

RETAINER RING, SUBSTRATE HOLDING APPARATUS, AND POLISHING
APPARATUS, AND RETAINER RING MAINTENANCE METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001]

This application claims the benefit of Japanese Priority Patent Application JP 2015-33668 filed on February 24, 2015, the entire contents of which are incorporated herein by reference.

FIELD

[0002]

The present technology relates to substrate holding apparatuses that hold substrates, such as wafers, and in particular, relates to a substrate holding apparatus used for polishing a surface of a substrate by pressing the substrate onto a polishing tool, such as a polishing pad. The present technology further relates to a polishing apparatus that uses such a substrate holding apparatus. The present technology still further relates to a retainer ring used in the above described substrate holding apparatus.

BACKGROUND AND SUMMARY

[0003]

A polishing apparatus for polishing a surface of a wafer is widely used in a process for manufacturing semiconductor devices. Such a kind of the polishing apparatus includes a

polishing table supporting a polishing pad having a polishing face, a substrate holding apparatus holding a wafer referred to as a top ring or a polishing head, and a polishing liquid supply nozzle supplying a polishing liquid onto the polishing face.

[0004]

The polishing apparatus polishes a wafer as described below. While allowing the polishing table to rotate together with the polishing pad, the apparatus supplies the polishing liquid onto the polishing face from the polishing liquid supply nozzle. The substrate holding apparatus holds and rotates the wafer at an axial center of the wafer. In this state, the substrate holding apparatus presses a surface of the wafer onto the polishing face of the polishing pad to allow the surface of the wafer to come into sliding contact with the polishing face while the polishing liquid is being supplied. The surface of the wafer is evenly polished through a mechanical action of abrasive grain contained in the polishing liquid and a chemical action of the polishing liquid. The described polishing apparatus is also referred to as a chemical mechanical polishing (CMP) apparatus.

[0005]

While polishing the wafer is underway, the surface of the wafer comes into sliding contact with the polishing pad, causing a friction force on the wafer. To prevent the wafer from coming off the substrate holding apparatus due to the friction force occurred while the wafer is polished, the substrate holding apparatus includes a retainer ring. The retainer ring is

arranged to enclose the wafer to press the polishing pad outside the wafer.

[0006]

A wafer polishing rate (or, removal rate) could change depending on polishing conditions such as a load of the wafer against the polishing pad, a load of the retainer ring, a rotating speed of the polishing table and the wafer, and a type of the polishing liquid. To obtain the same level of polishing finish when polishing a plurality of wafers successively, such polishing conditions are normally maintained at a constant level. However, a polishing profile at an edge of each of the plurality of wafers could change gradually as polishing of the plurality of wafers proceeds even though the polishing conditions are kept unchanged. Specifically, the polishing rate at the edge increases as many wafers are polished.

[0007]

A reason of such increase of the polishing rate is assumed to be that the retainer ring changes in shape. FIG. 19 is a schematic view illustrating a retainer ring while a wafer is polished. As shown in FIG. 19, a retainer ring 200 wears while polishing the wafer W is underway, because the retainer ring 200 is pressed against a polishing face 201a of a polishing pad 201. Inner and outer peripheral surfaces of the retainer ring 200 particularly wear, resulting in the rounded inner and outer peripheral surfaces. When the inner peripheral surface of the retainer ring 200 wears as shown in FIG. 19, a force of the retainer ring 200 to press a pad area near an edge of the wafer W lowers,

increasing the polishing rate at the edge.

[0008]

Therefore, there is a need for substrate holding apparatuses that are able to stabilize a substrate polishing rate even when successively polishing a plurality of substrates (wafers, for example). There is a further need for polishing apparatuses that use such substrate holding apparatuses. There is a still further need for retainer rings used in such substrate holding apparatuses, as well as a retainer ring maintenance method.

[0009]

According to one embodiment, a retainer ring for retaining a substrate to be polished, includes: an inside ring arranged to enclose the substrate; and an outside ring arranged outside the inside ring, abrasion-resistant of the outside ring being higher than abrasion-resistant of the inside ring, wherein the inside ring having a thickness in a radial direction in a range from a minimum of 0.05 mm to a maximum of 5 mm.

[0010]

According to another embodiment, a retainer ring for retaining a substrate to be polished, includes: an inside ring arranged to enclose the substrate; and an outside ring arranged outside the inside ring, the outside ring comprising a lower ring and an upper ring, wherein abrasion-resistant of the lower ring is higher than abrasion-resistant of the inside ring, and toughness of the upper ring is higher than toughness the lower ring.

[0011]

According to another embodiment, a retainer ring for retaining a substrate to be polished, includes: an inside ring arranged to enclose the substrate; an outside ring arranged outside the inside ring, abrasion-resistant of the outside ring being higher than abrasion-resistant of the inside ring and the outside ring being harder than the inside ring; wherein the outside ring and the inside ring are individually, vertically movable each other, and the outside ring is either contact-less with the polishing pad, or is pressed onto the polishing pad with a force smaller than another force pressing the inside ring onto the polishing pad.

[0012]

According to another embodiment, a substrate holding apparatus includes: a top ring body for holding a substrate; and the above retainer ring, the retainer ring being arranged to enclose the substrate held by the top ring body.

[0013]

According to another embodiment, a polishing apparatus includes: a polishing pad; and the substrate holding apparatus according to claim 10, the substrate holding apparatus pressing the substrate onto the polishing pad.

[0014]

According to another embodiment, a method for maintaining the above retainer ring, includes: removing the inside ring from the outside ring; and fixing a new inside ring onto the outside ring.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

FIG. 1 is a schematic view illustrating a polishing apparatus including a substrate holding apparatus according to an embodiment.

FIG. 2 is a view illustrating a detailed configuration of the polishing apparatus.

FIG. 3A is a cross-sectional view illustrating the top ring 1.

FIGS. 3B and 3C are enlarged cross-sectional views illustrating different phases of an outer periphery of a drive ring 81.

FIG. 4 is a plain view illustrating the drive ring 81 and the coupling member 75.

FIG. 5 is a view illustrating the spherical bearing 85.

FIG. 6A is a drawing illustrating vertical movement of the coupling member 75 relative to the spherical bearing 85.

FIGS. 6B and 6C are drawings illustrating tilt movement of the coupling member 75 together with the inner ring 101.

FIG. 7 is an enlarged cross-sectional view illustrating another configuration example of a spherical bearing 85.

FIG. 8A is a drawing illustrating vertical movement of the coupling member 75 relative to the spherical bearing 85.

FIGS. 8B and 8C are drawings illustrating tilt movement of the coupling member 75 together with the intermediate ring 91.

FIG. 9 is an enlarged partial cross-sectional view of the retainer ring 40.

FIG. 10 is a view schematically illustrating a change in a surface shape of the retainer ring 40 shown in FIG. 9 after used for a long period of time.

FIGS. 11A to 11D are graphs showing measurement results of cross sectional shapes of a typical retainer ring after used for a long period of time.

FIGS. 12 to 14 are graphs showing measurement results of shapes of lower surfaces of typical retainer rings after used for a long period of time.

FIGS. 15A to 15F are enlarged views of various outside rings 40b.

FIG. 16 is a cross-sectional view illustrating an example method for fixing an inside ring 40a and an outside ring 40b.

FIG. 17 is an enlarged partial cross-sectional view of a retainer ring 40', a modified example of the retainer ring 40 shown in FIG. 9.

FIG. 18 is a bottom view of a retainer ring 40.

FIG. 19 is a schematic view illustrating a retainer ring while a wafer is polished.

DETAILED DESCRIPTION OF NON-LIMITING EXAMPLE EMBODIMENTS

[0016]

A detailed description will hereinafter be given with reference to the drawings.

[0017]

According to one embodiment, a retainer ring for retaining a substrate to be polished, includes: an inside ring arranged to enclose the substrate; and an outside ring arranged outside the inside ring, abrasion-resistant of the outside ring being higher than abrasion-resistant of the inside ring, wherein the inside ring having a thickness in a radial direction in a range from a minimum of 0.05 mm to a maximum of 5 mm.

Since the outside ring is highly abrasion-resistant, and an appropriate distance is set between an inner peripheral surface of the inside ring and a convex portion, it is possible to maintain a load acting point of the retainer ring near an edge of the substrate, stabilizing a polishing rate.

[0018]

According to another embodiment, a retainer ring for retaining a substrate to be polished, includes: an inside ring arranged to enclose the substrate; and an outside ring arranged outside the inside ring, the outside ring comprising a lower ring and an upper ring, wherein abrasion-resistant of the lower ring is higher than abrasion-resistant of the inside ring, and toughness of the upper ring is higher than toughness of the lower ring.

Since the outside ring is highly abrasion-resistant, it is possible to maintain a load acting point of the retainer ring near an edge of the substrate, stabilizing a polishing rate. Also, the tough upper ring allows the retainer ring to firmly be attached with another component.

[0019]

It is preferable that a convex portion toward the polishing pad is formed on a lower surface of the outside ring.

By such a manner, the load acting point is prevented from being moved away from a substrate in a radial direction.

[0020]

It is more preferable that a distance between a tip of the convex portion and an end of the outside ring with no convex portion is below 30 μm .

Therefore, a substrate polishing rate can be stabilized.

[0021]

It is preferable that the inside ring is detachably attached to the outside ring.

Therefore, only the inside ring can be replaced when the inside ring is worn, while continuously using a highly abrasion-resistant outside ring.

[0022]

According to another embodiment, a retainer ring for retaining a substrate to be polished, includes: an inside ring arranged to enclose the substrate; an outside ring arranged outside the inside ring, abrasion-resistant of the outside ring being higher than abrasion-resistant of the inside ring and the outside ring being harder than the inside ring; wherein the outside ring and the inside ring are individually, vertically movable each other, and the outside ring is either contact-less with the polishing pad, or is pressed onto the polishing pad with a force smaller than another force pressing the inside ring onto the polishing pad.

Since the outside ring is highly abrasion-resistant, it is possible to maintain a load acting point of the retainer ring near an edge of the substrate, stabilizing a polishing rate.

[0023]

A material of the inside ring may include one or more of PPS, PEEK, PTFE, PP, PET, polycarbonate, and polyacetal. A material of the outside ring may include one or more of ceramic materials and metallic materials.

[0024]

Preferably, surface roughness of a lower surface of the outside ring is a maximum of Ra 1.6 μm , and Rockwell M hardness of the inside ring is in a range from a minimum of 70 to a maximum of 120.

[0025]

Preferably, on a lower surface of the inside ring and a lower surface of the outside ring, a plurality of grooves extending in radial directions and communicating the inside ring and the outside ring are formed.

[0026]

According to another embodiment, a substrate holding apparatus includes: a top ring body holding a substrate; and the above retainer ring, the retainer ring being arranged to enclose the substrate held by the top ring body.

[0027]

According to another embodiment, a polishing apparatus includes: a polishing pad; and the substrate holding apparatus according to claim 31, the substrate holding apparatus pressing

the substrate onto the polishing pad.

[0028]

According to another embodiment, a method for maintaining the above retainer ring, includes: removing the inside ring from the outside ring; and fixing a new inside ring onto the outside ring.

[0029]

FIG. 1 is a schematic view illustrating a polishing apparatus including a substrate holding apparatus according to an embodiment. As shown in FIG. 1, the polishing apparatus includes a top ring (substrate holding apparatus) 1 holding and rotating a wafer (substrate) W, a polishing table 3 supporting a polishing pad 2, a polishing liquid supply nozzle 5 supplying polishing liquid (slurry) onto the polishing pad 2, and a film thickness sensor 7 retrieving film thickness signals that changes depending a film thickness of the wafer W. The film thickness sensor 7 is arranged inside the polishing table 3, retrieving the film thickness signals at a plurality of areas including a center of the wafer W each time the polishing table 3 rotates once. The film thickness sensor 7 may be, for example, an optical sensor or an eddy current sensor.

[0030]

The top ring 1 is configured to hold the wafer W by vacuum contact onto the lower surface of the wafer W. The top ring 1 and the polishing table 3 rotate in the same direction indicated by an arrow, during which the top ring 1 presses the wafer W against a polishing face 2a of the polishing pad 2. The polishing

liquid supply nozzle 5 supplies the polishing liquid onto the polishing pad 2, during which the wafer W comes into sliding contact with the polishing pad 2 for polishing. While the wafer W is polished, the film thickness sensor 7 rotates together with the polishing table 3 across a surface of the wafer W, as indicated by symbol A, to retrieve the film thickness signals. The film thickness signals are index values directly or indirectly indicate film thicknesses, and the film thickness signals change as the film thickness of the wafer W decreases. The film thickness sensor 7 is connected to a polishing controller 9, to which the film thickness signals is sent. The polishing controller 9 stops polishing the wafer W upon the film thickness signals indicate that the film thickness of the wafer W reaches a predetermined target value.

[0031]

FIG. 2 is a view illustrating a detailed configuration of the polishing apparatus. The polishing table 3 is coupled, via a table shaft 3a, to a motor 13 arranged under the polishing table 3 so that the polishing table 3 can rotate around the table shaft 3a. The polishing pad 2 is pasted on an upper surface of the polishing table 3 so that an upper surface of the polishing pad 2 configures the polishing face 2a polishing the wafer W. The motor 13 rotates the polishing table 3, resulting in that the polishing face 2a moves relative to the top ring 1. The motor 13 therefore configures a polishing face moving mechanism that horizontally moves the polishing face 2a.

[0032]

The top ring 1 is connected to a top ring shaft 11 that vertically moves by a vertical movement mechanism 27 relative to a top ring head 16. By vertical movement of the top ring shaft 11, the top ring 1 raises or lowers entirely relative to the top ring head 16 for positioning. An upper end of the top ring shaft 11 is attached with a rotary joint 25.

[0033]

The vertical movement mechanism 27, which vertically moves the top ring shaft 11 and the top ring 1, includes a bridge 28 rotatably supporting the top ring shaft 11 via a bearing 26, a ball screw 32 attached to the bridge 28, a support table 29 supported by a support column 30, and a servomotor 38 arranged on the support table 29. The support table 29 supporting the servomotor 38 is fixed to the top ring head 16 via the support column 30.

[0034]

The ball screw 32 includes a screw shaft 32a coupled to the servomotor 38 and a nut 32b into which the screw shaft 32a is screwed. The top ring shaft 11 vertically moves together with the bridge 28. When the servomotor 38 is driven, accordingly the bridge 28 is vertically moved via the ball screw 32, and thus the top ring shaft 11 and the top ring 1 are vertically moved.

[0035]

The top ring shaft 11 is coupled to a rotating cylinder 12 via a key (not shown). An outer periphery of the rotating cylinder 12 is equipped with a timing pulley 14. A top ring

motor 18 is fixed to the top ring head 16, and the above described timing pulley 14 is connected, via a timing belt 19, to a timing pulley 20 attached to the top ring motor 18. Therefore, rotary-driving the top ring motor 18 allows the rotating cylinder 12 and the top ring shaft 11 to rotate together, via the timing pulley 20, the timing belt 19, and the timing pulley 14, and thus allows the top ring 1 to rotate at an axial center. The top ring motor 18, the timing pulley 20, the timing belt 19, and the timing pulley 14 configure a rotation mechanism rotating the top ring 1 at the axial center. The top ring head 16 is supported by a top ring head shaft 21 rotatably supported by a frame (not shown).

[0036]

The top ring 1 can hold the substrate, such as the wafer W, at the lower surface. The top ring head 16 is configured in a rotatable manner around the top ring head shaft 21, moving the top ring 1 holding the wafer W at the lower surface, through rotation of the top ring head 16, from a wafer W - receiving position to above the polishing table 3. The top ring 1 is then lowered to press the wafer W against the polishing face 2a of the polishing pad 2. At this time, the top ring 1 and the polishing table 3 are rotated separately, and the polishing liquid is supplied from the polishing liquid supply nozzle 5 arranged above the polishing table 3 onto the polishing pad 2. In this manner, the wafer W is come into sliding contact with the polishing face 2a of the polishing pad 2 to polish the surface of the wafer W.

[0037]

Next, the top ring 1 configuring the substrate holding apparatus will be described. FIG. 3A is a cross-sectional view illustrating the top ring 1. As shown in FIG. 3A, the top ring 1 includes a top ring body 10 holding and pressing the wafer W against the polishing face 2a, and a retainer ring 40 arranged to enclose the wafer W. The top ring body 10 and the retainer ring 40 are configured to rotate together through rotation of the top ring shaft 11. The retainer ring 40 is configured in a vertically movable manner relative to the top ring body 10. The present embodiment has an object to stabilize a polishing rate by appropriately configuring the retainer ring 40, the retainer ring 40 being described in detail in and after FIG. 9.

[0038]

The top ring body 10 includes a circular flange 41, a spacer 42 attached at a lower surface of the flange 41, and a carrier 43 attached at a lower surface of the spacer 42. The flange 41 is coupled to the top ring shaft 11. The carrier 43 is coupled, via the spacer 42, to the flange 41 so that the flange 41, the spacer 42, and the carrier 43 rotate together and vertically move. The top ring body 10 configured with the flange 41, the spacer 42, and the carrier 43 is molded of a resin such as engineer plastic (PEEK, for example). The flange 41 may be molded of metal such as SUS or aluminum.

[0039]

Under a lower surface of the carrier 43, an elastic film

45 that comes into contact with a back of the wafer W is attached. A lower surface of the elastic film 45 configures a substrate holding face 45a. The elastic film 45 has a plurality of annular partition walls 45b forming, between the elastic film 45 and the top ring body 10, four pressure chambers, i.e. a center chamber 50, a ripple chamber 51, an outer chamber 52, and an edge chamber 53. The four pressure chambers 50 to 53 are connected, via the rotary joint 25, to a pressure regulator 65 that supplies a pressurized fluid. The pressure regulator 65 can separately adjust pressure in the four pressure chambers 50 to 53. The pressure regulator 65 can further form negative pressure in the four pressure chambers 50 to 53.

[0040]

The elastic film 45 has a through hole (not shown) at a position corresponding to the ripple chamber 51 or the outer chamber 52 so that, by forming negative pressure in the through hole, the top ring 1 can hold the wafer W at the substrate holding face 45a. The elastic film 45 is molded of a highly strong and durable rubber material, such as ethylene propylene rubber (EPDM), polyurethane rubber, or silicone rubber. The center chamber 50, the ripple chamber 51, the outer chamber 52, and the edge chamber 53 are also connected to an atmosphere open mechanism (not shown) so that the center chamber 50, the ripple chamber 51, the outer chamber 52, and the edge chamber 53 are atmospherically open.

[0041]

The retainer ring 40 is arranged to enclose the carrier

43 and the elastic film 45 of the top ring body 10. The retainer ring 40 is a ring-shaped member for coming into contact with the polishing face 2a of the polishing pad 2. The retainer ring 40 is arranged to enclose an outer periphery edge of the wafer W to hold the wafer W so that the wafer W does not come off the top ring 1 while the wafer W is polished.

[0042]

FIGS. 3B and 3C are enlarged cross-sectional views illustrating different phases of an outer periphery of a drive ring 81. As shown in FIGS. 3B and 3C, an upper surface of the retainer ring 40 is positioned to the drive ring 81 by a plurality of reinforcing pins 82, and is fixed with a plurality of screws 83. The plurality of reinforcing pins 82 and the plurality of screws 83 are respectively arranged circumferentially and evenly. A top of the drive ring 81 is coupled to an annular retainer ring pressing mechanism 60 applying a load downwardly, evenly, and entirely to the upper surface of the retainer ring 40 via the drive ring 81 to press a lower surface of the retainer ring 40 against the polishing face 2a of the polishing pad 2.

[0043]

The retainer ring pressing mechanism 60 includes an annular piston 61 fixed to the top of the drive ring 81 and an annular rolling diaphragm 62 connected to an upper surface of the piston 61. A retainer ring pressure chamber 63 is formed inside the rolling diaphragm 62. The retainer ring pressure chamber 63 is connected to the pressure regulator 65 via the rotary joint 25.

[0044]

When the pressurized fluid (pressurized air, for example) is supplied from the pressure regulator 65 to the retainer ring pressure chamber 63, the rolling diaphragm 62 presses down the piston 61, and then the piston 61 presses down, via the drive ring 81, the retainer ring 40 entirely. The retainer ring pressing mechanism 60 presses in this manner the lower surface of the retainer ring 40 against the polishing face 2a of the polishing pad 2. In addition to this, the pressure regulator 65 can form negative pressure inside the retainer ring pressure chamber 63 to raise the retainer ring 40 entirely. The retainer ring pressure chamber 63 is also connected to the atmosphere open mechanism (not shown) so as to be atmospherically open.

[0045]

The drive ring 81 is detachably coupled to the retainer ring pressing mechanism 60. More specifically, the piston 61 is molded of a magnetic material, such as metal, and the top of the drive ring 81 is arranged with a plurality of magnets 70. The plurality of magnets 70 attracts the piston 61 to secure the drive ring 81 to the piston 61. The magnetic material used to mold the piston 61 may be, for example, corrosion-resistant magnetic stainless steel. In contrast, the drive ring 81 may be molded of a magnetic material, and the piston 61 may be arranged with a plurality of magnets.

[0046]

The retainer ring 40 is coupled to a spherical bearing 85 via the drive ring 81 and a coupling member 75. The spherical

bearing 85 is arranged inside the retainer ring 40 inwardly in a radial direction. FIG. 4 is a plain view illustrating the drive ring 81 and the coupling member 75. As shown in FIG. 4, the coupling member 75 includes a shaft 76 arranged at a center of the top ring body 10, a hub 77 fixed to the shaft 76, and a plurality of spokes 78 radially extending from the hub 77. [0047]

One end of the spokes 78 is fixed to the hub 77, and the other end of the spokes 78 is fixed to the drive ring 81. The hub 77 and the plurality of spokes 78 are integrally formed together with the drive ring 81. The carrier 43 is fixed with a plurality of pairs of drive pins 80, 80. Each pair of the drive pins 80, 80 is arranged on both sides of each of the spokes 78 to transmit rotation of the carrier 43 to the drive ring 81 and the retainer ring 40 via the drive pins 80, 80 so that the top ring body 10 and the retainer ring 40 can rotate together. [0048]

As shown in FIG. 3A, the shaft 76 extends longitudinally inside the spherical bearing 85. As shown in FIG. 4, in the carrier 43 is formed a plurality of radial grooves 43a accommodating the plurality of spokes 78 so that each of the spokes 78 are longitudinally movable in each of the grooves 43a. The shaft 76 of the coupling member 75 is longitudinally and movably supported by the spherical bearing 85 arranged at the center of the top ring body 10. According to the above described configuration, the coupling member 75 is longitudinally movable together with the drive ring 81 and the retainer ring 40 coupled

to the coupling member 75 relative to the top ring body 10. The drive ring 81 and the retainer ring 40 are further tiltably and movably supported by the spherical bearing 85.

[0049]

FIG. 5 is a view illustrating the spherical bearing 85. The shaft 76 is fixed to the hub 77 with a plurality of screws 79. The shaft 76 is formed with a longitudinally extending through hole 88. The through hole 88 acts as an air vent hole when the shaft 76 longitudinally moves relative to the spherical bearing 85, allowing the retainer ring 40 to longitudinally and smoothly move relative to the top ring body 10.

[0050]

The spherical bearing 85 includes an annular inner ring 101 and an outer ring 102 slidably supporting an outer peripheral surface of the inner ring 101. The inner ring 101 is coupled, via the coupling member 75, the drive ring 81 and the retainer ring 40. The outer ring 102 is fixed to a supporting member 103 fixed to the carrier 43. The supporting member 103 is arranged inside a recessed portion 43b of the carrier 43.

[0051]

The outer peripheral surface of the inner ring 101 has a spherical shape where a top and a bottom are cut into flat surfaces, and a center (fulcrum) O of the spherical shape positions at a center of the inner ring 101. An inner peripheral surface of the outer ring 102 is configured with a recessed surface along with the outer peripheral surface of the inner ring 101 so that the outer ring 102 slidably supports the inner ring 101.

The inner ring 101 is therefore tiltably and omni-directionally (360°) movable relative to the outer ring 102.

[0052]

An inner peripheral surface of the inner ring 101 is configured with a through hole 101a into which the shaft 76 is inserted. The shaft 76 is only longitudinally movable relative to the inner ring 101. The retainer ring 40 coupled to the shaft 76 therefore cannot move laterally, and thus a lateral (horizontal) position of the retainer ring 40 is secured by the spherical bearing 85. The spherical bearing 85 functions as a supporting mechanism to restrict lateral movement of the retainer ring 40 (i.e. securing the horizontal position of the retainer ring 40), while receiving a lateral force (a force in an outward radial direction of the wafer) applied from the wafer W against the retainer ring 40 due to friction between the wafer W and the polishing pad 2 while the wafer W is polished.

[0053]

FIG. 6A illustrates vertical movement of the coupling member 75 relative to the spherical bearing 85, while FIGS. 6B and 6C illustrate tilt movement of the coupling member 75 together with the inner ring 101. The retainer ring 40 coupled to the coupling member 75 is tiltably movable together with the inner ring 101 at the fulcrum O, and is vertically movable relative to the inner ring 101.

[0054]

FIG. 7 is an enlarged cross-sectional view illustrating another configuration example of a spherical bearing 85. As

shown in FIG. 7, the spherical bearing 85 includes an intermediate ring 91 coupled to a retainer ring 40 via a coupling member 75, an outer ring 92 slidably supporting the intermediate ring 91 from above, and an inner ring 93 slidably supporting the intermediate ring 91 from beneath. The intermediate ring 91 has a partial spherical shell shape where a lower half thereof is smaller than an upper half, the intermediate ring 91 being interposed between the outer ring 92 and the inner ring 93. [0055]

The outer ring 92 is arranged in a recessed portion 43b. The outer ring 92 has a brim 92a at an outer periphery of the outer ring 92, through which brim 92a, by securing the brim 92a onto a step of the recessed portion 43b with a bolt (not shown), the outer ring 92 is fixed to the carrier 43, as well as pressure can be applied onto the intermediate ring 91 and the inner ring 93. The inner ring 93 is arranged on a bottom of the recessed portion 43b to support from beneath the intermediate ring 91 so as to form a gap between a lower surface of the intermediate ring 91 and the bottom of the recessed portion 43b. [0056]

An inner surface 92b of the outer ring 92, an outer surface 91a and an inner surface 91b of the intermediate ring 91, and an outer surface 93a of the inner ring 93 are each configured in an approximate hemispherical shape formed around a fulcrum O. The outer surface 91a of the intermediate ring 91 slidably contacts with the inner surface 92b of the outer ring 92, while the inner surface 91b of the intermediate ring 91 slidably

contacts with the outer surface 93a of the inner ring 93. The inner surface 92b (sliding contact surface) of the outer ring 92, the outer surface 91a and the inner surface 91b (sliding contact surfaces) of the intermediate ring 91, and the outer surface 93a (sliding contact surface) of the inner ring 93 each has a partial spherical shape where a lower half thereof is smaller than an upper half. According to the above described configuration, the intermediate ring 91 is tiltably and omni-directionally (360°) movable relative to the outer ring 92 and the inner ring 93, and the fulcrum O, i.e. a center of tilt movement, positions below the spherical bearing 85.

[0057]

The outer ring 92, the intermediate ring 91, and the inner ring 93 are respectively formed with through holes 92c, 91c, and 93b into which a shaft 76 is inserted. A gap is formed between the through hole 92c of the outer ring 92 and the shaft 76, as well as another gap is formed between the through hole 93b of the inner ring 93 and the shaft 76. The through hole 91c of the intermediate ring 91 has a smaller diameter than diameters of the respective through holes 92c and 93b of the outer ring 92 and the inner ring 93 so that the shaft 76 is only longitudinally movable relative to the intermediate ring 91. The retainer ring 40 coupled to the shaft 76 therefore cannot substantially move laterally, and a lateral (horizontal) position of the retainer ring 40 is secured by the spherical bearing 85.

[0058]

FIG. 8A illustrates vertical movement of the coupling

member 75 relative to the spherical bearing 85, while FIGS. 8B and 8C illustrate tilt movement of the coupling member 75 together with the intermediate ring 91. As shown in FIGS. 8A to 8C, the retainer ring 40 coupled to the coupling member 75 is tiltably movable together with the intermediate ring 91 at the fulcrum O, as well as is vertically movable relative to the intermediate ring 91. The spherical bearing 85 shown in FIG. 7 is the same with the spherical bearing 85 shown in FIG. 5 in terms of the fulcrum O, i.e. a center of tilt movement, positioned on a central axis line of the retainer ring 40. However, the spherical bearing 85 shown in FIG. 7 is different from the spherical bearing 85 shown in FIG. 5 because the fulcrum O shown in FIG. 7 is positioned lower than the fulcrum O shown in FIG. 5. For the spherical bearing 85 shown in FIG. 7, a height of the fulcrum O may be the same or below a surface of the polishing pad 2.

[0059]

Next, the retainer ring 40, which is one of features of the present embodiment, will now be described herein.

FIG. 9 is an enlarged partial cross-sectional view of the retainer ring 40. The retainer ring 40 includes an inside ring 40a and an outside ring 40b. The inside ring 40a has an annular shape, enclosing the wafer W. The outside ring 40b also has an annular shape, and is arranged outside the inside ring 40a.

[0060]

When polishing the wafer W, an inner peripheral surface of the inside ring 40a comes into contact with the edge of the wafer W. To prevent the wafer W from being chipped or damaged,

the inside ring 40a is molded of a softer material than the wafer W, preferably a material having a Rockwell M hardness of in a range from a minimum of 70 to a maximum of 120. In addition, the inner peripheral surface of the inside ring 40a receives a force from the edge of the wafer W. To bear such a force, the inside ring 40a is molded of a highly abrasion-resistant material. Highly abrasion-resistant materials having low hardness property may be, for example, PPS (Poly Phenylene Sulfide), PEEK (Poly Ether Ether Ketone), PTFE (Poly Tetra Fluoro Etylene), PP (Poly Propylene), PET (Polyethylene Terephthalate), polycarbonate, polyacetal, and other resin materials that contain one or more of the described materials.

[0061]

A lower surface of the outside ring 40b is pressed by the polishing face 2a to be rotated. Therefore, the outside ring 40b is molded of a material that is more abrasion-resistant than a material of the inside ring 40a, preferably a material with a wear amount, due to contact with the polishing face 2a, of a maximum of one fifth of a wear amount of the inside ring 40a. Such a material may be, for example, a ceramic material, such as SiC, SiN, alumina, or zirconia, or a metallic material, such as stainless steel or titanium. The material of the outside ring 40b may be harder than a material of the inside ring 40a.

[0062]

The retainer ring 40 normally requires breaking-in polishing in an initial stage of use to stabilize surface roughness of a lower surface that comes into contact with the

polishing face 2a, because, if the retainer ring 40 having a rough surface is used when polishing the wafer W, an action of grinding a surface of the polishing pad 2 occurs, leading to an unstable polishing rate of the wafer W. Since the outside ring 40b is highly abrasion-resistant, and will be rarely worn in a polishing process, it is preferable that surface roughness be a maximum of Ra 1.6 μm (JIS B 0601:2001) in an initial state.

[0063]

FIG. 10 is a view schematically illustrating a change in a surface shape of the retainer ring 40 shown in FIG. 9 after used for a long period of time. The view shows that the lower surface of the retainer ring 40 wears through contact with the polishing face 2a, where wear on the inner peripheral surface of the inside ring 40a due to contact with the edge of the wafer W is ignored. Wear on a lower surface of the inside ring 40a advances through polishing of many wafers W in a long period of time due to contact with the polishing face 2a. In particular, the more close to the inner peripheral surface, the more the wear amount, and the more close to an outer periphery (i.e. more close toward the outside ring 40b), the less the wear amount. On the other hand, since the outside ring 40b is molded of a highly abrasion-resistant material, the lower surface is not changed significantly, almost keeping the initial shape.

[0064]

With the retainer ring 40 having such a shape, an innermost point A on the lower surface of the outside ring 40b becomes a load acting point against the wafer W. Accordingly, the load

acting point can be prevented from being moved away from the edge of the wafer W. As a result, even when the retainer ring 40 is used for a long period of time, a polishing rate at the edge of the wafer W can be prevented from being increased, achieving the stabilized polishing rate.

[0065]

An appropriate value of thickness d of the inside ring 40a in a radial direction will now be described herein.

[0066]

Since the inner peripheral surface of the inside ring 40a wears due to contact with the wafer W, a thickness d must be thicker than a wear amount.

FIGS. 11A to 11D are graphs showing measurement results of cross sectional shapes of a typical retainer ring after used for a long period of time. The typical retainer ring is molded of a single material (PPS), different from the retainer ring 40 including the inside ring 40a and the outside ring 40b shown in FIG. 9. FIGS. 11A to 11D respectively show the results of measuring the annular retainer ring at four points shifted by 90 degrees (0 deg., 90 deg., 180 deg., and 270 deg., respectively).

[0067]

Horizontal axes of FIGS. 11A to 11D each represents position R of the retainer ring in a radial direction, indicating that an inner peripheral surface of the unworn retainer ring is positioned at a value of 90 μm . Vertical axes each represents height Z of the retainer ring, indicating that a lower surface of the retainer ring is positioned at a value of 800 μm , and

an edge of a wafer W is coming into contact with a value of approximately 400 μm .

[0068]

As can be seen in the measurement results, the retainer ring wears approximately 0.04 mm after used for a long period of time. When using the retainer ring 40 configured with the inside ring 40a and the outside ring 40b, a preferable thickness d of the inside ring 40a be a minimum of 0.05 mm by taking into account some additional thickness because the inside ring 40a could be worn 0.04 mm. The thickness d of the inside ring 40a may be increased further, for example, a minimum of 0.1 mm, because a too thin thickness might be disadvantageous in terms of rigidity, as well as might lead to difficult processing.

[0069]

On the other hand, although the load acting point of the retainer ring 40 is the innermost point A on the lower surface of the outside ring 40b, a too high thickness d causes the load acting point of the retainer ring 40 to move away from the edge of the wafer W, leading to an unstable polishing rate. Therefore, the thickness d is set so that the load acting point of the retainer ring 40 comes close to the edge of the wafer W.

[0070]

FIGS. 12 to 14 are graphs showing measurement results of shapes of lower surfaces of typical retainer rings after used for a long period of time. The retainer rings used for the measurements were also molded of a single material (PPS), where the lower surfaces were flat initially. As can be seen in the

graphs, widths of the retainer rings (distances in a radial direction between an inner peripheral surface and an outer peripheral surface) were 5 mm (FIG. 12), 7.5 mm (FIG. 13), and 15 mm (FIG. 14). A horizontal axis of each of the graphs represents positions in radial direction relative to the inner peripheral surface of the retainer ring as an origin. A vertical axis represents a relative distance from the polishing face 2a, where a scale represents 10 μm . As can be seen, although the lower surfaces of the retainer rings were flat initially, the lower surfaces were worn after use for a long period of time, forming a downwardly raised portion (convex portion) P' on the lower surface.

[0071]

Regarding the retainer rings with the initial widths of 5 mm (FIG. 12) and 7.5 mm (FIG. 13), respectively, polishing rates were stable, and wafers W were polished successfully. On the other hand, regarding the retainer ring with the initial width of 15 mm (FIG. 14), a polishing rate was unstable, resulting in unsuccessful polishing of a wafer W.

[0072]

According to FIGS. 12 and 13 where proper polishing was realized, distances s' between the inner peripheral surfaces and the downwardly raised portions P' of the retainer rings were approximately 3 mm and 5 mm, respectively. The results mean, for the retainer ring 40 including the inside ring 40a and the outside ring 40b shown in FIG. 10, that a maximum thickness d of 5 mm can achieve a stabilized polishing rate.

[0073]

On the other hand, according to FIG. 14 where proper polishing was not realized, the distance s' between the inner peripheral surface and the downwardly raised portion P' of the retainer ring was approximately 7 mm. The result means, for the retainer ring 40 shown in FIG. 10, that a minimum thickness d of 7 mm could lead to an unstable polishing rate.

[0074]

Therefore, it is preferable that a thickness d should not be too high, but be below 7 mm, and more preferably a maximum of 5 mm.

[0075]

As shown in FIG. 9, although the lower surface of the outside ring 40b may be flat, it is preferable that a downwardly raised portion be formed toward the polishing face 2a (lower side).

[0076]

FIGS. 15A to 15F are enlarged views of various outside rings 40b. In the views, inside rings 40a are illustrated with two-dot chain lines. A downwardly raised portion P may be formed at an innermost side of an outside ring 40b (FIGS. 15A and 15D), or may be formed at a position slightly away from the innermost side (FIGS. 15B and 15E). In addition, lines from a downwardly raised portion P to both ends of a lower surface of an outside ring 40b may be straight (FIGS. 15A and 15B) or curved (FIGS. 15D and 15E).

By providing a downwardly raised portion P at a position near an inside ring 40a, the downwardly raised portion P becomes

a load acting point against a wafer W. Accordingly, the load acting point is prevented from being moved away from a wafer W in a radial direction.

[0077]

As shown in FIGS. 15C and 15F, downwardly raised portions P may be at outermost positions of outside rings 40b (or near outside). In each case of FIGS. 15C and 15F, an innermost point on an outside ring 40b becomes a load acting point against a wafer W, maintaining the load acting point near the wafer W as well.

[0078]

When a distance h between an end (where no downwardly raised portion P is formed) of an outside ring 40b and a downwardly raised portion P is too large, a load could concentrate into the downwardly raised portion P, leading to an unstable polishing rate, the worn downwardly raised portion P, and the damaged polishing face 2a.

[0079]

According to FIGS. 12 and 13 where proper polishing was realized, distances h' between tips of downwardly raised portions P' and ends of retainer rings, the distances h' being occurred due to wear, were approximately 5 μm and 20 μm , respectively. The results mean, for the retainer ring 40s, shown in FIGS. 15A to 15F where downwardly raised portions P are formed, that an acceptable distance h is a maximum of 20 μm .

[0080]

On the other hand, according to FIG. 14 where proper

polishing was not realized, the distance h' was approximately 30 μm . The result means, for the retainer rings 40 shown in FIGS. 15A to 15F, that a polishing rate becomes unstable if the distance h is a minimum of 30 μm . In other words, a maximum distance h of 30 μm can prevent a load from being excessively concentrated at a downwardly raised portion P.

[0081]

Therefore, it is preferable, for the retainer rings 40, that a distance h be below 30 μm , and more preferably, a maximum of 20 μm .

[0082]

Based on the above information, it is preferable that a thickness d of the inside ring 40a in a radial direction shown in FIG. 10 be in a range from a minimum of 0.05 mm to a maximum of 5 mm. When arranging a downwardly raised portion P on a lower surface of the outside ring 40b, it is preferable that a distance h between an end of the outside ring 40b and a tip of a downwardly raised portion P be below 30 μm .

[0083]

FIG. 16 is a cross-sectional view illustrating an example method for fixing an inside ring 40a and an outside ring 40b. The inside ring 40a and the outside ring 40b may be fixed using an adhesive agent. However, it is preferable that a screw 40c be used so that the inside ring 40a is detachable from the outside ring 40b. As shown in FIG. 10, the inside ring 40a could wear due to contact with the polishing face 2a, while the outside ring 40b rarely wears. By making the inside ring 40a detachable,

only the inside ring 40a can be replaced, if worn, in a cost effective manner.

[0084]

The inside ring 40a and the outside ring 40b are fixed each other at least when polishing a wafer W so as to vertically move together.

[0085]

A specific configuration example of FIG. 16 shows that the cross sections of the inside ring 40a and the outside ring 40b are L-shaped which can be engaged each other. Screw holes are formed in portions where the inside ring 40a and the outside ring 40b abut in a vertical direction. Through the screw holes, a screw 40c is tightened to secure the inside ring 40a and the outside ring 40b. A screw hole 40d is formed on the outside ring 40b to fix the retainer ring 40 onto the drive ring 81 by inserting one of the plurality of screws 83 shown in FIG. 3C.

Although this configuration only represents an example, it is obvious that those skilled in the art will understand that there are various methods of detachably fixing the inside ring 40a and the outside ring 40b.

[0086]

When replacing the inside ring 40a as a maintenance, firstly the screw 40c is removed to remove the inside ring 40a from the outside ring 40b. Next, a new inside ring 40a is fit onto the outside ring 40b, and then again the screw 40c is tightened to fix the inside ring 40a and the outside ring 40b.

[0087]

It is unnecessary to always fix the inside ring 40a and the outside ring 40b each other, but the inside ring 40a and the outside ring 40b may be vertically moved individually. In this case, a force pressing the inside ring 40a onto the polishing face 2a, and another force pressing the outside ring 40b onto the polishing face 2a may be the same, or may be different. For example, the outside ring 40b may be more strongly pressed onto the polishing face 2a. In contrast, the outside ring 40b may be more gently pressed onto the polishing face 2a, or the outside ring 40b may be contact-less with the polishing face 2a, if required.

[0088]

When the outside ring 40b is pressed onto the polishing face 2a separately from the inside ring 40a, an amount of wear of the inside ring 40a in a vertical direction can be refrained, comparing with a case where no outside ring 40b is provided, because, although a wear amount of the inside ring 40a increases since an outer periphery of the inside ring 40a strongly comes into contact with the polishing pad 2 when no outside ring 40b is provided, the outer periphery of the inside ring 40a can more gently come into contact with the polishing pad 2 when an outside ring 40b is provided.

[0089]

FIG. 17 is an enlarged partial cross-sectional view of a retainer ring 40', a modified example of the retainer ring 40 shown in FIG. 9. An outside ring 40b of the retainer ring 40' includes a lower ring 40b1 and an upper ring 40b2.

[0090]

Since the lower ring 40b1 comes into contact with the polishing face 2a, the lower ring 40b1 is molded of a highly abrasion-resistant, chemically stable material, such as a ceramic material, than a material of an inside ring 40a. Since the upper surface of the upper ring 40b2 is mechanically fixed to the drive ring 81 with a reinforcing pin 82, a screw 83 and the like (FIGS. 3B and 3C), the upper ring 40b2 is molded of a tougher (damage-resistant, or, rigid) material, such as a stainless steel metallic material or a resin material, than a material of the lower ring 40b1. The lower ring 40b1 and the upper ring 40b2 may be fixed each other with screws or an adhesive agent.

[0091]

FIG. 18 is a bottom view of a retainer ring 40. As shown in FIG. 18, a plurality of grooves 40d communicating the inside ring 40a and the outside ring 40b and extending in radial directions are formed at an approximately even interval so that a polishing liquid supplied onto the polishing face 2a can flow, through the plurality of grooves 40d, from inside to outside, and vice versa, of the retainer ring 40 for efficient polishing of a wafer W.

[0092]

As described above, configuring the retainer ring 40 in two pieces, i.e. the inside ring 40a and the outside ring 40b, while using a highly abrasion-resistant material for the outside ring 40b, allow a load acting point of the retainer ring 40 to

be kept close to an edge of the wafer W, stabilizing a rate of polishing the wafer W (the edge, particularly).

[0093]

While the embodiment has been described above, the present invention is not limited to the embodiment, and various other changes and modifications can be made within the spirit of the technology.

Claims

1. A retainer ring for retaining a substrate to be polished, the retainer ring comprising:

an inside ring arranged to enclose the substrate; and

an outside ring arranged outside the inside ring,

abrasion-resistant of the outside ring being higher than abrasion-resistant of the inside ring,

wherein the inside ring having a thickness in a radial direction in a range from a minimum of 0.05 mm to a maximum of 5 mm.

2. The retainer ring according to claim 1, wherein a convex portion toward the polishing pad is formed on a lower surface of the outside ring.

3. The retainer ring according to claim 2, wherein a distance between a tip of the convex portion and an end of the outside ring with no convex portion is below 30 μm .

4. The retainer ring according to claim 1, wherein the inside ring is detachably attached to the outside ring.

5. The retainer ring according to claim 1, wherein a material of the inside ring includes one or more of PPS, PEEK, PTFE, PP, PET, polycarbonate, and polyacetal.

6. The retainer ring according to claim 1, wherein a material

of the outside ring includes one or more of ceramic materials and metallic materials.

7. The retainer ring according to claim 1, wherein surface roughness of a lower surface of the outside ring is a maximum of Ra 1.6 μm .

8. The retainer ring according to claim 1, wherein Rockwell M hardness of the inside ring is in a range from a minimum of 70 to a maximum of 120.

9. The retainer ring according to claim 1, wherein on a lower surface of the inside ring and a lower surface of the outside ring, a plurality of grooves extending in radial directions and communicating the inside ring and the outside ring are formed.

10. A substrate holding apparatus comprising:
a top ring body for holding a substrate; and
the retainer ring according to claim 1, the retainer ring being arranged to enclose the substrate held by the top ring body.

11. A polishing apparatus comprising:
a polishing pad; and
the substrate holding apparatus according to claim 10, the substrate holding apparatus pressing the substrate onto the polishing pad.

12. A method for maintaining the retainer ring according to claim 4, comprising:

removing the inside ring from the outside ring; and
fixing a new inside ring onto the outside ring.

13. A retainer ring for retaining a substrate to be polished, the retainer ring comprising:

an inside ring arranged to enclose the substrate; and
an outside ring arranged outside the inside ring, the outside ring comprising a lower ring and an upper ring,

wherein abrasion-resistant of the lower ring is higher than abrasion-resistant of the inside ring, and

toughness of the upper ring is higher than toughness of the lower ring.

14. The retainer ring according to claim 13, wherein a convex portion toward the polishing pad is formed on a lower surface of the outside ring.

15. The retainer ring according to claim 14, wherein a distance between a tip of the convex portion and an end of the outside ring with no convex portion is below 30 μm .

16. The retainer ring according to claim 13, wherein the inside ring is detachably attached to the outside ring.

17. The retainer ring according to claim 13, wherein a material of the inside ring includes one or more of PPS, PEEK, PTFE, PP, PET, polycarbonate, and polyacetal.

18. The retainer ring according to claim 13, wherein a material of the outside ring includes one or more of ceramic materials and metallic materials.

19. The retainer ring according to claim 19, wherein surface roughness of a lower surface of the outside ring is a maximum of Ra 1.6 μm .

20. The retainer ring according to claim 10, wherein Rockwell M hardness of the inside ring is in a range from a minimum of 70 to a maximum of 120.

21. The retainer ring according to claim 11, wherein on a lower surface of the inside ring and a lower surface of the outside ring, a plurality of grooves extending in radial directions and communicating the inside ring and the outside ring are formed.

22. A retainer ring for retaining a substrate to be polished, the retainer ring comprising:

an inside ring arranged to enclose the substrate;

an outside ring arranged outside the inside ring, abrasion-resistant of the outside ring being higher than abrasion-resistant of the inside ring and the outside ring being

harder than the inside ring;

wherein the outside ring and the inside ring are individually, vertically movable each other, and

the outside ring is either contact-less with the polishing pad, or is pressed onto the polishing pad with a force smaller than another force pressing the inside ring onto the polishing pad.

23. The retainer ring according to claim 22, wherein a material of the inside ring includes one or more of PPS, PEEK, PTFE, PP, PET, polycarbonate, and polyacetal.

24. The retainer ring according to claim 22, wherein a material of the outside ring includes one or more of ceramic materials and metallic materials.

25. The retainer ring according to claim 22, wherein surface roughness of a lower surface of the outside ring is a maximum of Ra 1.6 μm .

26. The retainer ring according to claim 22, wherein Rockwell M hardness of the inside ring is in a range from a minimum of 70 to a maximum of 120.

27. The retainer ring according to claim 22, wherein on a lower surface of the inside ring and a lower surface of the outside ring, a plurality of grooves extending in radial directions and

communicating the inside ring and the outside ring are formed.

28. A substrate holding apparatus comprising:

a top ring body holding a substrate; and

the retainer ring according to claim 22, the retainer ring being arranged to enclose the substrate held by the top ring body.

29. A polishing apparatus comprising:

a polishing pad; and

the substrate holding apparatus according to claim 28, the substrate holding apparatus pressing the substrate onto the polishing pad.