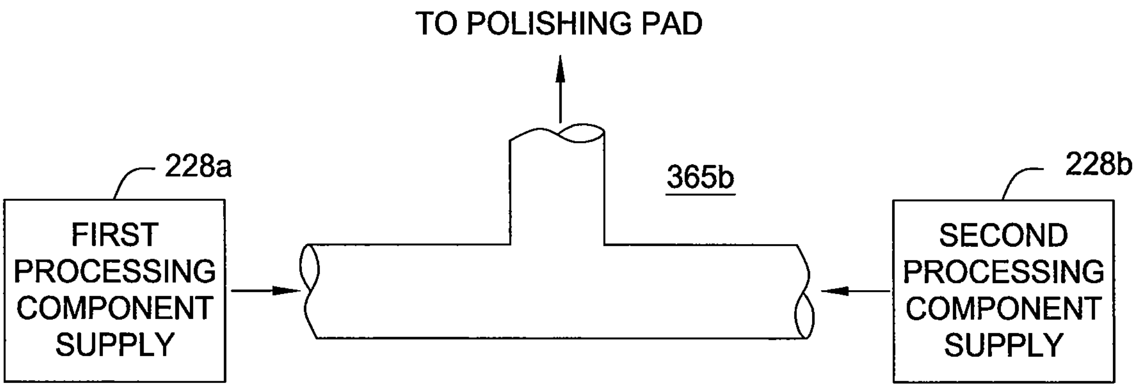


FIG. 3B

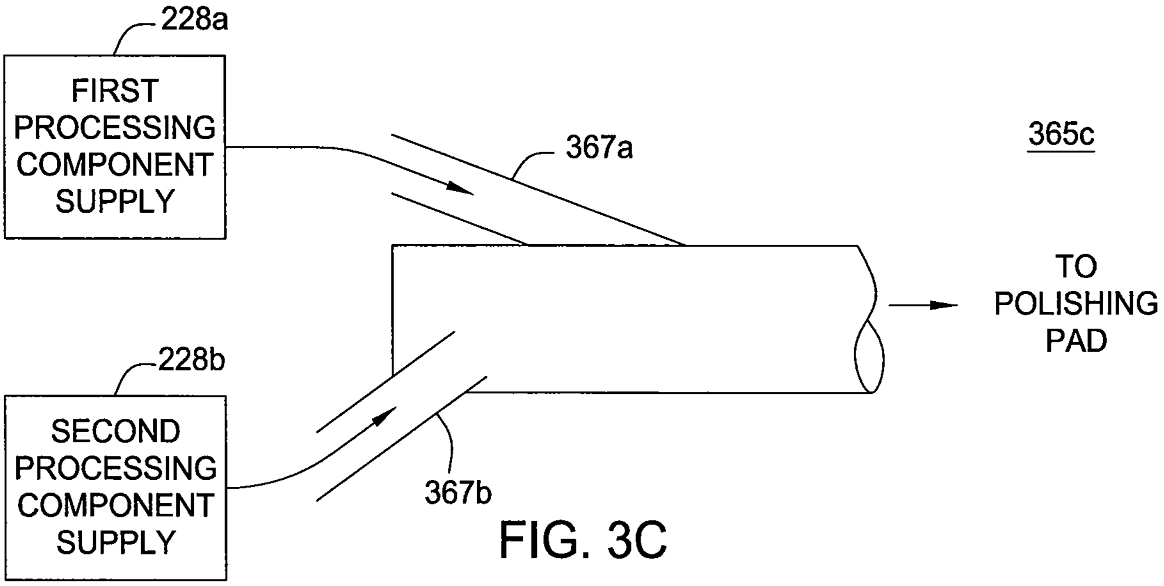


FIG. 3C

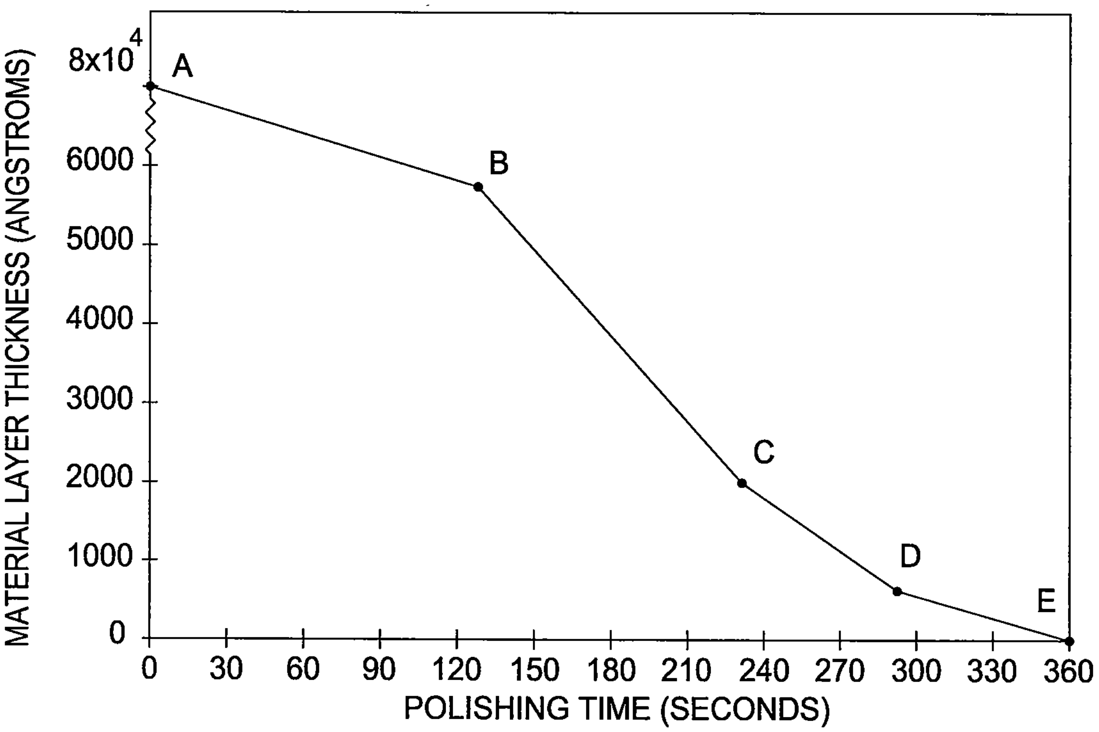

MATERIAL LAYER THICKNESS (ANGSTROMS)
$8x10^4$
6000
5000
4000
3000
2000
1000
0
A
B
C
D
E
0
30
60
90
120
150
180
210
240
270
300
330
360
POLISHING TIME (SECONDS)

FIG. 4A

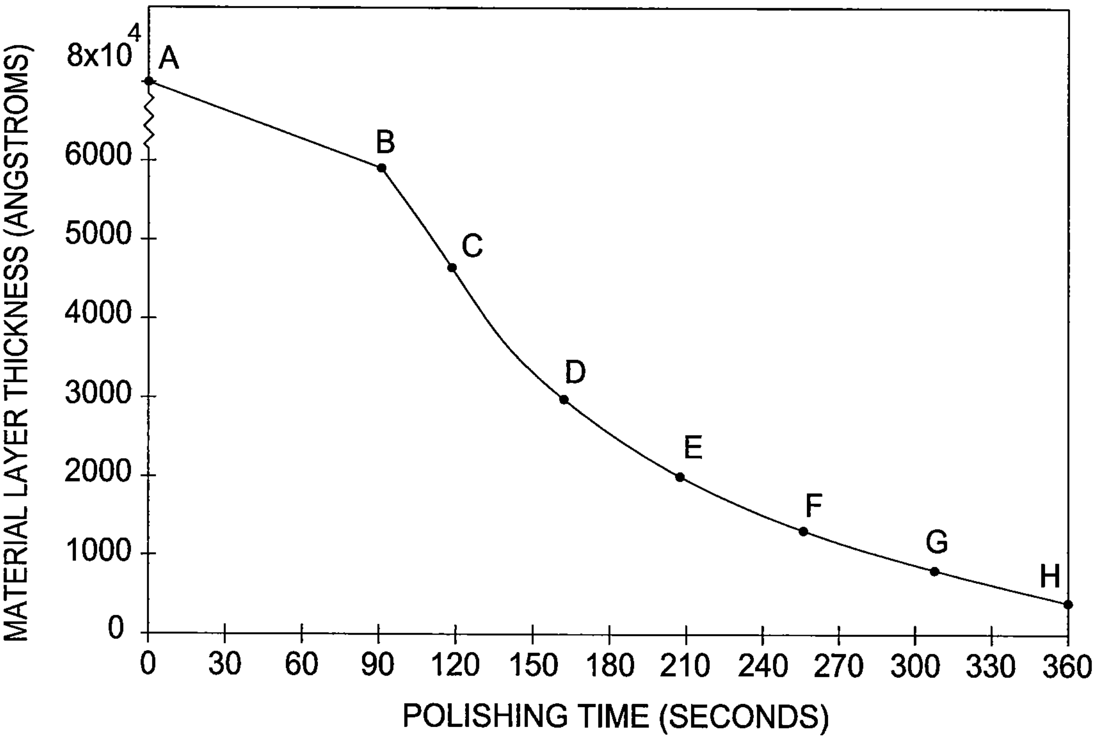
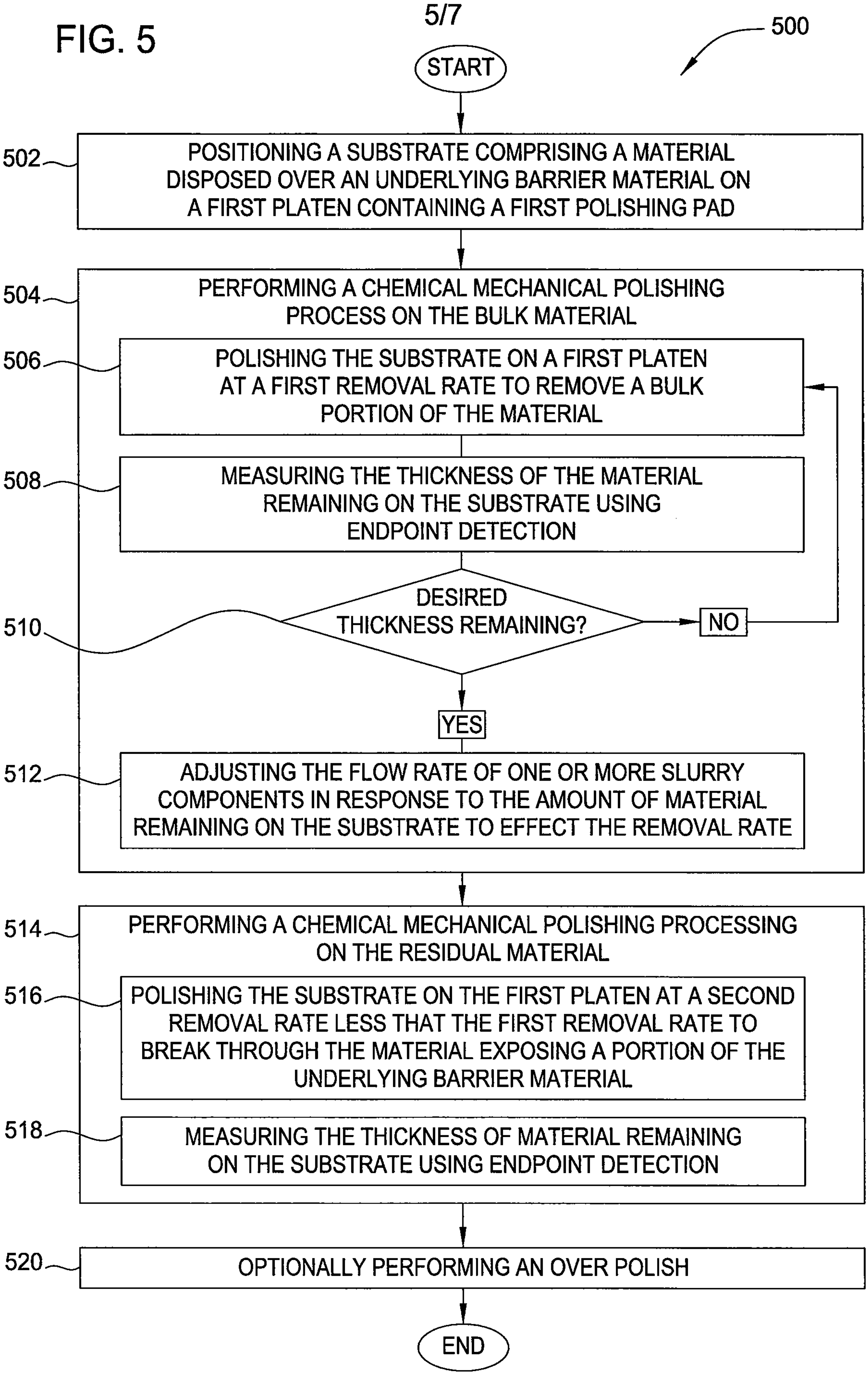

MATERIAL LAYER THICKNESS (ANGSTROMS)
$8x10^4$
6000
5000
4000
3000
2000
1000
0
A
B
C
D
E
F
G
H
0
30
60
90
120
150
180
210
240
270
300
330
360
POLISHING TIME (SECONDS)

FIG. 4B

FIG. 5


500
START
502
POSITIONING A SUBSTRATE COMPRISING A MATERIAL DISPOSED OVER AN UNDERLYING BARRIER MATERIAL ON A FIRST PLATEN CONTAINING A FIRST POLISHING PAD
504
PERFORMING A CHEMICAL MECHANICAL POLISHING PROCESS ON THE BULK MATERIAL
506
POLISHING THE SUBSTRATE ON A FIRST PLATEN AT A FIRST REMOVAL RATE TO REMOVE A BULK PORTION OF THE MATERIAL
508
MEASURING THE THICKNESS OF THE MATERIAL REMAINING ON THE SUBSTRATE USING ENDPOINT DETECTION
510
DESIRED THICKNESS REMAINING?
NO
YES
512
ADJUSTING THE FLOW RATE OF ONE OR MORE SLURRY COMPONENTS IN RESPONSE TO THE AMOUNT OF MATERIAL REMAINING ON THE SUBSTRATE TO EFFECT THE REMOVAL RATE
514
PERFORMING A CHEMICAL MECHANICAL POLISHING PROCESSING ON THE RESIDUAL MATERIAL
516
POLISHING THE SUBSTRATE ON THE FIRST PLATEN AT A SECOND REMOVAL RATE LESS THAT THE FIRST REMOVAL RATE TO BREAK THROUGH THE MATERIAL EXPOSING A PORTION OF THE UNDERLYING BARRIER MATERIAL
518
MEASURING THE THICKNESS OF MATERIAL REMAINING ON THE SUBSTRATE USING ENDPOINT DETECTION
520
OPTIONALLY PERFORMING AN OVER POLISH
END

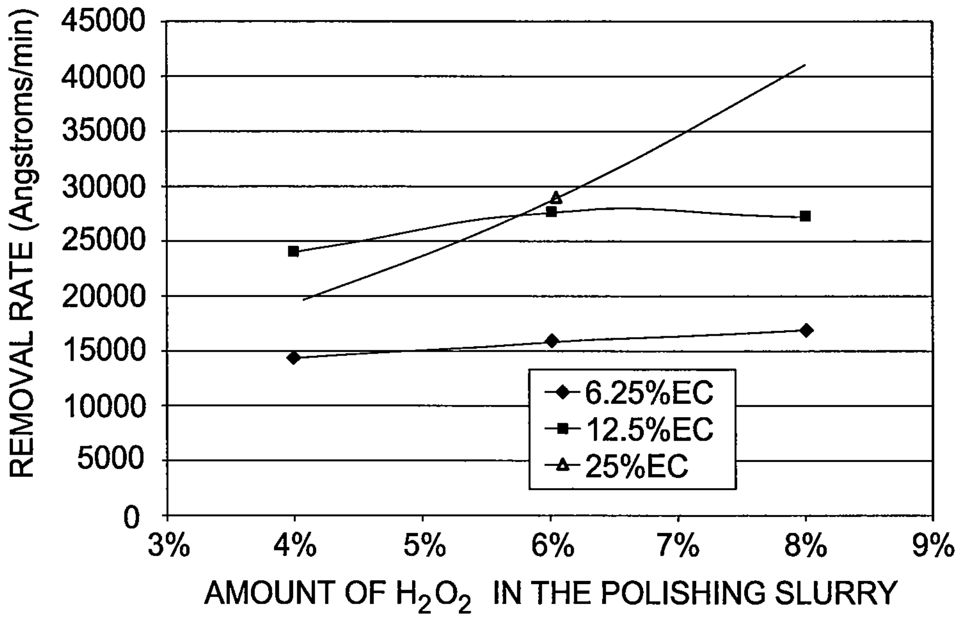

REMOVAL RATE (Angstroms/min)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
3%
4%
5%
6%
7%
8%
9%
AMOUNT OF H_2O_2 IN THE POLISHING SLURRY
◆ 6.25%EC
■ 12.5%EC
△ 25%EC

FIG. 6

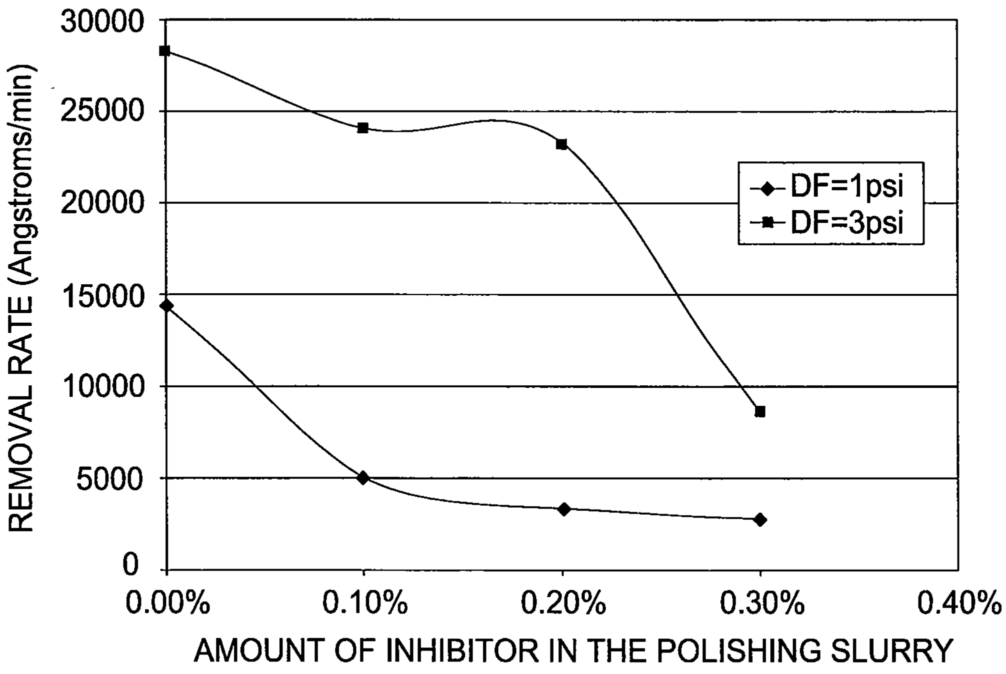

REMOVAL RATE (Angstroms/min)
30000
25000
20000
15000
10000
5000
0
0.00%
0.10%
0.20%
0.30%
0.40%
AMOUNT OF INHIBITOR IN THE POLISHING SLURRY
◆ DF=1psi
■ DF=3psi

FIG. 7

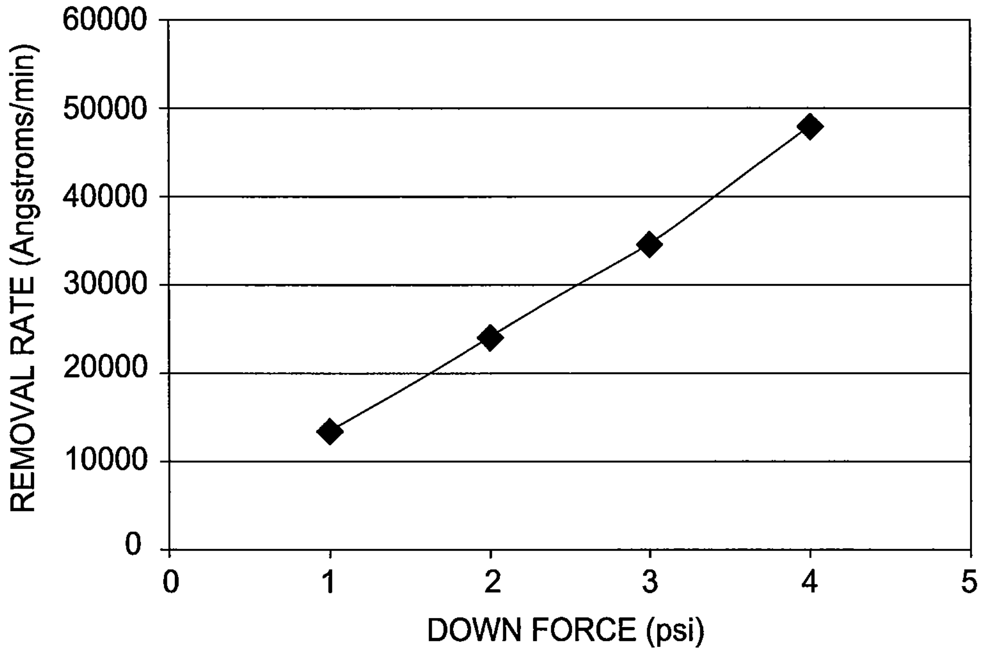

60000
50000
40000
30000
20000
10000
0
REMOVAL RATE (Angstroms/min)
0
1
2
3
4
5
DOWN FORCE (psi)

FIG. 8