A method and apparatus for controlling pressure or forces applied to a substrate in a polishing process is described. In one embodiment, a polishing system is described. The system includes a platen rotatably disposed on a base, the platen having a sidewall and a polishing pad disposed thereon forming an interior volume, and a pad pressure applicator disposed in the interior volume of the platen adjacent the underside of the polishing pad.
FIG. 2B

SHARP PRESSURE TRANSITION

PRESSURE APPLIED TO SUBSTRATE

0

225A

225B

POSITION ON SUBSTRATE

FIG. 2C

SMOOTHED PRESSURE TRANSITION

PRESSURE OF SUBSTRATE ON PAD

0

225A

225B

225B

POSITION ON SUBSTRATE
URGING A SUBSTRATE AGAINST THE FIRST SURFACE OF A POLISHING PAD USING A FIRST PRESSURE FROM A FIRST PRESSURE APPLICATOR IN CONTACT WITH A BACKSIDE OF THE SUBSTRATE

DELIVERING A SECOND PRESSURE TO A FEATURE SIDE OF THE SUBSTRATE THROUGH A SECOND SURFACE OF THE POLISHING PAD

FIG. 9

RETAINING A SUBSTRATE IN A CARRIER HEAD ADAPTED TO MOVE THE SUBSTRATE RELATIVE TO A POLISHING PAD, THE CARRIER HEAD HAVING A FIRST PRESSURE APPLICATOR THAT IS MOVABLE WITH THE SUBSTRATE, THE FIRST PRESSURE APPLICATOR HAVING ONE OR MORE PRESSURIZABLE ZONES THAT APPLY PRESSURE TO A FIRST SIDE OF THE SUBSTRATE

MOVING THE SUBSTRATE IN A SWEEP PATTERN RELATIVE TO A FIRST SIDE OF THE POLISHING PAD

DELIVERING A COUNTERPRESSURE TO A SECOND SIDE OF THE SUBSTRATE FROM A SECOND PRESSURE APPLICATOR AS THE SUBSTRATE MOVES IN THE SWEEP PATTERN, THE SECOND PRESSURE APPLICATOR DISPOSED ON A SECOND SIDE OF THE POLISHING PAD

FIG. 10
PRESSURE CONTROLLED POLISHING PLATEN

CROSS-REFERENCE TO RELATED APPLICATIONS:


BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] Embodiments of the present invention generally relate to polishing a substrate, such as a semiconductor wafer. More particularly, to modification of forces applied to or acting on a substrate during a polishing process.
[0004] 2. Description of the Related Art
[0005] Chemical mechanical polishing 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 by moving a feature side, i.e., a deposit receiving surface, of the substrate in contact with a polishing pad while in the presence of a polishing fluid. In a typical polishing process, the substrate is retained in a polishing head that urges or presses the backside of the substrate toward a polishing medium. Material is removed from the feature side of the substrate that is in contact with the polishing medium through a combination of chemical and mechanical activity.
[0006] Stiffness of the substrate plays an important role in providing the contact necessary to successfully and uniformly remove materials from the feature side of the substrate. Sharp transitions in the pressure applied to the backside of the substrate are sometimes desirable to facilitate uniform material removal. However, stiffness of the substrate tends to redistribute the pressure applied to the substrate such that the pressure applied to the substrate may be spread or smoothed. In some cases, this smoothing effect is undesirable and may cause undesirable polishing results on the substrate.

[0007] Therefore, there is a need for a method and apparatus that facilitates focused, high resolution control of pressure or force applied to a substrate to facilitate removal of materials from the feature side of the substrate.

SUMMARY OF THE INVENTION

[0008] A method and apparatus for controlling pressure or forces applied to a substrate in a polishing process is described. In one embodiment, a polishing system is described. The system includes a platen rotatably disposed on a base, the platen having a sidewall and a polishing pad secured to the platen at a perimeter thereof to form an interior volume and a pad pressure applicator disposed in the interior volume of the platen adjacent the underside of the polishing pad.

[0009] In another embodiment, a method for polishing a substrate is described. The method includes urging a substrate against a first surface of a polishing pad using a first pressure applied from a first pressure applicator to a backside of the substrate, and applying a second pressure towards a feature side of the substrate through a second surface of the polishing pad.

[0010] In another embodiment, a method for polishing a substrate is described. The method includes retaining a substrate in a carrier head adapted to move the substrate relative to a polishing pad, the carrier head having a first pressure applicator that is movable with the substrate, the first pressure applicator having one or more pressure zones that apply pressure to a first side of the substrate, moving the substrate in a sweep pattern relative to a first side of the polishing pad, and delivering a counter pressure to a second side of the substrate from a second pressure applicator as the substrate moves in the sweep pattern, the second pressure applicator disposed on a second side of the polishing pad.
plated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

**DETAILED DESCRIPTION**

[0031] FIG. 1 is a partial sectional view of one embodiment of a processing station 100 that is configured to perform a polishing process, such as a chemical mechanical polishing (CMP) process or an electrochemical mechanical polishing (ECMP) process. The processing station 100 may be a stand-alone unit or part of a larger processing system. Examples of a larger processing system that may be adapted to utilize the processing station 100 include REFLEXION® 1, REFLEXION® GT™, MIRRA MESA® polishing systems available from Applied Materials, Inc., located in Santa Clara, Calif., among other polishing systems.

[0032] The processing station 100 includes a platen 105 rotatably supported on a base 110. The platen 105 is operably coupled to a drive motor 115 adapted to rotate the platen 105 about a rotational axis A. The platen 105 supports a polishing pad 120 made of a polishing material 122. In one embodiment, the polishing material 122 of the polishing pad 120 is a commercially available pad material, such as polymer based pad materials typically utilized in CMP processes. The polymer material may be a polyurethane, a polycarbonate, fluoropolymers, polytetrafluoroethylene (PTFE), polyethylene sulfide (PPS), or combinations thereof. The polishing material 122 may further comprise open or closed cell foamed polymers, elastomers, felt, impregnated felt, plastics, and like materials compatible with the processing chemistries. In another embodiment, the polishing material 122 is a felt material impregnated with a porous coating. In other embodiments, the polishing material 122 includes a material that is at least partially conductive.

[0033] A carrier head 130 is disposed above a processing surface 125 of the polishing pad 120. The carrier head 130 retains a substrate 135 and controllably urges the substrate 135 towards the processing surface 125 (along the Z axis) of the polishing pad 120 during processing. The platen 105 contains a pad pressure applicator 138 (shown in phantom) that applies pressure to an underside of the polishing pad 120. The carrier head 130 is mounted to a support member 140 that supports the carrier head 130 and facilitates movement of the carrier head 130 relative to the polishing pad 120. The support member 140 may be coupled to the base 110 or mounted above the processing station 100 in a manner that includes the carrier head 130 above the polishing pad 120. In one embodiment, the support member 140 is a circular track that is mounted above the processing station 100. The carrier head 130 is coupled to a drive system 145 that provides at least rotational movement of the carrier head 130 about a rotational axis B. The drive system 145 may be configured to move the carrier head 130 along the support member 140 laterally (X and/or Y axis) relative to the polishing pad 120. In one embodiment, the drive system 145 moves the carrier head 130 vertically (Z axis) relative to the polishing pad 120 in addition to lateral movement. For example, the drive system 145 may be utilized to move the substrate 135 towards the polishing pad 120 in addition to providing rotational and/or lateral movement of the substrate 135 relative to the polishing pad 120. The lateral movement of the carrier head 130 may be a linear or an arcing or sweeping motion.

[0034] A conditioning device 150 and a fluid applicator 155 are shown positioned over the processing surface 125 of the polishing pad 120. The conditioning device 150 is coupled to the base 110 and includes an actuator 185 that may be adapted to rotate the conditioning device 150 or move the conditioning device 150 in one or more linear directions relative to the polishing pad 120 and/or the base 110. The fluid applicator 155 includes one or more nozzles 160 adapted to deliver polishing fluids to a portion of the polishing pad 120. The fluid applicator 155 is rotatably coupled to the base 110. In one embodiment, the fluid applicator 155 is adapted to rotate about a rotational axis C and provides a polishing fluid that is directed toward the processing surface 125. The polishing fluid may be a chemical solution, water, a polishing compound, a cleaning solution, or a combination thereof.

[0035] FIG. 2A is a schematic partial cross-sectional view of another embodiment of a processing station 200 having a carrier head 130 and a polishing pad 120 disposed on a platen 105 (shown in phantom). The carrier head 130 is shown having a substrate 135 disposed therein such that a feature side of the substrate 135 is in contact with the processing surface 125 of the polishing pad 120. The carrier head 130 includes a retaining ring 205 circumscribing and preventing the substrate 135 from slipping out of the carrier head 130 during processing. The carrier head 130 includes a flexible membrane 210 that contacts the backside of the substrate 135. In one embodiment, the carrier head 130 includes a body 215 that contains a head pressure applicator 220 that applies pressure or force to the flexible membrane 210. The forces acting on the flexible membrane 210 are transmitted to the backside of the substrate 135 to urge zones 225A-225B from the feature side of the substrate 135 toward the processing surface 125 of the polishing pad 120.

[0036] In one embodiment, head pressure applicator 220 includes one or more bladders 230 that are coupled to a fluid supply 235. The fluid supply 235 selectively provides a gas or liquid to each bladder 230 to apply pressure to the flexible membrane 210. The flexible membrane 210 in turn deflects to apply forces to the backside of the substrate 135. The pressure applied to the bladders 230 may be different and selected in response to factors such as stiffness of the substrate 135, desired center-to-edge uniformity or non-uniformity, among other factors. In one embodiment, pressure applied to the bladders 230 is between about 10 pounds per square inch (psi) to about 90 psi, for example, about 10 psi to about 80 psi.

[0037] Stiffness of the substrate 135 tends to redistribute the forces from the flexible membrane 210. For example, well defined pressure boundaries between the bladders 230 may be desired to produce desirable center-to-edge uniformity, as shown in the graph shown in FIG. 2B. As an example, it may be desirable to apply more pressure to the center zone 225A of the substrate 135 and less pressure to edge zone 225B of the substrate 135 (e.g., about 10 mm to about 20 mm inward of a periphery of the substrate 135), or vice versa. And, have a sharp pressure boundary between these zones. However, the stiffness of the substrate 135 tends to smooth these desired sharp pressure boundaries, as shown in the graph shown in FIG. 2C. As a result, the smoothing pressure effect is experienced by the feature side of the substrate 135 such that the center zone 225A may be over-polished in order to polish the edge zone 225B sufficiently. In an alternative result of the smoothing pressure effect, the edge zone 225B may be under-polished in order to polish the center zone 225A sufficiently. The smoothed pressure boundaries produce difficulty in controlling polishing uniformity. The smoothed pressure boundaries...
may negatively affect polishing and may additionally limit
tuning of the edge profile of the substrate 135.

[0038] Similar to the embodiment depicted in FIG. 1, the
processing station 200 includes a pad pressure applicator 138
housed in the platen 105. In one embodiment, the pad pres-
sure applicator 138 includes one or more pressure sources
240 that deliver a liquid or a gas from a pressure supply 260
that form a fluid bearing 245. The fluid bearing 245 may be
utilized to apply pressure independently to discrete regions
of the underside of the polishing pad 120. In one example, the
pad pressure applicator 138 includes a lid plate 250 coupled
to a housing 255 that contains the pressure sources 240. The
pressure sources 240 are adapted to provide multiple pressure
zones that may be independently controlled to apply a pre-
determined pressure to each zone defined by the pressure
sources 240. In one embodiment, the pressure sources 240
may include bladders, bulges, plenums or chambers formed
by walls that separate the pressure sources 240. The pressure
sources 240 may form pressure zones that are concentric
and/or symmetric or non-concentric and/or non-symmetric.
In one embodiment, the pressure sources 240 are in fluid
communication with the pressure supply 260 that is coupled
to a controller. Valves (not shown) are coupled between the
pressure supply 260 and each of the pressure sources 240 to
control fluids and/or pressure applied to the pressure sources
240.

[0039] In one embodiment, the lid plate 250 comprises a
perforated plate having a plurality of nozzles 265 adapted
to direct fluids from the housing 255 to an underside 270 of
the polishing pad 120. Each of the pressure sources 240 are
fluidly coupled to one or more nozzles 265 to provide the fluid
bearing 245 between the lid plate 250 and the underside 270
of the polishing pad 120. In this embodiment, the pressure
supply 260 contains a fluid, such as a gas or liquid. In one
embodiment, the pressure supply 260 contains a compressed
gas, such as air, nitrogen, helium, argon, derivatives thereof
and combinations thereof. In another embodiment, the pres-
sure supply 260 contains a liquid, such as de-ionized water.
The fluid may exit the interior of the platen 105 through an
opening 262 formed in a wall of the platen 105. In one
embodiment, the base 110 may include a drain port 264
adapted to receive the fluid as it exits the platen 105.

[0040] Each of the pressure sources 240 may be inde-
pendently controlled to provide pressurized fluids to the under-
side 270 of the polishing pad 120. In some embodiments, the
platen 105 may include a flexible backing 275 between the
underside 270 of the polishing pad 120. The flexible backing
275 may be a flexible plate or membrane adapted to cover the
platen 105 and prevent polishing fluids from entering an
interior volume 278 of the platen 105. In one embodiment, the
flexible backing 275 is a fabric/plastic composite material
with a low coefficient of friction and includes a thickness of
about 10 mils to about 20 mils. In one aspect, the flexible
backing 275 comprises a PEEK material reinforced by a
KEVLAR® fabric. The flexible backing 275 is utilized to
prevent liquids and polishing debris from entering the interior
volume 278 of the platen 105. Additionally, the flexible back-
ing 275 may also be used to control pressure application to the
underside 270 of the polishing pad 120. In one embodiment,
the flexible backing 275 is coupled to a perimeter of the platen
105 by a plurality of clamps or tensioner devices 280 that are
adapted to stretch the flexible backing 275 and facilitate taut-
ness of the flexible backing 275 on the platen 105. One or
more of the tensioner devices 280 may be configured as a
releasable clamp having a turnbuckle, spring or other tension
applying member coupled thereto.

[0041] In one embodiment, the pad pressure applicator 138
is coupled to the base 110 such that the pad pressure applica-
tor 138 is stationary relative to the base 110. In another
embodiment, the pad pressure applicator 138 is movable rela-
tive to the base 110. In one embodiment, the housing 255 of
the pad pressure applicator 138 is coupled to an actuator 285
that is adapted to move the housing 255 relative to the base
110. The actuator 285 is adapted to move the pad pressure
applicator 138 in at least a lateral direction (i.e., horizontally)
relative to the base 110 so the pad pressure applicator 138 may
move in the same direction as the substrate 135 retained in the
carrier head 130. In another embodiment, the actuator 285
may be configured to move the pad pressure applicator 138
toward and away (i.e., vertically) from the underside 270 of
the polishing pad 120.

[0042] In one embodiment, the pressure of the fluid applied
to the underside 270 of the polishing pad 120 is about 10 psi
to about 10 psi. The pressure may be constant or intermittent
within or between the pressure sources 240. In one embodi-
ment, the carrier head 130 is configured to move the substrate
135 laterally in a sweep pattern across the polishing sur-
face 125 of the polishing pad 120. In this embodiment, the pres-
sure applied to the underside 270 of the polishing pad 120
may be varied in response to the position of the substrate 135
relative to the pad pressure applicator 138. In another embodi-
ment, the pad pressure applicator 138 is configured to move
with the substrate 135 in the sweep pattern. In this embodi-
ment, the pressure applied to the underside 270 of the polish-
ing pad 120 may be varied or constant as the substrate 135
and the pad pressure applicator 138 move in the sweep pattern.

[0043] FIG. 3 is a schematic top plan view of one embodi-
ment of a processing station 300 showing an embodiment of a
polishing sweep pattern 305 of a substrate 135 on a polishing
pad 120. The substrate 135 is retained in a carrier head 130
(FIG. 1) that is not shown for clarity. The carrier head moves
the substrate 135 linearly or in an arc across the processing
surface 125 while rotating the substrate 135 relative to the
rotating polishing pad 120 to effect removal of material from
the substrate 135. A conditioning device 150 having a condi-
tioning disk 310 is shown in FIG. 3 is also shown to illustrate one embodiment of a conditioning sweep pattern 315 on the polishing pad 120. The conditioning disk 310 is swept across the processing
surface 125 to condition and/or refresh the polishing surface
125 to facilitate an enhanced removal rate of material from the
substrate 135.

[0044] The processing station 300 includes a first pad pres-
sure applicator 325A shown in phantom below the polishing
pad 120. The first pad pressure applicator 325A may be con-
figured similarly to the pad pressure applicator 138 as
described herein. In one embodiment, the first pad pressure
applicator 325A includes a dimension defining an area that is
greater than the area of the substrate 135. The area of the first
pad pressure applicator 325A may also be sized greater than
the sweep pattern 305 of the substrate on the polishing pad.
In one aspect, the shape of the first pad pressure applicator
325A is substantially elliptical in plan view having a major diameter
or axis substantially aligned with the length or greater axis of
the polishing sweep pattern 305. In one embodiment, the
shape of the first pad pressure applicator 325A in plan view
comprises a minor diameter or minor axis that is greater than
a diameter of the substrate 135 and a major diameter or minor
axis that is at least 2 times greater than the substrate 135.
example, the minor diameter or axis is about 310 mm to about 380 mm and the major diameter or axis is about 310 mm to about 760 mm for a 300 mm substrate.

In one embodiment, the processing station 300 also includes a second pad pressure applicator 325B shown in phantom below the polishing pad 120 adjacent the conditioning disk 310. The second pad pressure applicator 325B may be configured similarly to the pad pressure applicator 325A as described herein and is configured to apply pressure to the underside of the polishing pad 120 where the conditioning disk 310 is moved across the polishing surface 125. The second pad pressure applicator 325B may also include dimensions defining an area greater than a dimension of the conditioning disk 310. The area of the second pad pressure applicator 325B may also be sized greater than the conditioning sweep pattern 315.

FIG. 4A is an isometric top view of another embodiment of a processing station 400. The processing station 400 includes a platen 105 rotatably disposed on a base 110. A carrier head and polishing pad is not shown on the platen 105 to illustrate details of one embodiment of a first pad pressure applicator 325A and a second pad pressure applicator 325B that are housed within an interior volume 405 defined by a sidewall 409 of the platen 105 and the underside 270 of the polishing pad 120 (not shown). In one embodiment, the first pad pressure applicator 325A and the second pad pressure applicator 325B are coupled to a stationary base 407. The stationary base 407 is coupled to the base 110 through an opening 415 in a bottom of the platen 105. The stationary base 407 allows the first pad pressure applicator 325A and second pad pressure applicator 325B to be rigidly coupled to the base 110 while allowing rotation of the platen 105 relative to the first pad pressure applicator 325A and second pad pressure applicator 325B.

The first pad pressure applicator 325A includes a lid plate 250 disposed on a housing 255. The housing 255 contains one or more pressure zones shown in phantom as center pressure zone 440A and one or more edge pressure zones 440B-440E. Each of the pressure zones 440A-440E may be formed by the pressure sources 240 described in FIG. 2A. In one embodiment, a first pressure is applied to the backside of a substrate by the carrier head 130 (FIG. 2A) and the first pad pressure applicator 325A applies a second pressure to the feature side of the substrate through the polishing pad 120. In one aspect, each of the pressure zones 440A-440E may be configured to provide a sub-pressure to the underside of the polishing pad. In one embodiment, the center pressure zone 440A may be configured to provide a first sub-pressure to the underside of the polishing pad and the one or more edge pressure zones 440B-440E may be configured to provide a second sub-pressure to the underside of the polishing pad. The first sub-pressure may be the same as or different from the second sub-pressure. In one embodiment, the first sub-pressure is greater than the second sub-pressure in order to apply more pressure to a center of a substrate than the periphery of the substrate, or vice-versa.

In this embodiment, the pressure zones 440A-440E are asymmetric such that the pressures applied to the underside of the polishing pad are different and create transition regions adjacent the areas in contact with or in fluid communication with the pressure zones 440A-440E. In one example, the transition regions are adjacent boundaries of the pressure zones 440A-440E. In one embodiment, the first pad pressure applicator 325A includes non-pressurized areas 410. In one embodiment, the non-pressurized areas 410 comprise regions of the lid plate 250 that are not in contact or in fluid communication with a pressure zone 440A-440E. The non-pressurized areas 410 may be utilized to counter polishing effects that may result in over-polishing of the substrate 135. In one example, the non-pressurized areas 410 may be utilized to prevent or minimize over-polishing of the substrate 135 that may occur as the trailing edge of the rotating substrate 135 is over the first pad pressure applicator 325A. In another embodiment, non-pressurized areas 410 are reduced or eliminated and pressure in one or more of the pressure zones 440A-440E is reduced to counteract over-polishing of the substrate 135. In one embodiment, the pressure in one or more of the pressure zones 440A-440E may be reduced to vacuum (i.e., about ~10 psi) to counteract over-polishing of the substrate 135.

In one embodiment, the second pad pressure applicator 325B includes a lid plate 417 and a housing 420 that is similar to the pad pressure applicator 325A described in FIG. 2A. The housing 420 may contain a pressure zone 430 that is formed by a pressure source 240 that is described in FIG. 2A. While only one pressure zone 430 is shown, additional pressure zones may be utilized. The pressure zone 430 is adapted to apply pressure to the underside of the polishing pad where the conditioning disk 310 is swept across the polishing pad. The lid plate 417 may be similar to the lid plate 250 and may be perforated, adapted to contact the underside of the polishing pad, and combinations thereof to apply pressure to the underside of the polishing pad.

FIG. 4B is an isometric top view of another embodiment of a processing station 400 which is similar to the embodiment shown in FIG. 4A with the exception of symmetric or concentric pressure zones 440A-440E in the first pad pressure applicator 325A. In this embodiment, non-pressurized areas 410 (FIG. 4A) are eliminated and pressure in one or more of the pressure zones 440A-440E may be reduced to counteract over-polishing of the substrate 135.

FIG. 4C is an isometric cross-sectional view of the processing station 400 shown in FIGS. 4A and 4B. The second pad pressure applicator 325B is not shown in this view so details of the interface between the base 110 and the platen 105 can be seen. In one aspect, the polishing pad 120 is circular or ring-shaped. A perimeter of the polishing pad 120 is coupled to the platen 105 to bound one side of the interior volume 405. In one embodiment, the platen 105 is coupled to the motor 115 by a gear mechanism 450. The first pad pressure applicator 325A is coupled to the base 110 through the opening 415 and is offset from the gear mechanism 450 in a manner that does not interfere with rotation of the gear mechanism 450 and/or the platen 105. In another embodiment, the first pad pressure applicator 325A may be movably coupled to the base 110 by an actuator (such as actuator 285 shown in FIG. 2A).

FIG. 5A is a schematic cross-sectional view of another embodiment of a pad pressure applicator 500 that may be utilized in the processing station 100 of FIG. 1 or either of the first pad pressure applicator 325A and second pad pressure applicator 325B of FIGS. 4A and 4B. In this embodiment, the pad pressure applicator 500 includes a bearing surface 505 comprising a plurality of contact bearings 510 adapted to contact the underside 270 of the polishing pad 120. Each of the contact bearings 510 may comprise protrusions extending from the bearing surface 505, roller elements protruding from the bearing surface 505, and combinations
thereof. In one embodiment, the contact bearings 510 are protrusions or raised areas of the bearing surface 505 and are made from or include a material having a low coefficient of friction. In one embodiment, the contact bearings 510 comprise roller elements at least partially contained in pockets 515 disposed in a lid plate 250 of the pad pressure applicator 500. Each of the roller elements are made from or include a material having a low coefficient of friction.

[0053] In one embodiment, a housing 255 of the pad pressure applicator 500 includes one or more bladders 520 that are coupled to a pressure supply 260 adapted to apply force to the bearing surface 505 and/or the contact bearings 510. Pressure delivered to each of the bladders 520 may be independently controlled to provide a controlled force to the contact bearings 510 and to the underside 270 of the polishing pad 120. In one embodiment, the pressure of the fluid applied to the bladders 520 is about ~10 psi to about 10 psi.

[0054] FIG. 51 is a schematic cross-sectional view of another embodiment of a pad pressure applicator 525 that may be utilized in the processing station 100 of FIG. 1 or one of the first pad pressure applicator 325A and second pad pressure applicator 325B of FIGS. 4A and 4B. In this embodiment, the pad pressure applicator 500 includes a contact surface 530 adapted to contact a portion of the underside 270 of the polishing pad 120. The contact surface 530 comprises a flexible membrane 535 disposed in the housing 255 of the pad pressure applicator 525. The flexible membrane 535 may be disposed on the lid plate 250 (not shown) of the pad pressure applicator 500 or replace the lid plate 250. The flexible membrane 535 is adapted to contact the underside 270 of the polishing pad 120. The flexible membrane 535 may be made of a material having a low coefficient of friction, such as fluoropolymers, polytetrafluoroethylene (PTFE), high density polyethylene (HDPE), ultra-high molecular weight (UHMW) plastics, polyphenylene sulfide (PPS), or combinations thereof.

[0055] In one embodiment, a housing 255 of the pad pressure applicator 500 includes one or more chambers 540 that are coupled to a pressure supply 260 adapted to apply force to the flexible membrane 535. Pressure delivered to each of the chambers 540 may be independently controlled to provide a controlled force to the flexible membrane 535 and to the underside 270 of the polishing pad 120. In one embodiment, the pressure of the fluid applied to the chambers 540 is about ~10 psi to about 10 psi.

[0056] FIG. 6A is an isometric top view of another embodiment of a processing station 600 having another embodiment of a first pad pressure applicator 625A. Elements of the processing station 600 which are similar to the embodiment of the processing station 400 shown in FIGS. 4A and 4B will not be repeated for brevity. In this embodiment, the first pad pressure applicator 625A includes a plurality of rings 605, 610 and 615 movably disposed within the lid plate 250 and interspersed within one or more pressure zones 440A-440C. In one embodiment, one or more of the plurality of rings 605, 610 and 615 are semi-flexible rings that are independently movable within the lid plate 250 of the first pad pressure applicator 625A.

[0057] FIG. 6B is an isometric cross-sectional view of one embodiment of a first pad pressure applicator 625A that may be utilized in the processing station 600 of FIG. 6A. In this embodiment, the first pad pressure applicator 625A includes an inner pressure zone 620A, an intermediate pressure zone 620B, a first outer pressure zone 620C and a second outer pressure zone 620D. Each of the inner pressure zone 620A, the intermediate pressure zone 620B, the first outer pressure zone 620C and the second outer pressure zone 620D are coupled to one or more pressurized fluid sources that are independently controlled by a controller.

[0058] In one embodiment, the inner pressure zone 620A comprises a dual zone air bearing having a sub-inner zone 626A and sub-outside zone 626B that are independently controlled. The sub-inner zone 626A includes a first plenum 630A that is coupled to a pressure supply 260 by a conduit 635A while the sub-outside zone 626B is coupled to the pressure supply 260 by one or more conduits 635B. In one embodiment, the first plenum 630A is in communication with a plurality of openings 632 while the sub-outside zone 626B comprises a channel 634. Pressurized fluid is flowed from the pressure supply 260 to the channel 634 and/or the first plenum 630A where pressurized fluid is released to the lid plate 250 through the openings 632 and channel 634.

[0059] The intermediate pressure zone 620B comprises a second plenum 630B that is coupled to the pressure supply 260 by a conduit 635C. The second outer pressure zone 620D comprises a third plenum 630C that is coupled to the pressure supply 260 by a conduit 635D. Fluids from the pressure supply 260 are flowed to the plenums 630B and 630C and through the openings 632 in the lid plate 250. In one embodiment, the inner pressure zone 620A and intermediate pressure zone 620B provide a counter pressure to a center zone 225A (FIG. 2A) of a substrate while the first outer pressure zone 620D provides a counter pressure to a peripheral zone 225B (FIG. 2A) of the substrate. In one aspect, the first outer pressure zone 620C is positioned at the periphery of a substrate while the second outer pressure zone 620D is sized and positioned to provide a counter pressure to a retaining ring 205 of a carrier head 130 (both shown in FIG. 2A).

[0060] In this embodiment, the first outer pressure zone 620C comprises one or more rings 605, 610 and 615. In one embodiment, the first outer pressure zone 620C is positioned on the lid plate 250 to correspond with the periphery of the substrate. In one aspect, the diameter of the first outer pressure zone 620C is about 280 mm to about 320 mm, such as about 290 mm to about 310 mm. In one embodiment, one of the rings 605-615 comprises a diameter of about 300 mm while the other rings are concentric and include a diameter that may be slightly greater or less than 300 mm. Each of the rings 605, 610 and 615 is coupled to one or more actuators 640 that are independently controlled. In one embodiment, each of the actuators 640 include a piston 645 that is adapted to selectively raise and lower relative to a base 650 of the first pad pressure applicator 625A.

[0061] FIG. 7A is an isometric view of one embodiment of an annular plate 655 that may be utilized in the first pad pressure applicator 625A of FIG 6A. The annular plate 655 includes a rigid portion 660A on an inner diameter that couples to the base 650 of the first pad pressure applicator 625A. The rigid portion 660A includes holes 700 for mounting to the base 650 of the first pad pressure applicator 625A. The annular plate 655 also includes a flexible portion 660B on an outer diameter of the annular plate 655. A slot 705 is formed in the annular plate 655 to at least partially separate the rigid portion 660A from the flexible portion 660B and allow the connecting material 710 to form a live spring. The annular plate 655 may be fabricated from plastic materials or metallic materials, such as stainless steel.
FIG. 7B is an enlarged cross-sectional view of the first pad pressure applicator 625A of FIG. 6B. The piston 645 is adapted to contact the flexible portion 660B of the annular plate 655. The flexible portion 660B is adapted to bend upon pressure from the piston 645 and contact a leg 665A-665C coupled to each of the rings 605-615.

FIG. 7C is an enlarged cross-sectional view of the rings 605-615 of FIG. 7B. In one embodiment of a ring actuation arrangement, each ring 605-615 includes a leg 665A-665C that is adapted to engage a desired area of a flexible portion 660B of the annular plate 655. Each leg 665A-665C is positioned relative to the flexible portion 660B such that engagement of the flexible portion 660B contacts a specific leg 665A, 665B or 665C without contact with another leg, which allows the rings 605-615 to be individually actuated. In one aspect, each leg 665A-665C is shaped and/or staggered to be spaced apart from another leg to prevent more than one leg being contacted by the flexible portion 660B when actuated. Each leg 665A-665C may be fabricated from a rigid metallic material or plastic material.

Each of the rings 605-615 includes an annular channel 670 supporting a compressible member 675. The annular channel 670 may be fabricated from rigid plastics or metals. The annular channel 670 includes a structure and/or thickness that provides a stiff or rigid backing for the compressible member 675. In one embodiment, the annular channel 670 is fabricated from a stainless steel material. The compressible member 675 is adapted to contact the underside of the polishing pad (not shown) and is sized and shaped to prevent contact between the polishing pad and the annular channel 670. In one embodiment, the annular channel includes a C or U shaped cross-section while the compressible member 675 includes a T shaped cross-section as shown. The compressible member 675 may be made from compressible materials having a low coefficient of friction, such as PEEK. The PEEK material may also include other materials, such as carbon fibers, to form a composite material.

FIG. 8 is schematic plan view of another embodiment of a ring actuation arrangement 800. In this embodiment, the position of pistons 810A-810C are shown schematically relative to the rings 605-615. Each of the pistons 810A-810C are schematic representations of the piston 645 coupled to the actuator 640 of FIGS. 6B and 6C. In one aspect, each ring 605-615 is aligned with three pistons that are spaced at substantially equal intervals along the ring. For example, ring 605 is aligned with pistons 810C, ring 610 is aligned with pistons 810B and ring 615 is aligned with pistons 810A. Each of the pistons 810A-810C is independently actuable to provide pressure to at least a portion of each ring independent of other rings or pistons. In one embodiment, each ring 605-615 is independently actuable by three actuators. In one embodiment, each of the three actuators is spaced at about 120 degree intervals relative to one ring and/or a radius of one ring. In another embodiment, each of the actuators are spaced concentrically and spaced-apart angularly by about 40 degrees. In this embodiment, the annular plate 655 as described in FIGS. 6B and 6C may be utilized between each of the rings 605-615 and the pistons 810A-810C.

FIG. 9 is a flowchart showing another embodiment of a method 900. At step 910, a substrate 135 is urged against a first surface (e.g., processing surface 125) of a polishing pad 120. In one embodiment, at least a first pressure from a first pressure applicator (e.g., head pressure applicator 220) which is in communication with a backside of the substrate is utilized to urge the substrate 135 against the first surface. In one example, pressure is delivered to one or more bladders 230 disposed in the first pressure applicator to provide pressure to the backside of the substrate 135. The bladders 230 may provide a first pressure to a center zone 225A of the substrate 135 independently of a second pressure to an edge zone 225B of the substrate 135. The first pressure and second pressure may be the same or different. In one embodiment, the first pressure and second pressure applied to the bladders 230 is about −10 psi to about 80 psi.

At step 920, a second pressure is delivered to a feature side of the substrate 135. The second pressure is delivered through a second surface of the polishing pad from a second pressure applicator (e.g., pad pressure applicator 138, 325A, 500, 525 or 625A) disposed on an opposing side of the polishing pad 120 relative to the substrate 135. The second pressure may be substantially equal to or different than the first pressure. In one embodiment, the second pressure applicator includes a center pressure zone 440A and one or more edge pressure zones 440B-440E. The center pressure zone 440A and one or more edge pressure zones 440B-440E may comprise pressure sources 240 that comprise bladders or discrete chambers formed in the second pressure applicator. In one embodiment, the pressure delivered to each pressure source 240 includes at least a third pressure and a fourth pressure to the center pressure zone 440A and one or more edge pressure zones 440B-440E, respectively. The third pressure and fourth pressure may be the same or different. In one embodiment, the third pressure and fourth pressure applied to the pressure sources 240 may be about −10 psi to about 10 psi. In another embodiment, the second pressure is provided by one or more rings 605, 610 and 615 in addition to one or more pressure zones 620A-620D as described in FIG. 6A-6C.

FIG. 10 is a flowchart showing another embodiment of a method 1000. At step 1010, a substrate 135 is retained in a carrier head 130 adapted to move the substrate 135 relative to a polishing pad 120. The carrier head 130 includes a first pressure applicator (e.g., head pressure applicator 220) that is movable with the substrate. In one embodiment, the first pressure applicator includes one or more pressureizable zones (e.g., bladders 230) that apply a pressure to a first side (e.g., backside) of the substrate 135. In one embodiment, the pressure applied to the first side of the substrate is about −10 psi to about 80 psi.

At step 1020, the substrate 135 is moved relative to a first side of the polishing pad 120 (e.g., processing surface 125), for example, in a sweep pattern 305. At step 1030, a counter pressure is delivered to a second side (e.g., feature side) of the substrate 135. The counter pressure is provided from a second pressure applicator disposed on a second side (e.g., underside 270) of the polishing pad 120 (e.g., pad pressure applicator 138, 325A, 500, 525 or 625A) as the substrate moves in the sweep pattern. Thus, the first pressure acting on the first side of the substrate 135 may be countered by the second pressure as the substrate 135 travels across the polishing pad 120. In one embodiment, the second pressure applicator is stationary relative to the polishing pad 120. In another embodiment, the second pressure applicator is movable relative to the polishing pad 120. The counter pressure may be substantially equal to or different than the first pressure. In one embodiment, the counter pressure may be about −10 psi to about 10 psi. The counter pressure may be in the form of a static force or an air bearing.
A method and apparatus for controlling pressure or forces applied to a substrate in a polishing process is described. The method and apparatus described herein facilitates focused, high resolution control of pressure or force applied to a substrate, which facilitates enhanced removal of material from a substrate. The apparatus includes embodiments of a pad pressure applicator 138, 325A, 500, 525 or 625A as described herein. The pad pressure applicator 138, 325A, 500, 525 or 625A is utilized to control pressure boundaries the substrate may experience in a polishing process. Thus, improved control of pressures or forces acting on the substrate facilitates greater polishing uniformity, enhanced removal rate, as well as enhancing profile tuning. The pad pressure applicator 138, 325A, 500, 525 or 625A is adapted to apply a pressure between about –10 psi to about 10 psi as the substrate travels in a sweep pattern. In this manner, the substrate experiences a desired counter pressure along the entirety of the sweep pattern. Additionally, a second pad pressure applicator 325B is described for a conditioning device. The second pad pressure applicator 325B may be constructed and operated in a manner similar to the pad pressure applicator 138, 325A, 500, 525 or 625A. The counter pressure provided to the polishing pad 120 from the pad pressure applicators 138, 325A, 500, 525 or 625A may be controlled independently from the pressure applied to the polishing pad 120 from the second pad pressure applicator 325B.

While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof.

What is claimed is:
1. A polishing system, comprising:
a platen rotatably disposed on a base, the platen having a sidewall and a polishing pad secured to the platen at a perimeter thereof to form an interior volume; and
a pad pressure applicator disposed in the interior volume of the platen adjacent an underside of the polishing pad.
2. The system of claim 1, wherein the pad pressure applicator further comprises a plate having a plurality of perforations adapted to direct a fluid against the underside of the polishing pad.
3. The system of claim 2, wherein the plurality of perforations are coupled to a pressure source.
4. The system of claim 3, wherein the pressure source comprises one or more chambers disposed in a housing.
5. The system of claim 1, wherein the pad pressure applicator further comprises one or more concentric rings adapted to contact the underside of the polishing pad.
6. The system of claim 1, further comprising: a flexible membrane adapted to contact the underside of the polishing pad.
7. The system of claim 6, wherein the flexible membrane is coupled to a perimeter of the platen by one or more tensioner devices.
8. The system of claim 7, wherein the pad pressure applicator provides an air bearing between the flexible membrane and the pad pressure applicator.
9. The system of claim 8, wherein the air bearing comprises multiple, laterally spaced pressure zones.
10. The system of claim 1, wherein the pad pressure applicator is movable relative to the underside of the polishing pad.
11. A method for polishing a substrate, comprising:
urging a substrate against a first surface of a polishing pad using a first pressure applied from a first pressure applicator to a backside of the substrate; and
applying a second pressure from a second pressure applicator to a feature side of the substrate through a second surface of the polishing pad.
12. The method of claim 11, wherein the substrate is movable in a sweep pattern across the first surface of the polishing pad and the second pressure is in communication with the substrate as the substrate moves in the sweep pattern.
13. The method of claim 12, wherein the second pressure applicator is movable with the substrate in the sweep pattern.
14. The method of claim 11, wherein the substrate is movable in a sweep pattern across the first surface and applying the second pressure further comprises applying a variable pressure to the feature side of the substrate as the substrate is moved in the sweep pattern.
15. The method of claim 11, wherein applying the second pressure further comprises applying a first sub-pressure to a first zone of the second surface of the polishing pad and a second sub-pressure to a second zone of the second surface of the polishing pad.
16. A method for polishing a substrate, comprising:
retaining a substrate in a carrier head adapted to move the substrate relative to a polishing pad, the carrier head having a first pressure applicator that is movable with the substrate, the first pressure applicator having one or more pressure zones that apply pressure to a first side of the substrate;
moving the substrate in a sweep pattern relative to a first side of the polishing pad; and
delivering a counter pressure to a second side of the substrate from a second pressure applicator as the substrate moves in the sweep pattern, the second pressure applicator disposed on a second side of the polishing pad and being movable relative to the substrate.
17. The method of claim 16, wherein the second pressure applicator is adapted to form a fluid bearing between the second pressure applicator and the second side of the polishing pad.
18. The method of claim 17, wherein the fluid bearing comprises an air bearing.
19. The method of claim 16, wherein second pressure applicator comprises one or more pressure sources adapted to provide independent pressure to one or more pressure zones within the second pressure applicator.
20. The method of claim 19, wherein the second pressure applicator comprises one or more concentric rings in contact with a second side of the polishing pad.