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(54) METHOD FOR AN IMPROVED CHEMICAL MECHANICAL POLISHING SYSTEM

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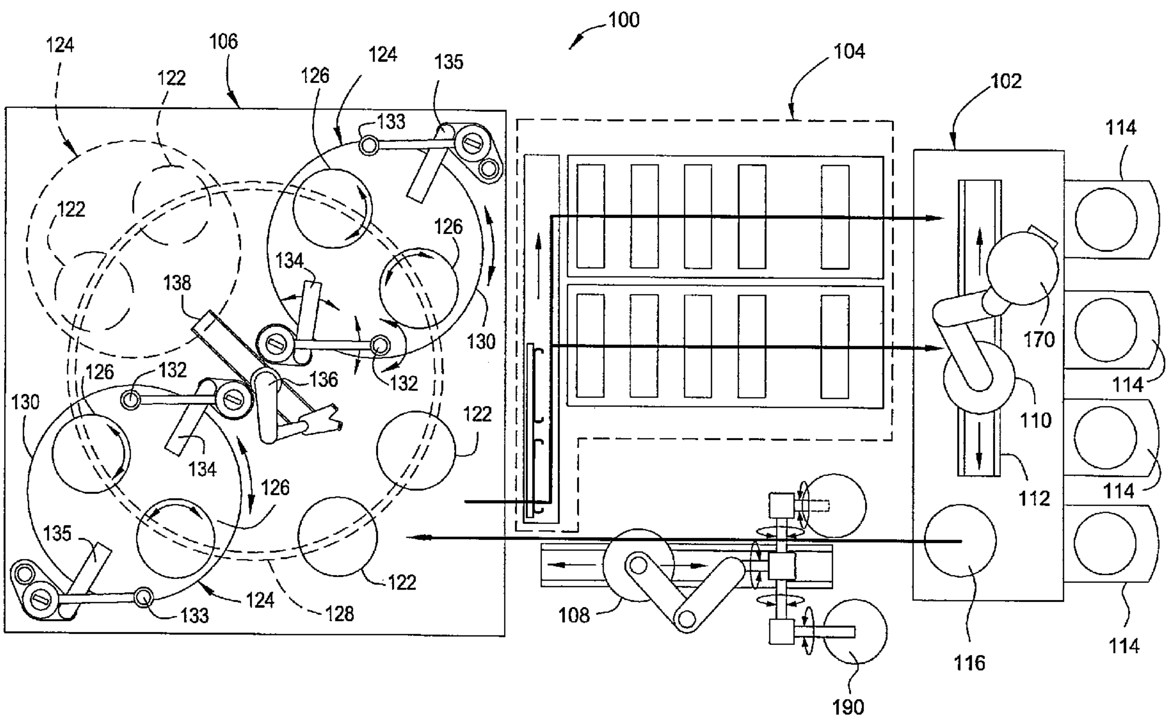
(57) ABSTRACT

A method for polishing a substrate on a pad large enough to accommodate polishing at least two substrates simultaneously The method includes simultaneously pressing a first substrate and a second substrate against a single polishing surface of a polishing module, providing polishing fluid from a first fluid delivery arm in front of the first substrate while the first substrate is pressed against the polishing surface, providing polishing fluid from a second fluid delivery arm at a location in front of the second substrate while the second substrate is pressed against the polishing surface, conditioning the polishing surface with a first conditioner at a location behind the first substrate while the first substrate is pressed against the polishing surface, and conditioning the polishing surface with a second conditioner at a location behind the second substrate while the second substrate is pressed against the polishing surface.



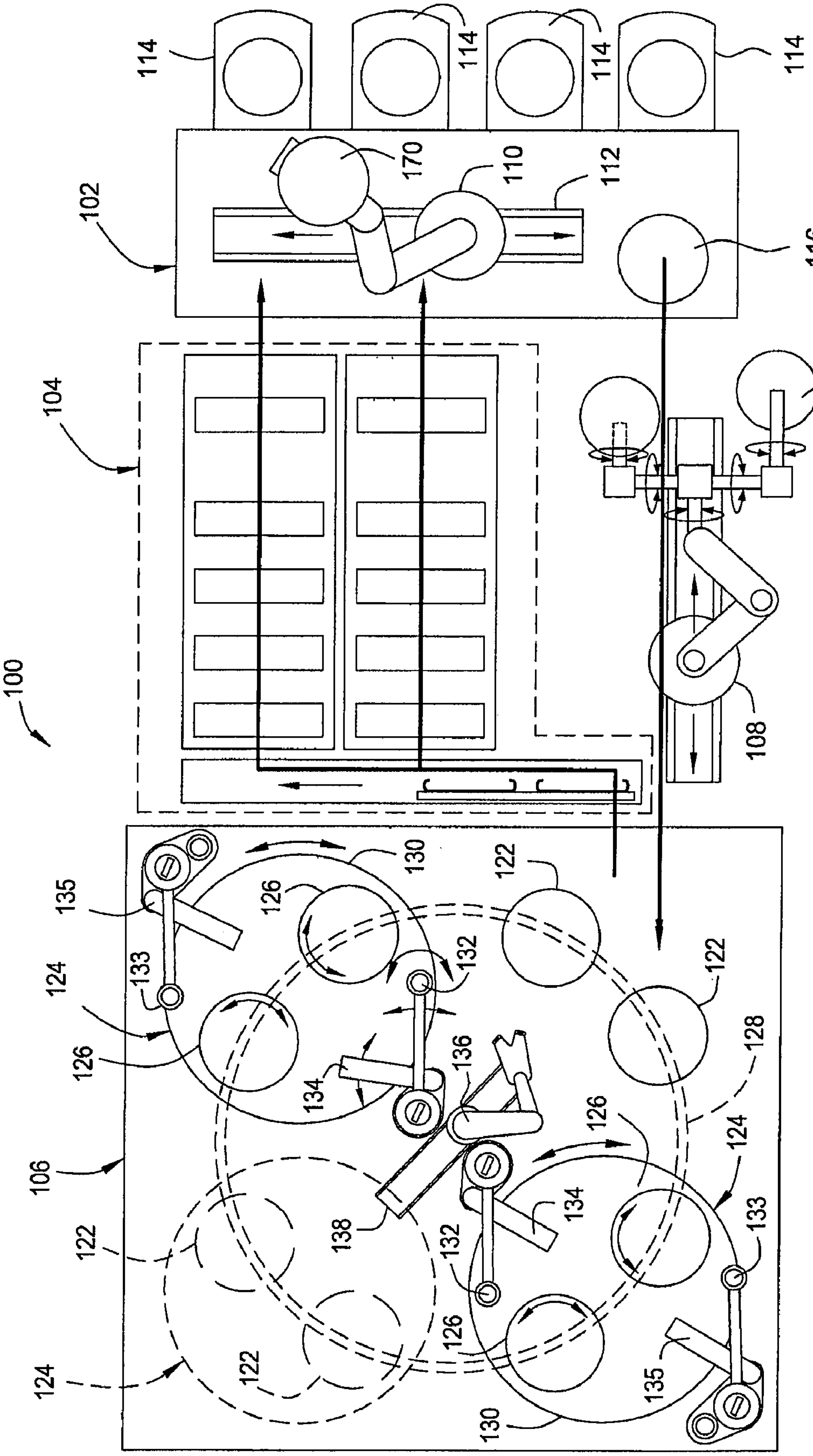

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FIG. 1

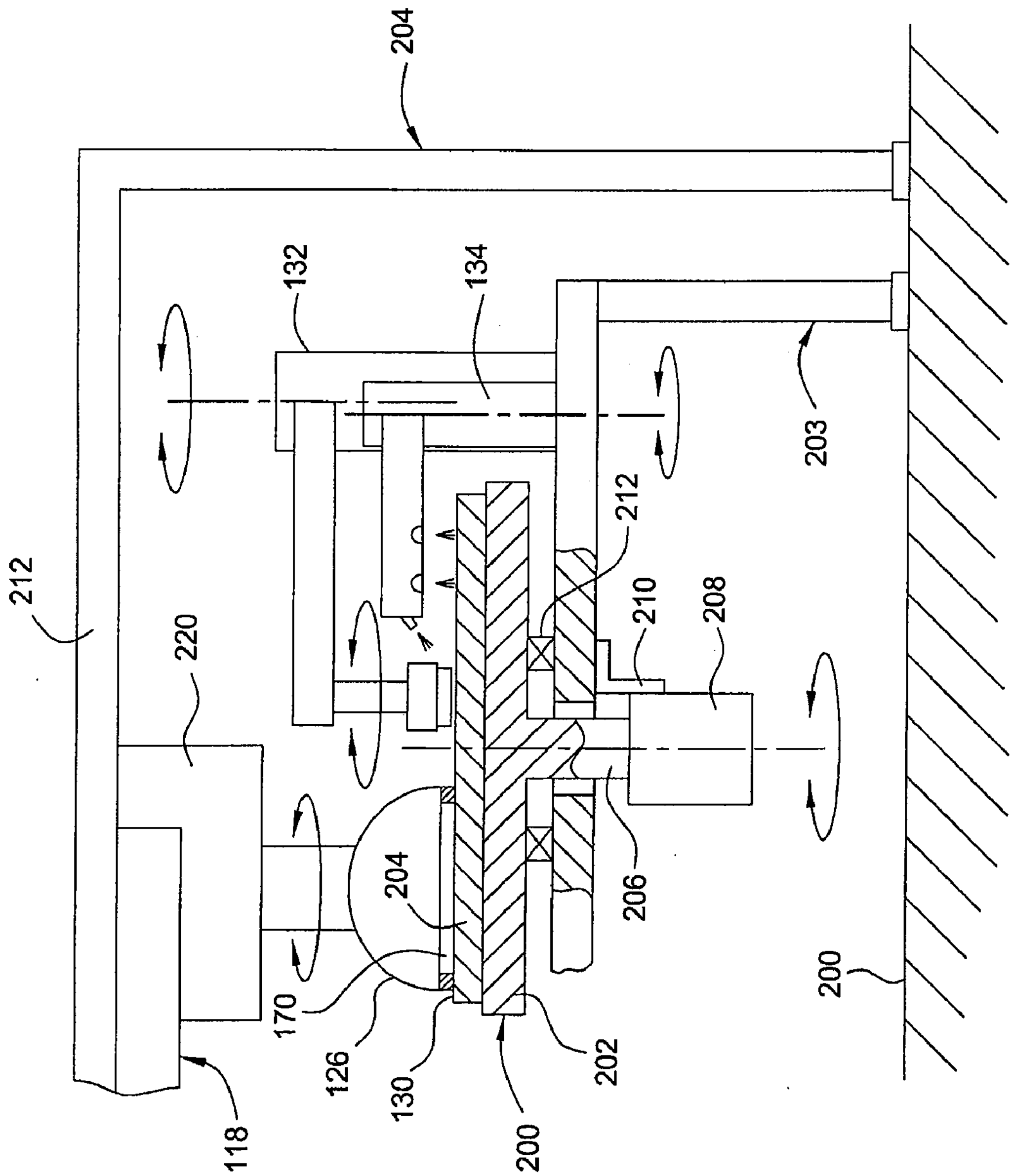
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FIG. 2

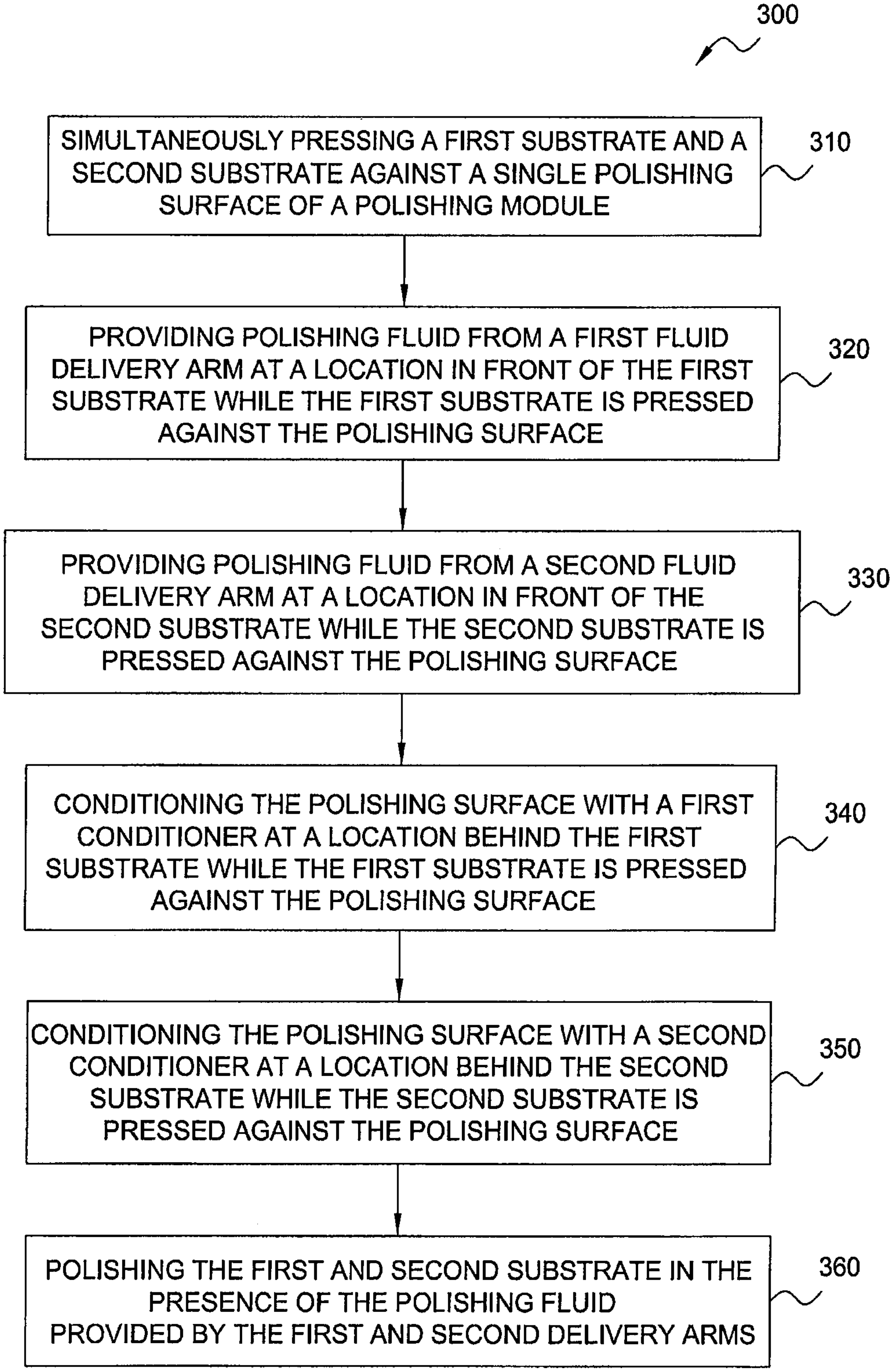
300
SIMULTANEOUSLY PRESSING A FIRST SUBSTRATE AND A SECOND SUBSTRATE AGAINST A SINGLE POLISHING SURFACE OF A POLISHING MODULE
310
PROVIDING POLISHING FLUID FROM A FIRST FLUID DELIVERY ARM AT A LOCATION IN FRONT OF THE FIRST SUBSTRATE WHILE THE FIRST SUBSTRATE IS PRESSED AGAINST THE POLISHING SURFACE
320
PROVIDING POLISHING FLUID FROM A SECOND FLUID DELIVERY ARM AT A LOCATION IN FRONT OF THE SECOND SUBSTRATE WHILE THE SECOND SUBSTRATE IS PRESSED AGAINST THE POLISHING SURFACE
330
CONDITIONING THE POLISHING SURFACE WITH A FIRST CONDITIONER AT A LOCATION BEHIND THE FIRST SUBSTRATE WHILE THE FIRST SUBSTRATE IS PRESSED AGAINST THE POLISHING SURFACE
340
CONDITIONING THE POLISHING SURFACE WITH A SECOND CONDITIONER AT A LOCATION BEHIND THE SECOND SUBSTRATE WHILE THE SECOND SUBSTRATE IS PRESSED AGAINST THE POLISHING SURFACE
350
POLISHING THE FIRST AND SECOND SUBSTRATE IN THE PRESENCE OF THE POLISHING FLUID PROVIDED BY THE FIRST AND SECOND DELIVERY ARMS
360

FIG. 3

METHOD FOR AN IMPROVED CHEMICAL MECHANICAL POLISHING SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] Embodiments of the present invention generally relate to a chemical mechanical polishing system suitable for use in semiconductor manufacturing.

[0003] 2. Description of the Related Art

[0004] In semiconductor substrate manufacturing, the use of chemical mechanical polishing, or CMP, has gained favor due to the widespread use of damascene interconnects structures during integrated circuit (IC) manufacturing. Although many commercially available CMP systems have demonstrated robust polishing performance, the move to smaller line widths requiring more precise fabrication techniques, along with a continual need for increased throughput and lower cost of consumables, drives and ongoing effort for polishing system improvements. Moreover, most conventional polishing systems have relatively limited flexibility for changes to processing routines, thereby limiting the diversity of processes that may be run through a single tool. Thus, certain new processing routines may require new or dedicated tools, or costly downtime for substantial tool configuration changes.

[0005] Therefore, there is a need for an improved chemical mechanical polishing system.

SUMMARY OF THE INVENTION

[0006] The present invention generally provides a method for polishing a substrate on a pad large enough to accommodate polishing at least two substrates simultaneously. In one embodiment, a method for polishing includes simultaneously pressing a first substrate and a second substrate against a single polishing surface of a polishing module, providing polishing fluid from a first fluid delivery arm in front of the first substrate while the first substrate is pressed against the polishing surface, providing polishing fluid from a second fluid delivery arm at a location in front of the second substrate while the second substrate is pressed against the polishing surface, conditioning the polishing surface with a first conditioner at a location behind the first substrate while the first substrate is pressed against the polishing surface, conditioning the polishing surface with a second conditioner at a location behind the second substrate while the second substrate is pressed against the polishing surface, and polishing the first and second substrates in the presence of the fluids dispensed from the first and second delivery arms.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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.

[0008] FIG. **1** is a top plan view of one embodiment of a chemical mechanical polishing system;

[0009] FIG. **2** is a partial side view of a polishing station of FIG. **1** according to one embodiment of the invention; and

[0010] FIG. **3** is a flow chart of a method for simultaneously polishing multiple substrates that may be practiced in the one embodiment according to the invention.

[0011] 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 and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

[0012] It is to be noted, however, that the appended drawings illustrate only exemplary 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.

DETAILED DESCRIPTION

[0013] Embodiments of the present invention provide methods and apparatus for an improved chemical mechanical polishing system.

[0014] FIG. **1** is a top plan view illustrating one embodiment of a chemical mechanical polishing ("CMP") 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**. In one embodiment depicted in FIG. **1**, four substrate storage cassettes **114** are shown. 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 polish substrates to the substrate storage cassettes **114**. Although one substrate transfer platform **116** is shown in the embodiment depicted in FIG. **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.

[0015] Still referring to FIG. **1**, the polishing module **106** includes a plurality of polishing stations **124** on which substrates are polished while retained in one or more polishing heads **126**. The polishing stations **124** are sized to interface with two or more polishing heads **126** simultaneously so that polishing of two or more substrates may occur using a single polishing station **124** at the same time. The polishing heads **126** are coupled to a carriage **220** (shown in FIG. **2**) that is mounted to an overhead track **128** that is shown in phantom in FIG. **1**. The overhead track **128** allows the carriage **220** to be selectively positioned around the polishing module **106** which facilitates positioning of the polishing heads **126** selectively over the polishing stations **124** and load cup **122**. In the embodiment depicted in FIG. **1**, the overhead track **128** has a circular configuration which allows the carriages **220** retaining the polishing heads **126** 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 polishing heads **126** may be facilitated using other suitable devices.

[0016] In one embodiment depicted in FIG. **1**, 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 polishing head **126**. Optionally, a third polishing station **124** (shown in phantom) may be positioned in the corner of the polishing module **126** 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.

[0017] Each polishing station **124** includes a polishing surface **130** capable of polishing at least two substrates at the same time and a matching number of polishing units for each of the substrates. Each of the polishing units includes a polishing head **126**, a conditioning module **132** and a polishing fluid delivery module **134**. In one embodiment, the conditioning module **132** may be a conditioner which dresses the pad by removing polishing debris and opening the pores of the pad. In another embodiment, the polishing fluid delivery module **134** may be a slurry delivery arm. The polishing surface **130** is supported on a platen assembly (not shown) which rotates the polishing surface **130** during processing. In one embodiment, the polishing surface **130** is suitable for at least one of a chemical mechanical polishing and/or an electrochemical mechanical polishing process. In another embodiment, the platen may be rotated during polishing at a rate from about 10 rpm to about 150 rpm, for example, about 50 rpm to about 110 rpm, such as about 80 rpm to about 100 rpm.

[0018] FIG. **2** is a partial side view showing one embodiment of one of the polishing stations **124** of FIG. **1**. Only one of the two or more polishing units is shown in FIG. **2** for ease of explanation. In the embodiment depicted in FIG. **2**, a platen assembly **200** supports a dielectric polishing pad **204**. The upper surface of the pad **204** forms the polishing surface **130**. The platen **202** is movably supported on an inner frame **203** by one or more bearings **212**. The platen **202** is coupled by a shaft **206** to a motor **208** that is operable to rotate the platen assembly **200**. The motor **208** may be coupled by a bracket **210** to the inner frame **203**. In one embodiment, the motor **208** is a direct drive motor. Other motors may also be utilized to rotate the shaft **206**. In one embodiment depicted in FIG. **2**, the motor **208** is utilized to rotate the platen assembly **200** such that the pad **204** retained thereon is rotated during processing while the substrate **170** is retained against the polishing surface **130** by the polishing head **126**.

[0019] In one embodiment, the polishing head **126** is rotated at a rate from a range of about 10 rpm to about 150 rpm, for example, about 50 rpm to about 110 rpm, such as about 80 rpm to about 100 rpm. The polishing head **126** may press the substrate **170** against the pad **204** at a pressure in range of about 0.5 psi to about 5.0 psi, for example, about 1 psi to about 4.5 psi, such as about 1.5 psi to about 4.0 psi, for example. The polishing head **126** may have a moving range preferably from about 10 to 14 inches. The polishing head **126** may be sweeping from a frequency of about 1 sweep per minute (swp/min) to about 40 swp/min, for example, about 5 swp/min to about 30 swp/min, such as about 12 swp/min to about 25 swp/min. Each sweep may be about 10 to about 14 inches.

[0020] The platen assembly **200** is large enough to support a polishing pad **204** which will accommodate polishing of at least two substrates retained by different polishing heads **126** and served by different polishing units. In one embodiment, the dielectric polishing pad **204** has a diameter greater than about 30 inches, for example, between about 30 and about 52 inches, such as 42 inches. Even though the dielectric polishing pad **204** may be utilized to polish two substrates simultaneously, the pad unit area per number of substrate simultaneously polished thereon is much greater than conventional single substrate pads, thereby allowing the pad service life to be significantly extended.

[0021] During processing or when otherwise desired, the conditioning module **132** may be activated to contact and condition the polishing surface **130**. Additionally, polishing fluid is delivered through the polishing fluid delivery module **134** to the polishing surface **130** during processing. The distribution of polishing fluid provided by the polishing fluid delivery module **134** may be selected to control the distribution of polishing fluid across the lateral surface of the polishing surface **130**. It should be noted that while only one polishing head **126**, conditioning module **132** and polishing fluid delivery module **134** are depicted in FIG. **2**, more numbers of polishing heads and conditioning modules, polishing fluid delivery modules are possible. For the sake of clarity, there is sufficient room to accommodate at least one additional polishing unit on the pad **204**, as shown in FIG. **1**. One embodiment includes at least two sets of polishing heads **126**, conditioning modules **132** and polishing fluid delivery modules **134** working simultaneously to accommodate for the polishing of at least two substrates simultaneously on one polishing pad **204**.

[0022] The methods of the present invention will now be described in detail below. It should be understood that each of the methods of the present invention may be practiced on a single or a multi-pad system. It should also be noted that different layers of metal may be polished using the same method. In one embodiment, the metal layer may be a copper layer. FIG. **3** is a flowchart of a method for simultaneously polishing multiple substrates on a single polishing surface that may be practiced in any polishing station embodiments described herein. The polishing method may be practiced in other suitable adapted systems, including those from the equipment manufacturers. The method **300** begins at step **310**, wherein a first substrate and a second substrate are pressed against a single polishing surface **130** of a polishing module **106** while the surface **130** is rotated. At step **320**, while the first substrate is pressed against the polishing surface **130**, a first slurry delivery arm **134** in front of the first substrate delivers a polishing liquid to the surface **130** in front of the first substrate. As a point of reference, the area of the pad to be rotated under the substrates is the "front" while the area of the pad just rotated from below the substrate is the "back." In one embodiment, the polishing fluid may be delivered to the pad surface **130** from the first slurry delivery arm **134** at a rate of about 100 sccm to about 1000 sccm, for example, about 200 sccm to about 800 sccm, such as about 300 sccm to about 600 sccm from each arm. At step **330**, while the second substrate is pressed against the polishing surface **130**, a second slurry delivery arm **135** in front of the second substrate delivers a polishing fluid to the area in front of the second substrate. The second slurry delivery arm **135** may provide fluid to the pad at substantially the same rate as the first arm **134**.

[0023] Additionally, the overall amount of slurry used per substrate may be reduced since both the substrates and the pad are polished with the same slurry agent. As a result, a reduced amount of slurry may be used to polish the next substrate. In one embodiment, silica may be used as the slurry agent. The parameters for the slurry usage rate per slurry delivery arm may be range from about 100 sccm to about 1000 sccm, for example, for about 200 sccm to about 800 sccm, such as about 300 sccm to about 600 sccm. The slurry delivery arm may sweep the polishing surface with a frequency from a range of about 1 swp/min to about 70 swp/min, preferably, for about 5 swp/min to about 60 swp/min, and more preferably, for about 10 swp/min to about 60 swp/min, for example. The movement of the slurry delivery arm may be from a range of about 2 inches to about 18 inches, for example, for about 6 inches to about 16 inches, such as about 7 inches to about 13 inches.

[0024] At step **360**, the first and second substrates are polished in the presence of the polishing fluid. Conditioning may occur before, during or after polishing. Conditioning while polishing has shown good results. While the substrate has been polished in the presence of the polishing fluid, an end point detection device coupled with the polishing station may be used to determine the removal rate of the metal layer. In one embodiment, eddy current endpoint detection may be used to monitor the removal rate of the metal layer. In another embodiment, optical techniques, such as In Situ Removal Monitor (ISRM) laser endpoint detection may be used to monitor the removal rate of material from the substrate and/or to detect the polishing endpoint.

[0025] At step **340**, while the first substrate is still pressed against the polishing surface **130**, the polishing surface **130** is conditioned with a first conditioner **132** at a location behind the first substrate. In step **350**, while the second substrate is still pressed against the polishing surface **130**, the polishing surface is conditioned with a second conditioner **133** at a location behind the second substrate.

[0026] Thus, as one region of the pad **204** against which one substrate is currently pressed and polished, rotates out from under the one substrate, this same region of the pad **204** is conditioned prior to contacting a next substrate. In one embodiment, the conditioner may include a diamond-containing surface that is swept across the polishing surface at a frequency of about 1 swp/min to about 40 swp/min, for example, about 5 swp/min to about 30 swp/min, such as about 12 swp/min to about 25 swp/min. The conditioner may have a sweep distance of about 0.5 to about 21 inches, for example, 1.0 to about 20 inches. The conditioner may rotate the diamond-containing surface against the pad **304** at a rotation rate of about 10 rpm to about 300 rpm, for example, about 50 rpm to about 200 rpm, such as about 80 rpm to about 150 rpm, for example.

[0027] In one embodiment, each substrate may be polished utilizing a two-step process. A first step includes removing the bulk thickness of copper followed by a copper clearance step. The bulk removal step ends at or about when the underlying material begins to be exposed through the copper layer. In one embodiment, the bulk removal step may remove copper at a polishing rate of between about 9,000 to about 10,000 Å/min. The platen speed may be maintained between about 83 to 113 revolutions per minute (rpm) while the head is rotated between about 77 and about 107 revolutions per minute. The polishing head may be oscillated with a frequency of about 19 sweeps per minute through a distance of between 10 to about 14 inches. The substrate is pressed against the polishing surface at a pressure of between about 2.2 to about 2.9 psi. A low silica content slurry having neutral pH may be utilized at about 300 sccm per slurry delivery arm. The slurry delivery arm may be swept between about 9 to 11 inches with a frequency of 19 to about 38 sweeps per minute. During polishing, the conditioner may be pressed against the pad with a force of between about 3 to about 5 psi while being rotated at about 108 rpm. The conditioner may be swept over a distance of about 1.5 to about 20 inches.

[0028] The copper clearance step may remove copper to expose a barrier layer at a rate of between 4,000 to 5,000 Å/min. During the copper clearance step, the platen may be rotated about 83 to 113 revolutions per minute while the polishing head is rotated between about 77 to about 107 rotations per minute. The substrate is pressed against the polishing pad with a force of between 1.1 to about 1.3 psi while the head is swept over a distance of about 10 to about 14 inches with a frequency of about 19 sweeps per minute. A low silica content polishing slurry having neutral pH may be provided at a rate of about 2 sccm per slurry delivery arm. The slurry delivery arm may be swept over a distance of about 9 to about 12 inches with a frequency of 19 to about 38 sweeps per minute. The conditioner may be pressed against the polishing surface while processing substrate with a force of between about 3 psi to about 5 psi while rotating the conditioner with an rpm of about 108, while sweeping the conditioner over a distance between about 1.5 to about 20 inches.

[0029] The invention provides an improved method for the CMP process by providing a pad large enough to accommodate polishing at least two substrates simultaneously while also providing a clean and conditioned polishing surface after each polishing of the substrates. Copper polish rates up to about 20,000 Angstrom per minute (Å/min) may be obtained, for example, about 2,000 Å/min to about 15,000 Å/min, such as about 3,000 Å/min to about 12,000 Å/min, for example, have been realized with good match of substrate to substrate results. Thus, the improved polishing repeatability and extended life of the polishing surface is advantageously obtained.

[0030] 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.

1. A method for polishing a substrate on a pad, comprising:

simultaneously pressing a first substrate and a second substrate against a single polishing surface of a polishing module;

providing a first polishing fluid from a first fluid delivery arm at a location in front of the first substrate while the first substrate is pressed against the polishing surface;

providing a second polishing fluid from a second fluid delivery arm at a location in front of the second substrate while the second substrate is pressed against the polishing surface;

conditioning the polishing surface with a first conditioner at a location behind the first substrate while the first substrate is pressed against the polishing surface; and

conditioning the polishing surface with a second conditioner at a location behind the second substrate while the second substrate is pressed against the polishing surface.

2. The method of claim **1**, further comprising using end point detection to determine a removal rate of a metal layer on at least one of the two substrates.

3. The method of claim **2**, wherein the metal layer is a copper layer.

4. The method of claim **1**, wherein a polishing rate is from about 3000 Å/min to about 12000 Å/min.

5. The method of claim **2**, wherein the end point detection includes eddy current endpoint detection or In Situ Removal Monitor (ISRM) laser endpoint detection.

6. The method of claim **1**, further comprising conditioning a region of the polishing pad, where a previously polished substrate was located, with additional polishing fluid before the region contacts a next substrate.

7. The method of claim **6**, wherein the conditioner has a sweeping frequency within a range from about 12 swp/min to about 25 swp/min.

8. The method of claim **6**, wherein the conditioner has a rotation rate within a range from about 80 rpm to about 150 rpm.

9. The method of claim **6**, wherein slurry agent is used as additional polishing fluid.

10. The method of claim **9**, wherein the slurry agent is silica.

11. The method of claim **9**, wherein the slurry usage rate per slurry delivery arm has a rotation rate within a range from about 300 sccm to about 600 sccm,

12. The method of claim **9**, wherein the slurry delivery arm sweeps the polishing surface with a frequency rate within a range from about 10 swp/min to about 60 swp/min.

13. The method of claim **9**, wherein the slurry delivery arm has a range within about 7 inches to about 13 inches.

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