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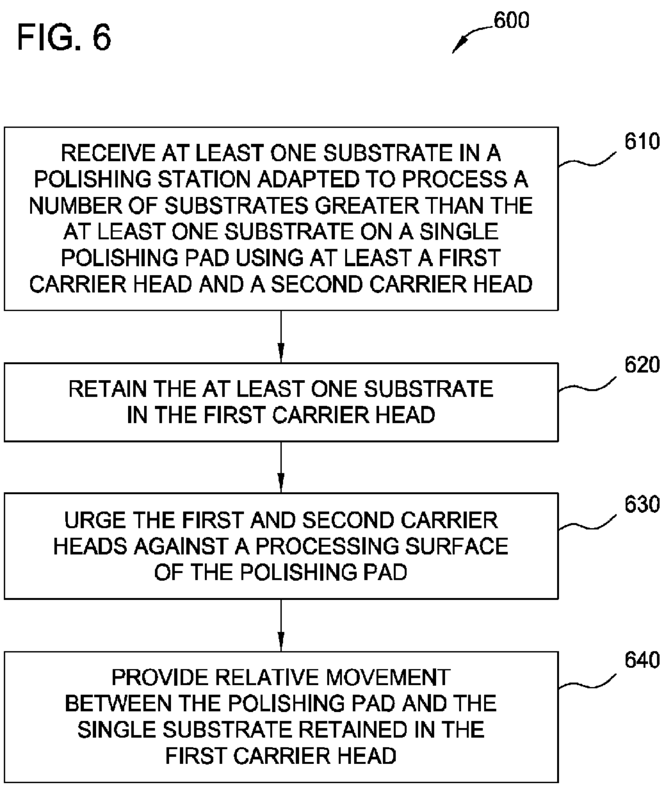
[Continued on next page]

(54) Title: TUNING OF POLISHING PROCESS IN MULTI-CARRIER HEAD PER PLATEN POLISHING STATION

FIG. 6



(57) Abstract: An apparatus and method for simulating a substrate being polished in a multiple carrier head per platen station when no substrate is provided in one or more of the multiple carrier heads is described. In one embodiment, a method for processing a substrate includes providing a single substrate to a polishing station adapted to process a plurality of substrates on a single polishing pad using at least a first carrier head and a second carrier head, retaining the single substrate in the first carrier head while the second carrier head remains substrate-free, urging the first carrier head and the second carrier head toward a polishing surface of the polishing pad; and providing relative movement between the polishing pad and the first carrier head.

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TUNING OF POLISHING PROCESS IN MULTI-CARRIER HEAD PER PLATEN POLISHING STATION

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to polishing a substrate, such as a semiconductor substrate. More specifically, embodiments relate to tuning a polishing process on a substrate in a multi-carrier head per platen polishing station.

Description of the Related Art

[0002] Chemical mechanical polishing (CMP) is one process commonly used in the manufacture of high-density integrated circuits to planarize or polish a layer of material deposited on a substrate. The substrate may be provided to a polishing station and retained in a carrier head that controllably urges the substrate against a moving polishing pad mounted on a platen. CMP is effectively employed by providing contact between a feature side of the substrate and moving the substrate relative to the polishing pad while in the presence of a polishing fluid. Material is removed from the feature side of the substrate that is in contact with the polishing surface through a combination of chemical and mechanical activity.

[0003] Conventional CMP polishing stations may contain multiple carrier heads per platen such that multiple substrates may be processed simultaneously on a common polishing pad supported by a platen. The conventional polishing stations are effective in increasing throughput by polishing more than one substrate at a time and/or reducing tool footprint. These stations are effectively utilized when the number of substrates to be polished equal the number of carrier heads per platen. Process recipes in these stations are known and factors such as polishing fluid concentration, polishing fluid distribution, as well as heat generated by multiple substrates being polished on a single pad are utilized to provide optimum removal rates and removal profiles. However, there may be instances when one or more of the carrier heads are not utilized in a polishing process. The non-use of the one or more carrier heads may detrimentally affect the polishing process on other substrates being polished in the used carrier heads.

[0004] Therefore, there is a need for a method and apparatus that is utilized to control polishing parameters on a substrate being polished in a carrier head in a multiple carrier head per platen station other carrier heads do not contain a substrate.

SUMMARY OF THE INVENTION

[0005] The present invention generally provides an apparatus and method for simulating a substrate being polished in one or more carrier heads in a multiple carrier head per platen station when no substrate is present in the one or more carrier heads. In one embodiment, a method for tuning a polishing process on a substrate in a processing station having at least a first carrier head and a second carrier head adapted to retain and process a substrate using a common polishing pad is described. The method includes retaining a single substrate in a first retaining ring disposed on the first carrier head while the second carrier head remains empty, urging the first carrier head and the single substrate toward a polishing surface of the polishing pad while bringing the second retaining ring disposed on the second carrier head into contact with the polishing surface, the second carrier head remaining empty, providing relative motion between the single substrate and the polishing pad, and varying at least one of a pressure of the second retaining ring against the polishing pad and a rotational speed of the second retaining ring relative to the polishing pad.

[0006] In another embodiment, a method for tuning a polishing process on at least a first substrate in a polishing station adapted to process at least one substrate greater than the first substrate on a common polishing pad is described. The method includes retaining the first substrate in a first retaining ring disposed on at least one used carrier head, urging the first retaining ring disposed on the at least one used carrier head and a second retaining ring disposed on at least one empty carrier head toward a polishing surface of the polishing pad, the at least one empty carrier head remaining substrate-free, and providing relative movement between the polishing pad and the at least one used carrier head.

[0007] In another embodiment, a method for processing a substrate is described. The method includes receiving at least one substrate in a polishing station adapted to process a number of substrates greater than the at least one substrate on a common polishing pad using at least a first carrier head and a second carrier head, positioning the at least one substrate in a retaining ring disposed on the first carrier head while the second carrier head remains empty, urging the first carrier head and the second carrier head toward a polishing surface of the polishing pad, and providing relative movement between the polishing pad and the first carrier head.

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 plan view of a polishing module.

[0010] Figure 2 is a partial cross-sectional view of one embodiment of a polishing station of Figure 1.

[0011] Figure 3 is a graph representing removal rates of substrates retained in one of the carrier heads of the polishing station of Figure 2.

[0012] Figure 4 is a graph representing removal profiles of substrates retained in one of the carrier heads of the polishing station of Figure 2.

[0013] Figure 5 is a graph representing topographical data obtained from polishing substrates retained in one of the carrier heads of the polishing station of Figure 2.

[0014] Figure 6 is a flowchart showing one embodiment of a method of the present invention.

[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 polishing a substrate, such as a semiconductor substrate, utilizing a chemical mechanical polishing (CMP) process. The CMP process is described in a polishing system having multiple polishing stations. Each of the polishing stations contain multiple carrier heads operable on a common platen to increase throughput and/or reduce tool footprint. A multiple carrier head per platen station that may benefit from embodiments of the invention is a REFLEXION GT™ polishing system available from Applied Materials, Inc. of Santa Clara, California. However, the REFLEXION GT™ polishing system is only representative and other polishing systems and/or polishing stations may benefit as well. The CMP process is exemplarily described utilizing a circular pad disposed on a rotatable platen. However, other embodiments may be used on polishing pads having other shapes, such as rectangular polishing pads or belt-type polishing pads.

[0017] Figure 1 is a plan view of a polishing module 100 for processing one or more substrates. The polishing module 100 includes a polishing platform 106 that at least partially supports and houses a plurality of polishing stations 124. Each of the plurality of polishing stations 124 are adapted to polish substrates that are retained in one or more carrier heads 126. The polishing stations 124 may be sized to interface with the one or more carrier heads 126 simultaneously so that polishing of one or more substrates may occur at a single polishing station 124 at the same time. The carrier heads 126 are coupled to a carriage 108 that is mounted to an overhead track 128. The platform 106 also includes one or more load cups 122 adapted to facilitate transfer of a substrate between the carrier heads 126 and a factory interface (not shown) or other device (not shown) by a transfer robot 110. The load cups 122 generally facilitate transfer between the robot 110 and each of the carrier heads 126.

[0018] The overhead track 128 allows each carriage 108 to be selectively positioned around the polishing platform 106. The configuration of the overhead track 128 and carriages 108 facilitates positioning of the carrier heads 126 selectively over the polishing stations 124 and the load cups 122. In the embodiment depicted in Figure 1, the overhead track 128 has a circular configuration (shown in phantom) which allows the carriages 108 retaining the carrier heads 126 to be selectively rotated over and/or clear of the load cups 122 and the polishing stations 124. It is contemplated that the overhead track 128 may have other configurations including elliptical, oval, linear or other suitable orientation.

[0019] Each polishing station 124 generally includes a polishing pad 130 supported on a platen (not shown in Figure 1) which rotates the polishing pad 130 during processing. In one embodiment, each polishing station 124 can accommodate two carrier heads 126 that are capable of retaining two substrates simultaneously. In one embodiment, each polishing station 124 includes two conditioning modules 132 and two polishing fluid delivery modules 134. The conditioning modules 132 are utilized to condition or roughen a polishing surface of the polishing pad 130 while the polishing fluid delivery modules 135 provide a polishing fluid to the polishing pad 130. Additionally, each of the polishing fluid delivery modules 134 are positioned to independently provide a predetermined distribution of polishing fluid on the polishing pad 130. In one embodiment, the polishing pad 130 is suitable for at least one of a chemical mechanical polishing and/or an electrochemical mechanical polishing process.

[0020] Figure 2 is a partial cross-sectional view of the polishing station 124 of Figure 1. The polishing station 124 includes a platen 200 with a polishing pad 130 mounted thereon. The platen 200 is coupled to a shaft 202 and a motor 204 to rotate the platen 200 and the polishing pad 130 about a rotational axis. The polishing station 124 includes two carrier heads 206A, 206B similar to carrier heads 126 as shown in Figure 1.

[0021] Each of the carrier heads 206A, 206B are coupled to a shaft 208A, 208B, which are coupled to a motor 210 to independently lift or lower the respective carrier head 206A, 206B in the Z direction relative to a polishing surface 212 of the polishing pad 130. Each of the carrier heads 206A, 206B are coupled to a rotary actuator 214 that is adapted to independently rotate the respective carrier head 206A, 206B about a rotational axis relative to the polishing pad 130 and platen 200. The carrier heads 206A, 206B may also be adapted to sweep across the polishing surface 212 of polishing pad 130 in a linear (X or Y direction) or arcuate (X and Y direction) motion provided by actuators (not shown) disposed between the track 128 and carriages 108. A polishing fluid supply nozzle 218 is disposed above the polishing pad 130 for supplying a polishing fluid 220 onto the polishing pad 130.

[0022] The polishing pad 130 may be a polymer material, which may be solely dielectric to facilitate removal of materials from substrates during a polishing process. Alternatively, the polishing pad 130 may be at least partially conductive to facilitate electrochemical dissolution of material from substrates in an electrochemical mechanical polishing (ECMP) process. Suitable polymeric materials that may be used include polyurethane, polycarbonate, fluoropolymers, PTFE, PTFA, polyphenylene sulfide (PPS), or combinations thereof, and other polishing materials used in polishing substrate surfaces. In one embodiment, polishing pad 130 includes at least a polishing surface made of a polymeric material, such as open-pored or closed-pored polyurethane material typically used in the fabrication of polishing pads for service in the polishing of semiconductor substrates. In another application, the polishing pad 130 may contain fixed abrasives. Thus, the polishing fluid 220 may be a slurry or an electrolytic fluid depending on the polishing process used.

[0023] Each of the carrier heads 206A, 206B include a body 222 circumscribed by a retaining ring 224. Each of the carrier heads 206A, 206B also contain a bladder 228 that is adjacent a flexible membrane 230 which contacts a backside of the substrates 216A, 216B as the substrates 216A, 216B are retained in the carrier heads 206A, 206B. The bladder 228 may be pressurized to apply force to the flexible membrane 230 which may distort the flexible membrane 230. The bladder

228 may be divided into two or more variable pressure zones adapted to be pressurized individually. In one embodiment, the bladder 228 is divided into five separate pressurizable zones adapted to contain different pressures that may be applied to the substrate through the flexible membrane 230. Forces applied to the flexible membrane 230 from the bladder 228 are transmitted to portions of the substrates 216A, 216B and may be used to urge portions of the substrates 216A, 216B toward the polishing surface 212. Additionally, vacuum ports (not shown) may be provided in the carrier heads 206A, 206B to apply suction to the backside of the substrates 216A, 216B facilitating retention of the substrates 216A, 216B in the carrier head.

[0024] Each retaining ring 224 may contain a material which is chemically inert in a CMP process, such as a plastic, *e.g.,* polyphenylene sulfide (PPS), polyetheretherketone (PEEK), a carbon containing PEEK material, a TEFLON® containing PEEK material, or a composite material. Each retaining ring 224 is in fluid communication with a variable pressure source 226. The variable pressure source 226 allows the retaining ring 224 to move relative to the body 222 of the respective carrier head 206A, 206B in at least the Z direction. The variable pressure source 226 is adapted to provide the Z directional movement of the retaining ring 224 independent of movement provided by the motor 210. The variable pressure source 224 may provide movement of the retaining ring 224 by applying negative pressure or positive pressure to the retaining ring 224. In one aspect, negative pressure is applied to the retaining ring 224 to space the retaining ring 224 away from the polishing surface 212. In another embodiment, the variable pressure source 226 applies a pressure of about 1 pound per square inch (PSI) to about 12 PSI to urge the retaining ring 224 in the Z direction toward the polishing surface 212. Examples of carrier heads that may be utilized include the TITAN HEAD™ carrier head and the TITAN PROFILER™ carrier head, both available from Applied Materials, Inc. of Santa Clara, California.

[0025] When an even number of substrates, such as two semiconductor substrates 216A, 216B, are provided to the load cups 122 of the polishing module 100 (Figure 1), each carrier head 206A, 206B is positioned over the load cups 122 to facilitate transfer of the two substrates 216A, 216B from the load cups 122 to the carrier heads 206A, 206B. Each carrier head 206A, 206B is adapted to hold the substrates 216A, 216B by vacuum applied by the carrier heads 206A, 206B acting on the backside of the substrates and/or pressure applied to the retaining rings 224 from the variable pressure source 226. Once the substrates 216A, 216B are retained in the carrier heads 206A, 206B, the carrier heads 206A, 206B are positioned over the polishing pad 130 by action of the carriages 108 (Figure 1) and motors 210 (Figure 2). Each carrier head 206A, 206B is urged toward the processing surface 212 of the polishing pad 130 during processing by forces provided by one or a combination of the motors 210 and movement of the retaining ring 224 by pressure from the variable pressure source 226.

[0026] The substrates 216A, 216B are held in the retaining rings 224 in a manner that facilitates contact between the feature side of the substrate and the polishing surface 212 of the polishing pad 130. The variable pressure source 226 provides a pressure of about 6 PSI to about 8 PSI to urge the substrate toward the polishing surface 212. Processing factors such as concentration of the polishing fluid 220, distribution of the polishing fluid 220, roughness of the polishing surface 212 as well as heat generated by two substrates being polished on the polishing pad 130 are optimized to provide an optimum removal rate and removal profile on the substrates 216A, 216B retained in the carrier heads 206A, 206B. However, when only one substrate is present, the temperature and fluid flow produced affect the polishing process.

[0027] For example, when there is a mismatch in the number of substrates to be polished and the number of available carrier heads, only a fraction of the carrier heads will be utilized. For example, when there are two available carrier heads and a single substrate, such as substrate 216A or 216B, is provided to the polishing station 124, only one of the carrier heads 206A, 206B will be utilized to polish the single substrate. When only one of the carrier heads 206A or 206B are utilized to polish the single substrate, the processing dynamics are changed and may detrimentally affect the polishing process on the single substrate.

[0028] Various adjustments may be made to the polishing parameters to optimize the polishing of the single substrate. In one example, the unused carrier head 206A or 206B may be actuated to be spaced away from the polishing surface 212 while the other carrier head is utilized to polish the single substrate. Adjustments to flow rate of polishing fluid 220, rotational speed and downforce of the carrier head with the single substrate may be made in an attempt to achieve an optimum removal rate and removal profile on the single substrate. However, the adjustments may be based on trial and error and are time consuming and costly. In another example, a dummy substrate may be retained in the unused carrier head. However, chip manufacturers are disinclined to use a dummy substrate due to particle contamination and/or chemical reactions that may occur due to mismatches between film chemistry and the polishing fluid 220.

[0029] The inventors have discovered that the unused or empty carrier head 206A or 206B may be utilized to mimic the polishing of two substrates. Additionally, the unused carrier head may be used as a control knob to tune the polishing process on the single substrate. Thus, processing factors in the polishing of a single substrate may be maintained in a manner that is substantially similar to the processing factors of the polishing of two substrates. Further, the unused or empty carrier head 206A or 206B may be utilized to tune the polishing process on the single substrate. For example, removal rate, removal profile and/or topography of the single substrate may be controlled by manipulating the empty carrier head 206A or 206B over the polishing pad 130.

[0030] Figure 3 is a graph 300 representing removal rate data obtained from sequential polishing of three individual substrates retained in one of the carrier heads 206A or 206B while the remaining carrier head was empty. Data from each of the three substrates retained in the used carrier head are represented as lines 305, 310 and 315 showing removal rates in a time period of 30 seconds. Processing parameters utilized in polishing each of the substrates, such as rotational speeds of the platen and/or carrier head, downforce, retaining ring pressure, polishing fluid flow rates as well as other processing parameters were maintained as if both of the carrier heads contained substrates and were used in a simultaneous polishing process. Each of the lines 305, 310 and 315 represent removal rates of respective substrates. The graph 300 shows how the empty carrier head may be utilized to vary or tune the removal rate of each substrate using various pressures applied to the retaining ring 224 of the empty carrier head.

[0031] Line 305 shows a copper removal rate of about 4,000 Angstroms (Å) per 0.5 minutes when the retaining ring 224 of the empty carrier head was maintained at vacuum, which caused the retaining ring 224 to be spaced away from the polishing surface 212. Line 310 shows a copper removal rate of about 4,500 Å per 0.5 minutes when the retaining ring 224 of the empty carrier head was urged against the polishing surface 212 at a pressure of about 5 PSI. Line 315 shows a copper removal rate of about 5,000 Å per 0.5 minutes when the retaining ring 224 of the empty carrier head was urged toward the polishing surface 212 at a pressure of about 7 PSI. Thus, variations in pressure applied to the empty carrier head may be manipulated to tune the removal rate of the single substrate.

[0032] Figure 4 is a graph 400 representing removal profile data obtained from sequential polishing of two individual substrates retained in one of the carrier heads 206A or 206B while the remaining carrier head was empty. Processing parameters utilized in polishing each of the substrates, such as rotational speeds of the platen and/or carrier head, downforce, retaining ring pressure, polishing fluid flow rates as well as other processing parameters were maintained as if both of the carrier heads contained substrates and were used in a simultaneous polishing process. The pressure applied to the retaining ring of the empty carrier head was about 2 PSI to about 8 PSI, such as about 3 PSI to about 6 PSI. Data from each of the two substrates retained in the used carrier head are represented as lines 405 and 410. The graph 400 shows how the empty carrier head may be utilized to vary or tune the removal profile of substrates using various rotational speeds applied to the empty carrier head. The varied rotational speeds create varied friction which results in changes in temperature of the polishing surface of the polishing pad and/or polishing liquid. Additionally, the varied rotational speeds alter the flow of the polishing fluid across the polishing surface of the polishing pad. One or a combination of the temperature change and flow dynamics of the polishing fluid change the removal profile of the single substrate.

[0033] Line 405 shows the removal profile of a first substrate retained in one of the carrier heads while the rotational speed of the empty carrier head was about 7 revolutions per minute (RPM). Line 410 shows the removal profile of a second substrate retained in one of the carrier heads while the rotational speed of the empty carrier head was about 77 RPM. Thus, variations in rotational speeds applied to the empty carrier head may be manipulated to tune the removal profile of the single substrate.

[0034] Figure 5 is a graph 500 representing topographical data obtained from polishing three individual substrates retained in one of the carrier heads 206A or 206B while the remaining carrier head was empty. Data from each of the three substrates retained in the used carrier head are represented as bars 505, 510 and 515. Processing parameters utilized in polishing of each substrate, such as rotational speeds of the platen and/or carrier head, downforce, retaining ring pressure, polishing fluid flow rates as well as other processing parameters were maintained as if both of the carrier heads 206A or 206B contained substrates and were used in a simultaneous polishing process. Each of the bars 505, 510 and 515 represent topographical measurements relative to feature density. The graph 500 shows how the empty carrier head 206A or 206B may be utilized to vary or tune the topography of each of the three substrates using various pressures applied to the retaining ring 224 of the empty carrier head.

[0035] Areas A-H represent various regions of each of the three substrates. Area A represents 100 μm line width/100 μm space or distance between features. Area B represents 50 μm line width/1 μm space or distance between features. Area C represents 9 μm line width/1 μm space or distance between features. Areas D, E, F, G and H represent isolated line widths (*e.g.*, where no features are near the lines). Areas D, E, F, G and H represent 10 μm, 20 μm, 30 μm, 50 μm and 100 μm isolated line widths, respectively.

[0036] Bar 505 shows data at each area where the retaining ring 224 of the empty carrier head was maintained at vacuum, which caused the retaining ring 224 to be spaced away from the polishing surface 212. Bar 510 shows data at each area where the retaining ring 224 of the empty carrier head was urged against the polishing surface 212 at a pressure of about 3 PSI. Bar 515 shows data at each area where the retaining ring 224 of the empty carrier head was urged toward the polishing surface 212 at a pressure of about 6 PSI.

[0037] Thus, graph 500 shows that pressure applied to the empty carrier head may be used to alter the topography of the single substrate. Additionally, as features become more dense, the empty carrier head may dramatically affect the topography of the single substrate.

[0038] The data shown in Figures 3-5 results from a complex set of interactions that affect the polishing of the single substrate. Pressure and/or rotational velocity applied to the retaining ring 224 of the empty carrier head influences temperature of the polishing pad 130, asperities on the polishing surface 212, as well as polishing fluid and by-product distribution. In one example, the combined influences result in higher topography on the single substrate as greater pressure is applied to the retaining ring 224 of the empty carrier head.

[0039] Figure 6 is a flowchart showing one embodiment of a method 600 of the present invention. At 610, a substrate is provided to a polishing station having at least a first carrier head and a second carrier head adapted to process a plurality of substrates on a single polishing pad. In one embodiment, the substrate is a single substrate provided to a polishing station containing two carrier heads per polishing pad.

[0040] At 620, the single substrate is retained in the first carrier head. The second carrier head remains substrate-free or empty. At 630, the first and second carrier heads are urged against a processing surface of the single polishing pad. At 640, relative motion between the polishing pad and the single substrate retained in the first carrier head is provided.

[0041] While the method 600 has been described in a polishing station having two carrier heads sharing a common polishing pad, the method may also be utilized on a polishing station containing three or four carrier heads per polishing pad. In one example, the polishing station may contain enough carrier heads to retain and polish at least one additional substrate simultaneously on the single polishing pad than is provided to the station. In one embodiment, the substrate(s) provided to the polishing station may be referred to as an “n” substrate, where n is an integer that is less than the number of carrier heads per platen. In this embodiment, the number of available carrier heads per platen may be referred to as “h” carrier heads. For example, two substrates may be provided to a polishing station having three carrier heads. In this example, n equals 2 substrates and h equals 3 carrier heads. In one embodiment, the unused carrier head(s) in the exemplary polishing station is referred to as a “h-n” carrier head and the used carrier head(s) is referred to as an “h+n” carrier head.

[0042] In one aspect, the unused carrier head or the h-n carrier head(s) is utilized to tune the polishing process of a single substrate disposed in the h+n carrier heads. The polishing process on the substrate being polished may be altered by varying rotational speeds of the unused carrier head or the h-n carrier head(s), varying pressure of the unused carrier head or the h-n carrier head(s) against the polishing pad, and combinations thereof.

[0043] In one embodiment, a retaining ring disposed on the used carrier head or h+n carrier head(s) is urged toward the polishing pad at a first pressure of about 6 PSI to about 8 PSI while a retaining ring disposed on the unused carrier head or the h-n carrier head(s) is urged toward the polishing pad at a second pressure that is lower than the first pressure. In one example, the second pressure is about 2 PSI to about 7 PSI, such as about 5 PSI. In another embodiment, the first pressure and the second pressure are substantially equal.

[0044] In another embodiment, the used carrier head or h+n carrier head(s) is rotated relative to the rotating polishing pad at a first rotational speed and the unused carrier head or the h-n carrier head(s) is rotated relative to the rotating polishing pad at a second rotational speed. In one aspect, the first rotational speed and the second rotational speed are different. For example, the first rotational speed of the used carrier head or h+n carrier head(s) is about 77 RPM while the second rotational speed of the unused carrier head or the h-n carrier head(s) is about 7 RPM to about 15 RPM. In another embodiment, the first rotational speed of the used carrier head or h+n carrier head(s) and the second rotational speed of the unused carrier head or the h-n carrier head(s) are substantially equal.

[0045] Embodiments described herein generally provide an apparatus and method for simulating a substrate being polished in a multiple carrier head per platen station when no substrate is provided in one or more of the multiple carrier heads. The multiple carrier head per platen stations typically utilize polishing and cleaner recipes on substrates having the same film thickness, die layout and integration layer. The multiple carrier head per platen stations work well when the number of substrates provided to the station equal the number of carrier heads on the station. In the case where one or more of the multiple carrier heads are not provided with a substrate, embodiments described herein provide a method of using unused carrier heads in the multiple carrier head per platen station to mimic the dynamics of polishing substrates in each of the carrier heads. Further, the unused carrier head or heads may be used to tune the removal rate, removal profile and/or the topography of the substrate being polished. The method as described herein may be utilized in the polishing of metal films, such as copper or tungsten as well as barrier and dielectric films, such as tetraethyl orthosilicate (TEOS), tantalum nitride (TaN) and carbon doped silicon dioxide films.

[0046] In one operational example, a single substrate is provided to the polishing station 124 of Figure 2. The single substrate is retained in carrier head 206A while carrier head 206B remains empty. The platen 200 is caused to rotate at a rotational velocity of about 70 RPM to about 90 RPM, such as about 80 RPM to about 86 RPM, for example about 83 RPM. Concurrently, the carrier head 206A is caused to rotate at about 70 RPM to about 84 RPM, such as about 72 RPM to about 80 RPM, for example about 77 RPM. Polishing fluid 220 is flowed from both polishing fluid delivery modules 135 (Figure 1) at a flow rate of about 300 milliliters per minute. A pressure of about 0.5 PSI to about 3.5 PSI, such as about 1.5 PSI to about 2.8 PSI, for example 2.4 PSI is applied to the bladder 228 disposed in the carrier head 206A. The bladder 228 applies pressure to the backside of the substrate and urges regions of the substrate against the polishing surface 212. The retaining ring 224 on the carrier head 206A is pressurized at a pressure of about 3 PSI to about 10 PSI, such as about 4 PSI to about 8 PSI, for example about 6 PSI in order to perform a polishing process on the single substrate.

[0047] Simultaneously, the empty carrier head 206B is caused to rotate at about 70 RPM to about 84 RPM, such as about 72 RPM to about 80 RPM, for example about 77 RPM. A negative pressure to about 0.0 PSI is applied to the bladder 228 disposed in the carrier head 206B to prevent the flexible membrane 230 from contacting the polishing surface 212. The retaining ring 224 on the carrier head 206B is pressurized at a pressure of about 3 PSI to about 10 PSI, such as about 4 PSI to about 8 PSI, for example about 6 PSI in order to promote contact between the polishing surface 212 and the retaining ring 224 on the carrier head 206B. Thus, the carrier head 206B is adapted to create or mimic the dynamics of two substrates being polished on the common polishing pad 130. In this example, the removal rate and/or the removal profile of the single substrate being polished may be substantially equal to the removal rates and/or the removal profile of two substrates being polished on the common polishing pad 130.

[0048] 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.

Claims:

1. A method for tuning a polishing process on a substrate in a processing station having at least a first carrier head and a second carrier head adapted to retain and process a substrate using a common polishing pad, the method comprising:

retaining a single substrate in a first retaining ring disposed on the first carrier head while the second carrier head remains empty;

urging the first carrier head and the single substrate toward a polishing surface of the polishing pad while bringing the second retaining ring disposed on the second carrier head into contact with the polishing surface, the second carrier head remaining empty;

providing relative motion between the single substrate and the polishing pad; and

varying at least one of a pressure of the second retaining ring against the polishing pad and a rotational speed of the second carrier head relative to the polishing pad.

2. The method of claim 1, further comprising:

urging the first retaining ring disposed on the first carrier head toward the polishing surface of the polishing pad at a first pressure.

3. The method of claim 2, wherein the second retaining ring disposed on the second carrier head is urged toward the polishing surface at a second pressure that is less than the first pressure.

4. The method of claim 2, wherein the second retaining ring disposed on the second carrier head is urged toward the polishing surface at a second pressure, the first pressure and the second pressure being substantially equal.

5. The method of claim 1, wherein the first carrier head is rotated at a first velocity relative to the polishing pad and the second carrier head is rotated at a second velocity relative to the polishing pad that is less than the first velocity.

6. The method of claim 1, wherein the first carrier head is rotated at a first velocity relative to the polishing pad and the second carrier head is rotated at a second velocity relative to the polishing pad that is substantially equal to the first velocity.

7. The method of claim 1, wherein the first retaining ring is urged toward the polishing surface of the polishing pad at a first pressure and the second retaining ring disposed on the second carrier head is urged toward the polishing surface of the polishing pad at a second pressure, wherein the second pressure is less than or equal to the first pressure.

8. A method for tuning a polishing process on at least a first substrate in a polishing station adapted to process at least one substrate greater than the first substrate on a common polishing pad, the method comprising:

retaining the first substrate in a first retaining ring disposed on at least one used carrier head;

urging the first retaining ring disposed on the at least one used carrier head and a second retaining ring disposed on at least one empty carrier head toward a polishing surface of the polishing pad, the at least one empty carrier head remaining substrate-free; and

providing relative movement between the polishing pad and the at least one used carrier head.

9. The method of claim 8, wherein the first retaining ring is urged toward the polishing pad at a first pressure and the second retaining ring is urged toward the polishing surface at a second pressure that is less than the first pressure.

10. The method of claim 8, wherein the first retaining ring is urged toward the polishing pad at a first pressure and the second retaining ring is urged toward the polishing surface at a second pressure, the first pressure and the second pressure being substantially equal.

11. The method of claim 8, further comprising:

providing relative motion between the empty carrier head and the polishing pad.

12. The method of claim 11, wherein the used carrier head is rotated at a first velocity and the empty carrier head is rotated at a second velocity that is less than the first velocity.

13. The method of claim 11, wherein the first retaining ring is urged toward the polishing pad at a first pressure and the second retaining ring is urged toward the polishing surface at a second pressure that is less than the first pressure.

14. The method of claim 11, wherein the first retaining ring is urged toward the polishing pad at a first pressure and the second retaining ring is urged toward the polishing surface at a second pressure, the first pressure and the second pressure being substantially equal.

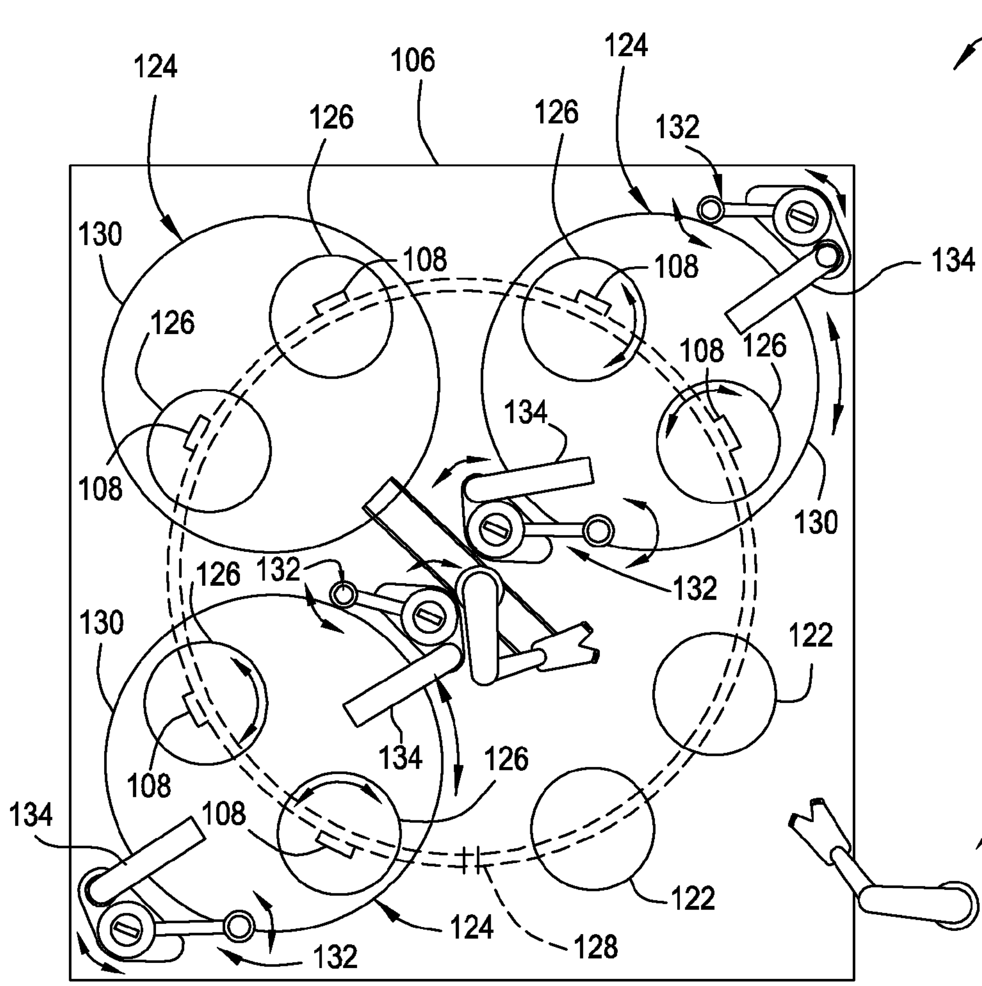
15. A method for processing a substrate, comprising:

receiving at least one substrate in a polishing station adapted to process a number of substrates greater than the at least one substrate on a common polishing pad using at least a first carrier head and a second carrier head;

positioning the at least one substrate in a retaining ring disposed on the first carrier head while the second carrier head remains empty;

urging the first carrier head and the second carrier head toward a polishing surface of the polishing pad; and

providing relative movement between the first carrier head, the second carrier head, and the polishing pad.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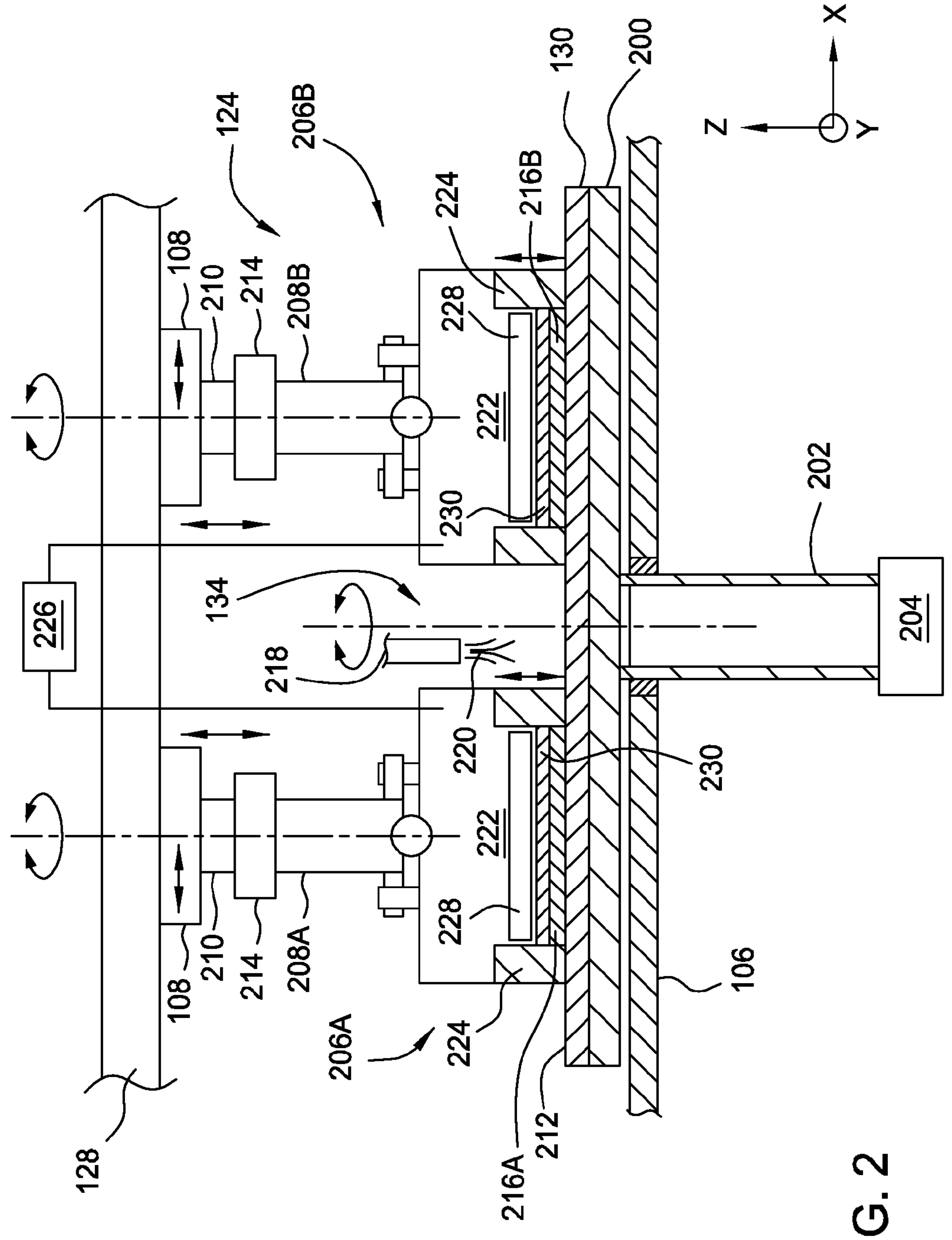
126
108
134
108
110
122
132
124
128

FIG. 1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X
Z
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226
134
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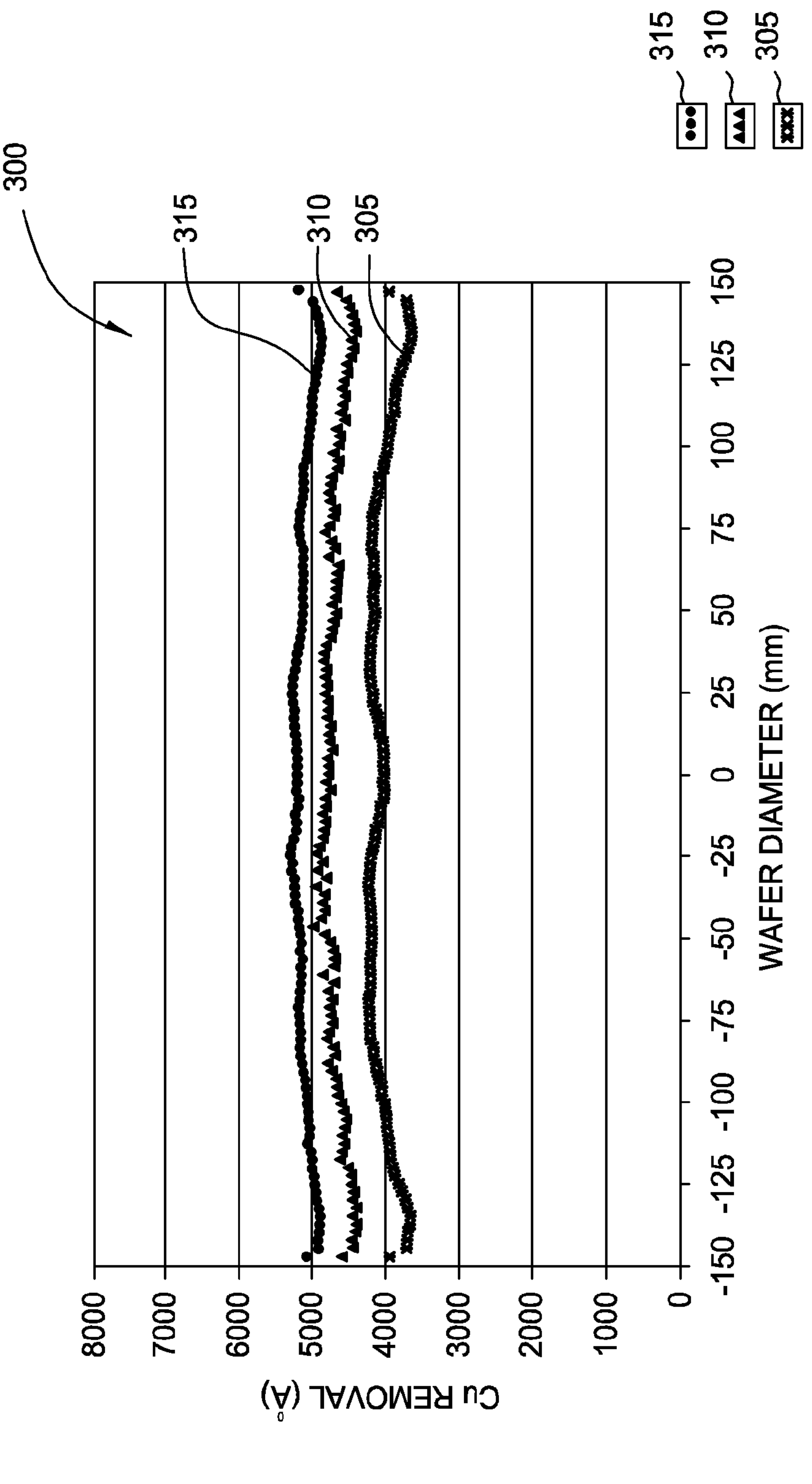
230
202
204
222
228
108
210
214
208A
224
206A
128
216A
212
106

FIG. 2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315
310
305
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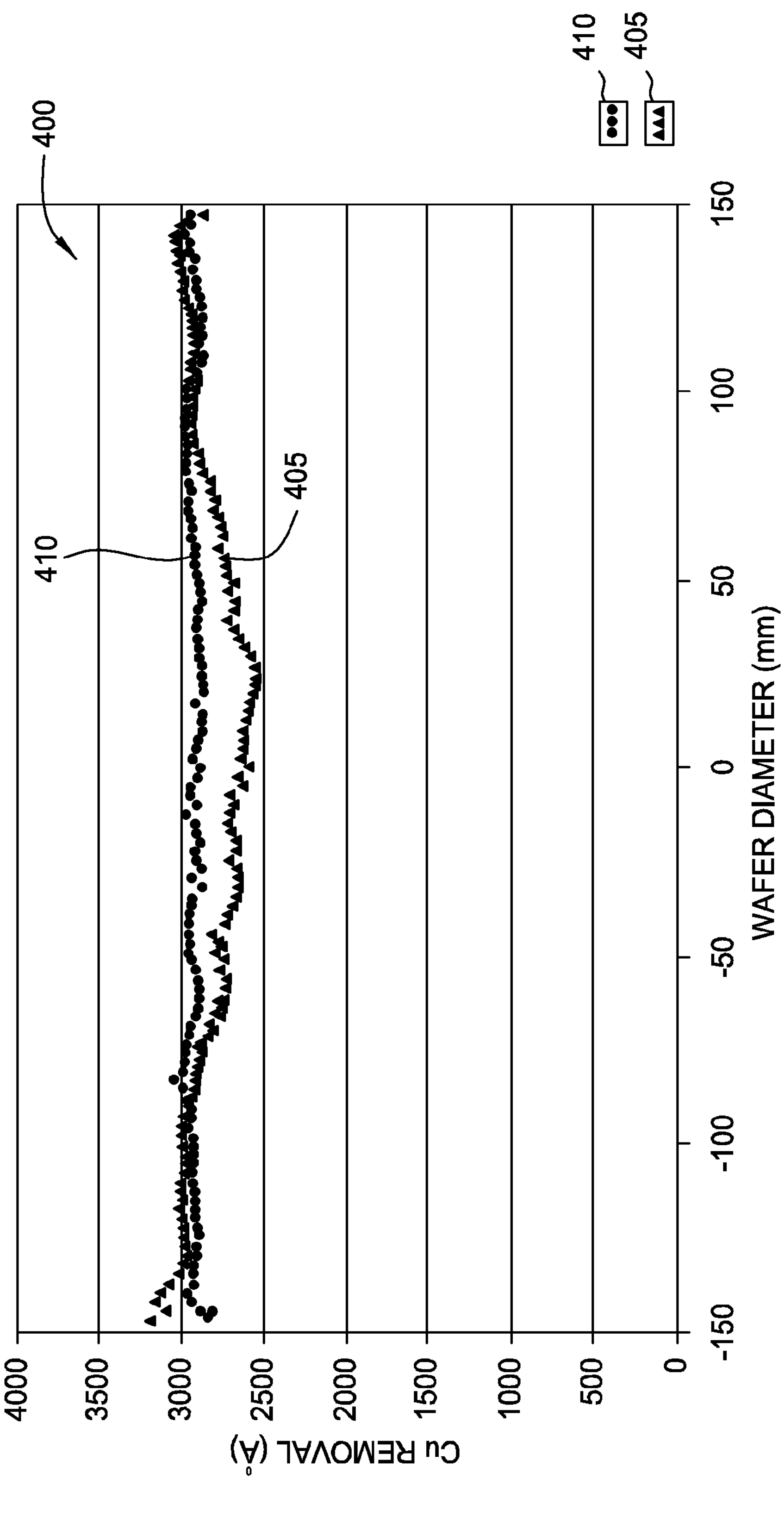
7000
6000
5000
4000
3000
2000
1000
0
-150
-125
-100
-75
-50
-25
0
25
50
75
100
125
150
WAFER DIAMETER (mm)

FIG. 3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410
405
Cu REMOVAL (Å)
WAFER DIAMETER (mm)
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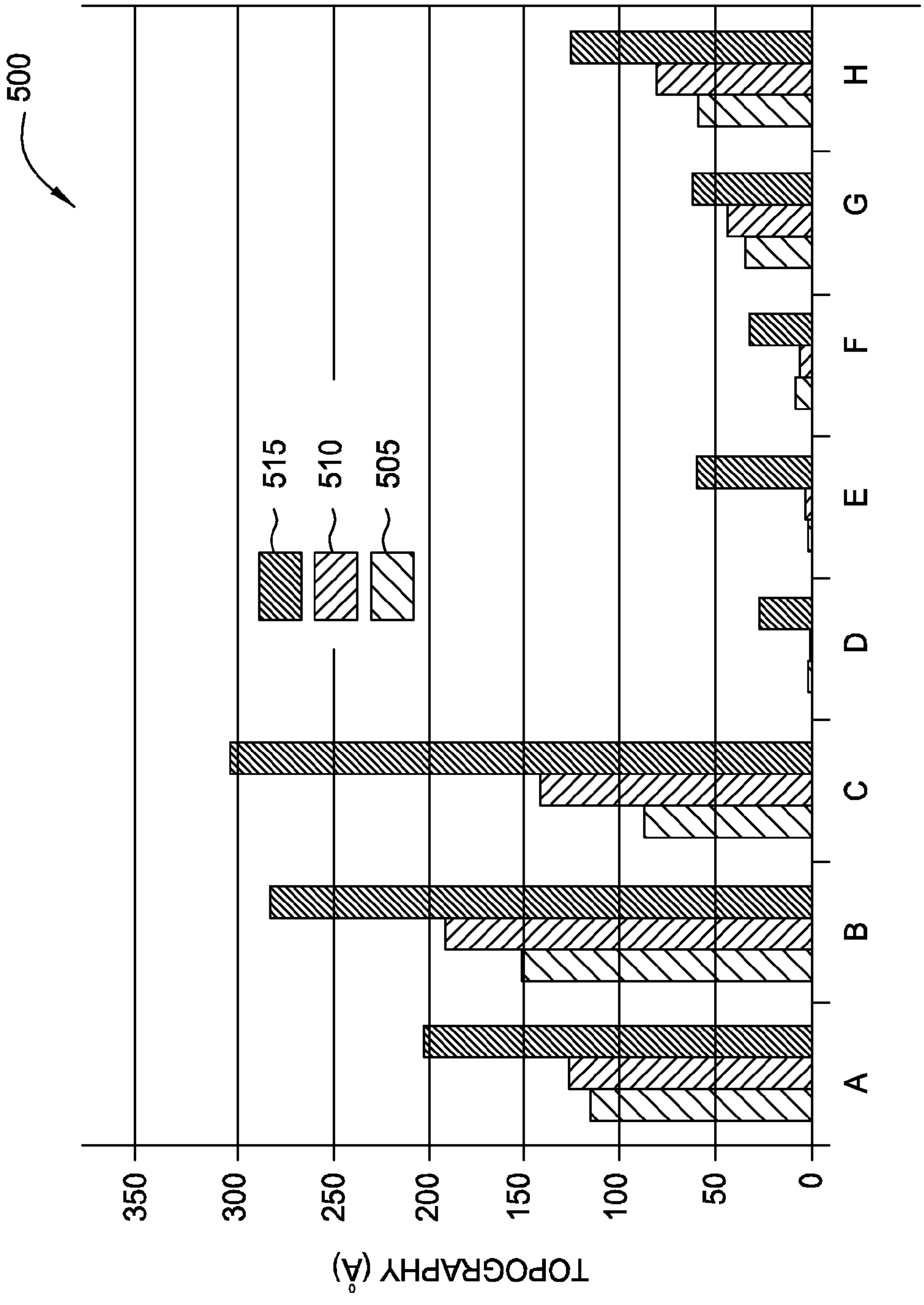
3000
2500
2000
1500
1000
500
0
-150
-100
-50
0
50
100
150

FIG. 4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515
510
505
A
B
C
D
E
F
G
H
0
50
100
150
200
250
300
350
TOPOGRAPHY (Å)

FIG. 5

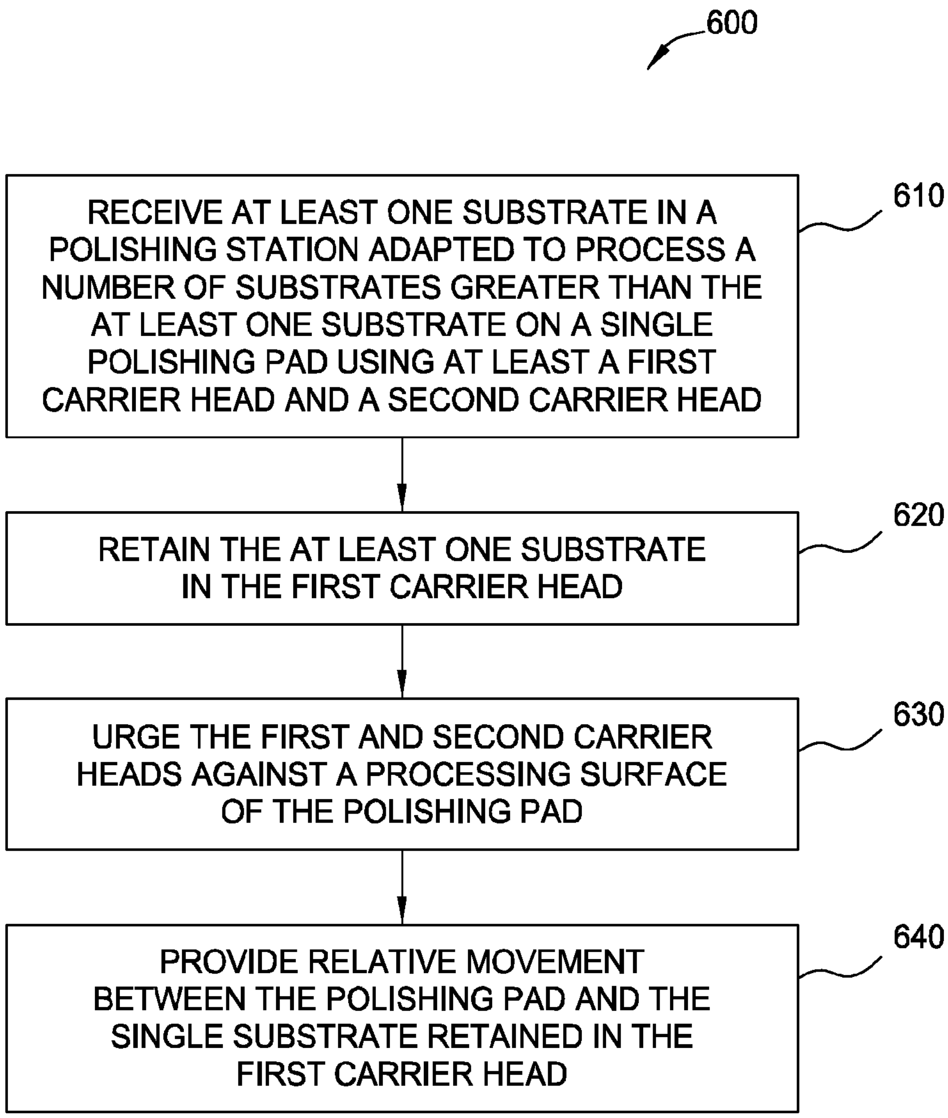
600
RECEIVE AT LEAST ONE SUBSTRATE IN A POLISHING STATION ADAPTED TO PROCESS A NUMBER OF SUBSTRATES GREATER THAN THE AT LEAST ONE SUBSTRATE ON A SINGLE POLISHING PAD USING AT LEAST A FIRST CARRIER HEAD AND A SECOND CARRIER HEAD
610
RETAIN THE AT LEAST ONE SUBSTRATE IN THE FIRST CARRIER HEAD
620
URGE THE FIRST AND SECOND CARRIER HEADS AGAINST A PROCESSING SURFACE OF THE POLISHING PAD
630
PROVIDE RELATIVE MOVEMENT BETWEEN THE POLISHING PAD AND THE SINGLE SUBSTRATE RETAINED IN THE FIRST CARRIER HEAD
640

FIG. 6