Closed-loop control of CMP slurry flow

1. Measuring polishing pad thickness
2. Comparing the measured polishing pad thickness to an initial pre-polishing pad thickness to determine the amount of pad wear and the polishing pad groove depth
3. Adjusting the polishing slurry flow rate in response to the determined polishing pad groove depth
4. Polishing a pre-determined number of substrates
5. Repeating steps 380 through 388

FIG. 3
Published:
— without international search report and to be republished upon receipt of that report (Rule 48.2(g))
CLOSED-LOOP CONTROL OF CMP SLURRY FLOW

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to methods of chemical mechanical polishing a substrate.

Description of the Related Art

[0002] 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. However, as more substrates are polished in the CMP apparatus the efficiency of the polishing pad changes, and the polishing pad eventually requires replacement. Polishing pads and polishing slurries can be costly components, and it is preferable to reduce the amount of downtime required to replace polishing pads. Therefore, it is preferable to decrease the frequency at which pads are replaced, and to utilize polishing slurries more efficiently.

[0003] Thus, there is a need for a method of polishing a substrate using a polishing pad with longer useful life, and efficiently utilizing polishing slurry delivered thereto.
SUMMARY OF THE INVENTION

[0004] Embodiments of the present invention generally relate to methods for chemical mechanical polishing a substrate. The methods generally include measuring the thickness of a polishing pad having grooves or other slurry transport features on a polishing surface. Once the depth of the grooves on the polishing surface is determined, a flow rate of a polishing slurry is adjusted in response to the determined groove depth. A predetermined number of substrates are polished on the polishing surface. The method can then optionally be repeated.

[0005] In one embodiment, a method includes measuring a thickness of a polishing pad having grooves disposed in a polishing surface of the polishing pad. A depth of the grooves disposed in the polishing surface is determined, and a flow rate of a polishing slurry introduced to the polishing surface is adjusted in response to the determined depth of the grooves disposed in the polishing surface. A predetermined number of substrates is polished, and the method is repeated.

[0006] In another embodiment, a method includes measuring a thickness of a polishing pad having grooves disposed in a polishing surface of the polishing pad. The measured thickness of the polishing pad is compared to an initial pre-polish thickness of the polishing pad to determine a reduction in the polishing pad thickness. A depth of the grooves disposed in the polishing surface is then calculated. A flow rate of a polishing slurry introduced to the polishing surface is adjusted in response to the calculated depth of the grooves disposed in the polishing surface. A predetermined number of substrates are then polished. The polishing comprises contacting each of the predetermined number of substrates to the polishing pad, and introducing the polishing slurry to the polishing pad at the adjusted flow rate for each of the predetermined number of substrates. The method is then repeated.

[0007] In another embodiment, a method includes measuring a thickness of a polishing pad having grooves disposed in a polishing surface. The measured thickness of the polishing pad is compared to an initial pre-polish thickness of the
polishing pad to determine a reduction in polishing pad thickness, and a depth of the grooves disposed in the polishing surface is calculated. The calculated depth of the grooves is compared to a value stored in a look-up table. A slurry is introduced to the polishing pad at a predetermined flow rate, and the predetermined flow rate is dependent upon the calculated depth of the grooves. A predetermined number of substrates are polished, and then the method is repeated.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0008] 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.

[0009] Figure 1 is a top schematic view illustrating one embodiment of a chemical mechanical polishing system.

[0010] Figure 2 is a partial perspective view of a polishing station having a pad conditioning assembly.

[0011] Figure 3 is a flow diagram illustrating one embodiment of chemical mechanical polishing.

[0012] Figure 4 is a sectional schematic illustrating polishing pad groove depth.

[0013] Figures 5A-5C are sectional schematics illustrating polishing pad groove depths.

[0014] Figure 6 is a chart illustrating slurry flow rate versus oxide removal for polishing pads having different groove depths.
[0015] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

[0016] Embodiments of the present invention generally relate to methods for chemical mechanical polishing a substrate. The methods generally include measuring the thickness of a polishing pad having grooves or other slurry transport features on a polishing surface. Once the depth of the grooves on the polishing surface is determined, a flow rate of a polishing slurry is adjusted in response to the determined groove depth. A predetermined number of substrates are polished on the polishing surface. The method can then optionally be repeated.

[0017] While the particular apparatus in which the embodiments described herein can be practiced is not limited, it is particularly beneficial to practice the embodiments in a REFLEXION GT™ system, REFLEXION® LK CMP system, and MIRRA MESA® system sold by Applied Materials, Inc., of Santa Clara, California. Additionally, CMP systems available from other manufacturers may also benefit from embodiments described herein.

[0018] Figure 1 is a top schematic view illustrating one embodiment of a chemical mechanical polishing system 100. The CMP system 100 includes a factory interface 102, a cleaner 104 and a polishing module 106. A wet robot 108 is provided to transfer substrates 170 between the factory interface 102 and the polishing module 106. The wet robot 108 may also be configured to transfer substrates between the polishing module 106 and the cleaner 104. The factory interface 102 includes a dry robot 110 which is configured to transfer substrates 170 between one or more cassettes 114 and one or more transfer platforms 116. The dry robot 110 has sufficient range of motion to facilitate transfer between the four cassettes 114 and the one or more transfer platforms 116. Optionally, the dry robot 110 may be mounted on a rail or track 112 to position the robot 110 laterally within the factory.
interface 102, thereby increasing the range of motion of the dry robot 110 without requiring large or complex robot linkages. The dry robot 110 additionally is configured to receive substrates from the cleaner 104 and return the clean polished substrates to the substrate storage cassettes 114. Although one substrate transfer platform 116 is shown in the embodiment depicted in Figure 1, two or more substrate transfer platforms may be provided so that at least two substrates may be queued for transfer to the polishing module 106 by the wet robot 108 at the same time.

[0019] The polishing module 106 includes a plurality of polishing stations 124 on which substrates are polished while retained in one or more carrier heads 126a, 126b. The polishing stations 124 are sized to interface with two or more carrier heads 126a, 126b simultaneously so that polishing of two or more substrates may occur using a single polishing station 124 at the same time. The carrier heads 126a, 126b are coupled to a carriage (not shown) that is mounted to an overhead track 128 that is shown in phantom in Figure 1. The overhead track 128 allows the carriage to be selectively positioned around the polishing module 106 which facilitates positioning of the carrier heads 126a, 126b selectively over the polishing stations 124 and load cup 122. The overhead track 128 has a circular configuration which allows the carriages retaining the carrier heads 126a, 126b to be selectively and independently rotated over and/or clear of the load cups 122 and the polishing stations 124. The overhead track 128 may have other configurations including elliptical, oval, linear or other suitable orientation and the movement of the carrier heads 126a, 126b may be facilitated using other suitable devices.

[0020] Two polishing stations 124 are shown located in opposite corners of the polishing module 106. At least one load cup 122 is in the corner of the polishing module 106 between the polishing stations 124 closest the wet robot 108. The load cup 122 facilitates transfer between the wet robot 108 and the carrier heads 126a, 126b. Optionally, a third polishing station 124 (shown in phantom) may be positioned in the corner of the polishing station 124 opposite the load cups 122. Alternatively, a second pair of load cups 122 (also shown in phantom) may be located in the corner of the polishing module 106 opposite the load cups 122 that are
positioned proximate the wet robot. Additional polishing stations 124 may be integrated in the polishing module 106 in systems having a larger footprint.

[0021] Each polishing station 124 includes a polishing pad having a polishing surface 130 capable of polishing at least two substrates at the same time. The polishing pad may be formed from polyurethane. Each of the polishing stations 124 also includes a pad conditioning assembly 140. In one embodiment, the pad conditioning assembly 140 may comprise a conditioning head 132 which dresses the polishing surface 130 of the polishing pad by removing polishing debris and opening the pores of the pad, and a polishing fluid delivery arm 134. In one embodiment, each polishing station 124 comprises multiple pad conditioning assemblies 140. The polishing pad is supported on a platen assembly which rotates the polishing surface 130 during processing. The polishing surface 130 is suitable for at least one of a chemical mechanical polishing and/or an electrochemical mechanical polishing process. The system 100 is coupled with a power source 180.

[0022] To facilitate control of the polishing system 100 and processes performed thereon, a controller 190 comprising a central processing unit (CPU) 192, memory 194, and support circuits 196, is connected to the polishing system 100. The CPU 192 may be one of any form of computer processor that can be used in an industrial setting for controlling various drives and pressures. The memory 194 is connected to the CPU 192. The memory 194, or computer-readable medium, may be one or more of readily available memory such as random access memory (RAM), read only memory (ROM), floppy disk, hard disk, or any other form of digital storage, local or remote. The support circuits 196 are connected to the CPU 192 for supporting the processor in a conventional manner. These circuits include cache, power supplies, clock circuits, input/output circuitry, subsystems, and the like.

[0023] CMP polishing systems, such as polishing system 100 shown in Figure 1, typically use polishing pads having one or more grooves (not shown) on a polishing surface 130 to assist in removing material from a substrate. The groove depth of a typical pad is about 15 mils or about 30 mils, and the pad may have a thickness of
about 80 mils. As polishing pads are used for polishing, the polishing surface wears away and the groove depth decreases. In order to increase the useful life of polishing pads, the thickness of the polishing pads can be increased, for example up to 120 mils. Correspondingly, the groove depth is also increased, for example, to about 40 mils, 50 mils, or 60 mils. However, if the groove depth of the polishing pad is increased, and all other process parameters are maintained constant, then a pad with a groove depth of 40 mils will have a lower polishing rate than a pad with a groove depth of 30 mils. Thus, the amount of polishing slurry applied to a polishing pad having a groove depth of 40 mils should be greater than the amount of polishing slurry applied to a polishing pad having a groove depth of 30 mils in order to generate equal polishing rates. Conversely, as the groove depth on the polishing pad is reduced, the polishing removal rate increases if all other processing parameters are maintained constant. In addition to or as an alternative to grooves, polishing pads may also utilize other slurry transport features, such as perforations. Although embodiments herein shall generally refer to grooves, it is to be understood that the use of pads having other slurry transport features, such as perforations, may also be utilized and benefit from embodiments herein.

[0024] As the polishing pad having a groove depth of 40 mils polishes substrates, the groove depth is reduced and the polishing rate increases. It would be wasteful to continue supplying a constant amount of polishing slurry since the polishing rate is already increasing due to pad wear. Thus, embodiments of the present invention provide methods for closed-loop control of polishing slurry flow rate in response to a measured groove depth of a polishing pad.

[0025] Figure 2 is a partial perspective view of a polishing station 224 having a pad conditioning assembly 240 according to embodiments described herein. In one embodiment, the pad conditioning assembly 240 comprises a conditioning head 232 supported by a support assembly 246 with a support arm 244 therebetween. The pad conditioning assembly 240 further comprises a displacement sensor 260 coupled with the support arm 244. In another embodiment, the displacement sensor 260 may be coupled with the conditioning head 232. Carrier heads 226a and 226b
are disposed above the polishing surface 230. A polishing fluid delivery arm 234 is positioned above the polishing surface 230 and is adapted to provide a polishing fluid or slurry to the polishing pad 236 during processing. The flow rate of the polishing slurry provided through the polishing fluid delivery arm 234 is controlled by a controller (not shown). Additionally, a conditioning disk 248 is located adjacent to the polishing pad surface 230, and is adapted to condition the polishing pad 236.

[0026] The support assembly 246 is adapted to position the conditioning head 232 in contact with the polishing surface 230, and further is adapted to provide a relative motion therebetween. The support arm 244 has a distal end coupled to the conditioning head 232 and a proximal end coupled to the base 247. The base 247 rotates to sweep the conditioning head 232 across the polishing surface 230 to condition the polishing surface 230. The polishing surface 230 of the polishing pad 236 has grooves 201 disposed therein. As a result of the relative motion of the conditioning head 232 with respect to the polishing surface 230 of the polishing pad 236, the displacement sensor 260 may take thickness measurements of the polishing surface 230 and the polishing pad 236.

[0027] The sensor coupled to the conditioning arm allows a thickness of the polishing pad 236 to be measured at various points during a portion of a normal operation cycle, while the accompanying logic allows the measurement data to be captured and displayed. In some embodiments, the displacement sensor 260 may utilize an inductive sensor.

[0028] In embodiments where the displacement sensor 260 is a laser based sensor, the thickness of the polishing pad 236 is measured directly. The support arm 244 is in a fixed position with respect to the platen assembly 241, and the laser is in a fixed position with respect to the arm. Consequently, the laser is in a fixed position with respect to the platen assembly 241. By measuring the distance to the processing pad and calculating the difference between the distance to the polishing pad 236 and the distance to the platen assembly 241, the remaining thickness of the polishing pad 236 may be determined. In some embodiments, the resolution of the
thickness measurement using the laser-based displacement sensor 260 may be within 25um.

[0029] In embodiments where the displacement sensor 260 is an inductive sensor, the thickness of the polishing pad 236 is measured indirectly. The support arm 244 is actuated around a pivot point until the conditioning head 232 comes in contact with the processing pad 236. An inductive sensor, which emits an electromagnetic field, is mounted to the end of the pivot based conditioning support arm 244. In accordance with Faraday's law of induction, the voltage in a closed loop is directly proportional to the change in the magnetic field per change in time. The stronger the applied magnetic field, the greater the eddy currents developed and the greater the opposing field. A signal from the sensor is directly related to the distance from the tip of the sensor to the metallic platen assembly 241. As the platen assembly 241 rotates the conditioning head 232 rides on the surface of the pad and the inductive sensor rises and falls with the conditioning support arm 244 according to the profile of the polishing pad 236. As the inductive sensor gets closer to the metallic platen assembly 241 the voltage of the signal increases, which is an indication of processing pad wear. The signal from the sensor is processed and captures the variation in the thickness of the polishing pad 236. In some embodiments, the resolution of the thickness measurement using the inductive sensor 260 may be within 1um.

[0030] Figure 3 is flow diagram illustrating one embodiment of chemical mechanical polishing. In step 380, the thickness of a polishing pad is measured using at least one of the sensors described above. This measurement is relayed to a controller. In step 382, the measured thickness of the polishing pad is compared to an initial pre-polish thickness of the polishing pad, e.g., the thickness of the pad at the beginning of the process. Typically, the initial pre-polish thickness is also stored in the controller. For example, if the polishing pad is a new pad, and the initial thickness is known, then this value may be entered into the controller. Alternatively, if the thickness of the processing pad is unknown, the initial pre-polish thickness of
the polishing pad may be measured with the sensor, and then relayed to the controller for storage.

[0031] By comparing the measured polishing pad thickness to the initial pre-polish pad thickness, a change in pad thickness can be determined by the controller. Since the polishing pad wears away at the polishing surface, the difference in pad thickness also directly relates to a change in the depth of the grooves disposed in the polishing surface. For example, the polishing pad thickness and the groove depth are reduced at the same rate. Thus, by measuring a change in polishing pad thickness, a change in groove depth can also be determined. Additionally, since the number and location (or pitch) of grooves is fixed during pad fabrication, and since typical polishing pads have grooves with approximately vertical sidewalls, the determined groove depth can also be used to calculate groove volume.

[0032] In step 384, the closed-loop controller adjusts the polishing slurry flow rate provided to the polishing pad in response to the polishing pad groove depth determined in step 382. Typically, prior to beginning a polishing process, a user-input look-up table is stored in the controller. The look-up table correlates a predetermined flow rate of polishing slurry to a determined or measured groove depth. The flow rates may vary from process to process, and may depend upon pad composition, slurry composition, or substrate material. Typically, the flow rates are determined empirically.

[0033] In step 386, the polishing slurry is provided to the polishing pad at the corresponding flow rate for each substrate processed thereafter, and a predetermined number of substrates are subsequently polished. For example, 200, 300, 500 or 1000 wafers may be consecutively polished using the flow rate of polishing slurry corresponding to the last determined polishing pad groove depth. In optional step 388, steps 380, 382, 384, and 386 are repeated. Although steps 380, 382, 384, and 386 may be repeated more often than every few hundred substrates, for example, after every substrate is polished, it is generally not advantageous to do so. Typically, there is not enough of a change in groove depth to cause a noticeable
change in polishing slurry flow rate after polishing only a single substrate. Therefore, it is sufficient to determine polishing pad groove depth and adjust polishing slurry flow rate after at least about 500 substrates have been polished. However, as the polishing pad thickness decreases and the polishing pad approaches its process end-life, it may be desirable to measure polishing pad thickness and determine groove depth more frequently. This is due to the fact that polishing pads experience a "spike" in polishing removal rate near the end of the useful life of the pad. By measuring the pad thickness more often, it can be easier to identify when the pad needs replacement. Additionally, more frequent pad measurements can help to avoid substrate damage caused by over-polishing during the "spike," and also help to avoid wasting excess consumables such as polishing slurry.

[0034] Figure 4 a sectional schematic illustrating polishing pad groove depth. In the embodiment shown in Figure 4, the polishing pad 436 may have grooves 401 of different depths. The grooves may initially have a pre-polish depth of about 40 mils. However, after polishing, the grooves 401 may have a reduced depth, such as about 30 mils or 15 mils. Additionally or alternatively, the pad may have multiple grooves with different depths prior to polishing. When the grooves 401 approach or surpass a depth of about 5 mils, the pad generally should be replaced.

[0035] Figures 5A-5C are sectional schematics illustrating polishing pad groove depths. In Figure 5A, the polishing pad 536a has grooves 501a which have depths of 40 mils. The thickness of polishing pad 536a may be between about 80 mils and 120 mils. Figure 5B shows a polishing pad 536b which has grooves 501b. The grooves 501b have a depth of about 30 mils. Polishing pad 536b may have a thickness of about 100 mils. When the groove depth reaches about 5 mils, the pad is considered to be worn out, and typically requires replacement shortly thereafter. Figure 5C illustrates a polishing pad 536c having grooves 501c with depths of about 15 mils. In order to increase the usable lifetime of polishing pads, the polishing pad thickness and polishing pad groove depth may be increased. For example, the groove depth may be increased from about 30 mils for a conventional pad to about 40 mils, as is shown in Figure 5A. In another embodiment, the groove depth may be
increased to about 50 mils or about 60 mils. As noted above, a polishing pad having a groove depth of about 40 mils generally needs a greater flow rate of polishing slurry than a polishing pad having a groove depth of 30 mils to produce a similar polishing rate. Thus, as the groove depth is reduced, the flow rate of polishing slurry may also be reduced, yet the polishing rate may be maintained substantially constant.

[0036] Figure 6 is a chart illustrating slurry flow rate versus silicon oxide removal for polishing pads having different groove depths. As can be seen in Figure 6, the polishing pad having groove depths of 40 mils needs a higher polishing slurry flow rate (e.g., the slurry flow rate is shifted to the right) to obtain the same polishing removal rate as a polishing pad having groove depths of 30 mils. For the polishing pad having groove depths of 30 mils, a slurry flow rate of 100 milliliters per minute is capable of removing about 1200 angstroms per minute. When the slurry flow rate is increased to 200 milliliters per minute, the polishing pad having groove depths of 30 mils is capable of removing about 1750 angstroms per minute. When the slurry flow rate is increased to 300 milliliters per minute, the polishing pad having groove depths of 30 mils is capable of removing about 1800 angstroms per minute.

[0037] In comparison, the polishing pad having groove depths of 40 mils only removes about 1400 angstroms per minute of material when the polishing slurry flow rate is 200 milliliters per minute. When the slurry flow rate is increased to 300 milliliters per minute, the polishing pad having groove depths of 40 mils is capable of removing about 1600 angstroms per minute. The polishing pad having groove depths of 40 mils requires a slurry flow rate of 400 milliliters per minute to produce a removal rate of about 1750 angstroms per minute, which is approximately what a pad with a groove depth of 30 mils removes with a slurry flow rate of 200 milliliters per minute.

[0038] Additionally, methods herein can be used for pads having an initial groove depth of less than 40 mils, for example, about 30 mils. However, groove depth is only a secondary factor affecting polishing rate when the groove depth is less than
30 mils. A stronger relationship between groove depth and removal rate can be seen when the groove depth is greater than 30 mils; therefore, it is of greater concern to utilize closed-loop control of slurry flow when using pads having groove depths greater than 30 mils.

[0039] A closed-loop control system allows a constant polishing rate to be maintained while reducing the amount of slurry delivered to the polishing pad as the pad wears. Closed-loop control of slurry flow allows for the use of pads having a longer useful life, which reduces the frequency at which pads need to be replaced. Additionally, closed-loop control of slurry flow in response to pad thickness allows the slurry flow rate to be tailored to the pad thickness and groove depth, which helps ensure the excess slurry is not being wastefully provided to the pad. The closed-loop control of polishing slurry should lead to significant cost savings over the life of the polishing pad by not wasting consumable materials. Embodiments disclosed herein allow for efficient use of thicker polishing pads with longer useful lives, while still maintaining a high substrate throughput.

[0040] 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, comprising:
   (a) measuring a thickness of a polishing pad, the polishing pad having grooves disposed in a polishing surface of the polishing pad;
   (b) determining a depth of the grooves disposed in the polishing surface;
   (c) adjusting a flow rate of a polishing slurry introduced to the polishing surface in response to the determined depth of the grooves disposed in the polishing surface;
   (d) polishing a predetermined number of substrates; and
   (e) repeating (a)-(d).

2. The method of claim 1, wherein the predetermined number of substrates is about 500 substrates.

3. The method of claim 1, wherein the predetermined number of substrates is about 1000 substrates.

4. The method of claim 1, wherein the grooves disposed in the polishing pad surface have an initial depth of about 40 mils.

5. The method of claim 1, wherein the adjusting the flow rate comprises reducing the flow rate of the polishing slurry as the depth of the grooves decreases.

6. The method of claim 5, wherein the measuring a thickness of a polishing pad comprises measuring the thickness using an inductive sensor.

7. The method of claim 6, wherein the adjusting the flow rate comprises associating the determined depth of the grooves to a predetermined slurry flow rate located in a look-up table, the look-up table stored on a computer-readable medium.
8. A method, comprising:
   (a) measuring a thickness of a polishing pad, the polishing pad having grooves disposed in a polishing surface of the polishing pad;
   (b) comparing the measured thickness of the polishing pad to an initial pre-polish thickness of the polishing pad to calculate a reduction in polishing pad thickness;
   (c) calculating a depth of the grooves disposed in the polishing surface;
   (d) adjusting a flow rate of a polishing slurry introduced to the polishing surface in response to the determined depth of the grooves disposed in the polishing surface;
   (e) polishing a predetermined number of substrates, the polishing comprising contacting each of the predetermined number of substrates to the polishing pad, and introducing the polishing slurry to the polishing pad at the adjusted flow rate for each of the predetermined number of substrates; and
   (f) repeating (a)-(e).

9. The method of claim 8, wherein the adjusting a flow rate of a polishing slurry comprises reducing the flow rate of the polishing slurry as the depth of the grooves disposed in the polishing surface decreases, such that a substantially constant polishing removal rate is maintained.

10. The method of claim 9, wherein the adjusting a flow rate comprises associating the determined depth of the grooves to a slurry flow rate located in a look-up table stored in a computer-readable medium.

11. The method of claim 10, wherein the measuring a thickness of a polishing pad comprises measuring the thickness using an inductive sensor.

12. A method, comprising:
   (a) measuring a thickness of a polishing pad, the polishing pad having grooves disposed in a polishing surface of the polishing pad;
(b) comparing the measured thickness of the polishing pad to an initial pre-polish thickness of the polishing pad to determine a reduction in polishing pad thickness;
(c) calculating a depth of the grooves disposed in the polishing surface;
(d) comparing the calculated depth of the grooves to a value stored in a look-up table;
(e) introducing a slurry to the polishing pad at a predetermined flow rate; the predetermined flow rate dependent upon the calculated depth of the grooves;
(f) polishing a predetermined number of substrates; and

13. The method of claim 12, further comprising replacing the polishing pad when the grooves have a depth of about 5 mils or less.

14. The method of claim 13, wherein the introducing a slurry to the polishing pad comprises reducing the flow rate of the polishing slurry as the depth of the grooves disposed in the polishing surface decreases, such that a substantially constant polishing removal rate is maintained.

15. The method of claim 14, wherein the measuring a thickness of the polishing pad comprises measuring the thickness using an inductive sensor, and wherein the calculating a depth of the grooves disposed in the polishing surface further comprises determining the volume of the grooves disposed in the polishing surface.
FIG. 3

380: MEASURING POLISHING PAD THICKNESS

382: COMPARE THE MEASURED POLISHING PAD THICKNESS TO AN INITIAL PRE-POLISHING PAD THICKNESS TO DETERMINE THE AMOUNT OF PAD WEAR AND THE POLISHING PAD GROOVE DEPTH

384: ADJUSTING THE POLISHING SLURRY FLOW RATE IN RESPONSE TO THE DETERMINED POLISHING PAD GROOVE DEPTH

386: POLISHING A PRE-DETERMINED NUMBER OF SUBSTRATES

388: REPEATING STEPS 380 THROUGH 386