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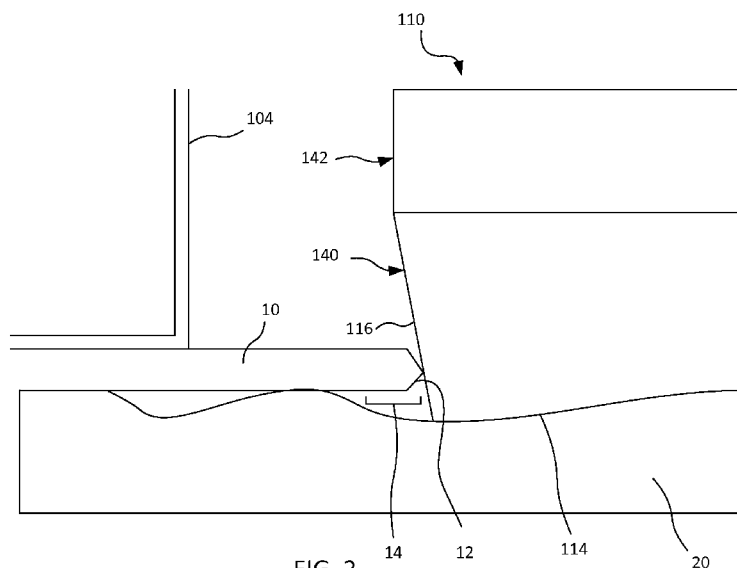
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(54) Title: RETAINING RING WITH SELECTED STIFFNESS AND THICKNESS



(57) Abstract: A retaining ring for holding a substrate below a carrier head during chemical mechanical polishing includes an annular lower portion and an annular upper portion secured to the lower portion. The annular lower portion has a main body with a bottom surface for contacting a polishing pad during polishing, and is a first material. A top surface of the upper portion is configured to be secured to the carrier head. The upper portion is a second material that is more rigid than the first material. A thickness and stiffness of the lower portion is selected for a particular polishing environment to improve polishing uniformity near an edge of the substrate.



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RETAINING RING WITH SELECTED STIFFNESS AND THICKNESS

TECHNICAL FIELD

The present disclosure relates to a retaining ring for a carrier head for
5 chemical mechanical polishing.

BACKGROUND

Integrated circuits are typically formed on substrates, particularly silicon wafers, by the sequential deposition of conductive, semiconductive or insulative layers. One fabrication step involves depositing a filler layer over a non-planar
10 surface and planarizing the filler layer. For certain applications, the filler layer is planarized until the top surface of a patterned layer is exposed. A conductive filler layer, for example, can be deposited on a patterned insulative layer to fill the trenches or holes in the insulative layer. After planarization, the portions of the conductive layer remaining between the raised pattern of the insulative layer form vias, plugs,
15 and lines that provide conductive paths between thin film circuits on the substrate. For other applications, such as oxide polishing, the filler layer is planarized until a predetermined thickness is left over the non-planar surface. In addition, planarization of the substrate surface is usually required for photolithography.

Chemical mechanical polishing (CMP) is one accepted method of
20 planarization. This planarization method typically requires that the substrate be mounted on a carrier head. The exposed surface of the substrate is typically placed against a rotating polishing pad. The carrier head provides a controllable load on the substrate to push it against the polishing pad. A polishing liquid, such as slurry with abrasive particles, is typically supplied to the surface of the polishing pad.

25 The substrate is typically retained below the carrier head by a retaining ring. Some retaining rings include an upper metal portion and a lower plastic portion.

SUMMARY

The geometry of the bottom surface of a retaining ring can impact the pressure distribution on the substrate near the substrate edge, and thus affect the polishing
30 uniformity. However, the stiffness and height of the lower plastic portion of the

retaining ring can also impact the pressure distribution near the substrate edge. selecting a combination of stiffness and height of the lower plastic portion of the retaining ring, pressure uniformity can be improved.

In one aspect, a retaining ring for holding a substrate below a carrier head during chemical mechanical polishing includes an annular lower portion and an annular upper portion secured to the lower portion. The annular lower portion main body with a bottom surface for contacting a polishing pad during polishing is a first material. A top surface of the upper portion is configured to be secured to the carrier head. The upper portion is a second material that is more rigid than the first material. A thickness and stiffness of the lower portion is selected for a particular polishing environment to improve polishing uniformity near an edge substrate.

Implementations may include one or more of the following features. The first material may be a plastic and the second material may be a metal. The lower portion may have a flexural modulus of about 0.5 to 1.5×10^6 psi. The lower portion may have a thickness of 25 to 50 mils.

In another aspect, a retaining ring for holding a substrate below a carrier head during chemical mechanical polishing includes an annular lower portion and an annular upper portion secured to the lower portion. The annular lower portion main body with a bottom surface for contacting a polishing pad during polishing has a thickness between 5 and 45 mils and is a first material having a flexural modulus between 1.1 and 1.5×10^6 psi. A top surface of the upper portion is configured to be secured to the carrier head. The upper portion is a second material that is more rigid than the first material.

Implementations may include one or more of the following features. The annular lower portion may have a thickness between 10 and 20 mils. The annular lower portion may have a thickness between 25 and 45 mils.

In another aspect, a method of selecting a retaining ring includes polishing a first test substrate with the first test substrate held in a carrier head having a first retaining ring having an upper portion and a lower portion with a first stiffness

lower portion with a second stiffness and a second thickness, polishing a second substrate with the second test substrate held in the carrier head having the second retaining ring, and polishing a plurality of device substrates using a plurality of carrier heads having a plurality of retaining rings, each retaining ring of the plurality of retaining rings having an upper portion and a lower portion with a second stiffness and the second stiffness.

Implementations may include one or more of the following features. Measuring polishing uniformity may include determining that a perimeter portion of the first test substrate is overpolished relative to a center portion of the first test substrate, and the second hardness may be greater than the first hardness and/or the second thickness may be less than the first thickness. Measuring polishing uniformity may include determining that a perimeter portion of the first test substrate is underpolished relative to a center portion of the first test substrate, and the second hardness may be less than the first hardness and/or the second thickness may be greater than the first thickness.

Advantages of implementations may include one or more of the following. Pressure uniformity can be improved, and within-wafer non-uniformity (WIWNU) can be reduced.

The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic cross-sectional view of a carrier head.

FIG. 2 is a schematic expanded cross-sectional view of a substrate being polished by a retaining ring.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

During a polishing operation, one or more substrates can be polished by

Referring to FIG. 1, an exemplary simplified carrier head 100 includes housing 102, a flexible membrane 104 that provides a mounting surface for the substrate, a pressurizable chamber 106 between the membrane 104 and the housing 102, and a retaining ring 110 secured near the edge of the housing 102 to hold substrate below membrane 104. Although FIG. 1 illustrates the membrane 104 clamped between the retaining ring 110 and the base 102, one or more other parts, e.g., clamp rings, could be used to hold the membrane 104. A drive shaft 120 is provided to rotate and/or translate the carrier head across a polishing pad. A port may be fluidly connected to the chamber 106 through a passage 108 in the housing to control the pressure in the chamber 106 and thus the downward pressure of the flexible membrane 104 on the substrate.

The retaining ring 110 may be a generally annular ring secured at the outer edge of the base 102, e.g., by screws or bolts 136 that extend through passages in the base 102 into aligned threaded receiving recesses 139 (see FIG. 2) in the upper surface 112 of the retaining ring 110. In some implementations, the drive shaft can be raised and lowered to control the pressure of a bottom surface 114 of the retaining ring 110 on a polishing pad. Alternatively, the base 102 can be movable relative to the drive shaft 120, e.g., a housing can be connected to the drive shaft. The carrier head 100 can include an internal chamber which can be pressurized to control a downward pressure on the base, e.g., as described in U.S. Patent No. 6,183,301, which is incorporated by reference. Alternatively, the retaining ring 110 can be movable relative to the base 120 and the carrier head 100 can include an internal chamber which can be pressurized to control a downward pressure on the retaining ring, e.g., as described in U.S. Patent No. 7,575,504, which is incorporated by reference.

The retaining ring 110 can be removable from the base 102 (and the rest of the carrier head) as a unit. This means that an upper portion 142 of the retaining ring remains secured to a lower portion 140 of the retaining ring while the retaining ring 110 is removed, without requiring disassembly of the base 102 or removal of the base 102 from the carrier head 100.

An inner surface 116 of retaining ring 110 defines, in conjunction with lower surface of the flexible membrane 104, a substrate receiving recess. The retaining ring 110 prevents the substrate from escaping the substrate receiving

Referring to FIGS. 1-2, the retaining ring 110 includes two vertically stacked sections, including the annular lower portion 140 having the bottom surface 114 which may contact the polishing pad, and the annular upper portion 142 connected to the lower portion 140. The lower portion 140 can be secured to the upper portion 142 with an adhesive, e.g., epoxy, or with mechanical fasteners 144, e.g., screws or bolts. The retaining ring 110 is structured so that there is no passage between the upper surface 112 and the bottom surface 114. In some implementations, the passages 138 can extend partially but not entirely through the upper portion 142. In some implementations, the passages 138 can extend through the upper portion 142 and into, but not through, the lower portion 140.

The upper portion 142 of retaining ring 110 is composed of a more rigid material than the lower portion 140. The lower portion 140 can be a plastic, while the upper portion can be a metal, e.g., stainless steel or aluminum, or a ceramic material. An advantage of having the material of the upper portion 142 be harder than the material of the lower portion 140 is that the overall rigidity of the retaining ring 110 can be increased, thus reducing deformation of the lower portion 140 when the retaining ring 110 is attached to the carrier head 100, and reducing break-in time.

The material of the lower portion 140 is chemically inert in a CMP process. In addition, lower portion 140 should be sufficiently elastic that contact of the substrate edge against the retaining ring does not cause the substrate to chip or crack. On the other hand, lower portion 140 should be sufficiently rigid to have sufficient lifetime under wear from the polishing pad (on the bottom surface) and substrate (on the top surface).

The bottom surface 114 of the retaining ring 110 can be substantially flat. In some implementations it may have a plurality of channels 144 that extend from the inner surface 116 to the outer surface 118 of the retaining ring to facilitate the transport of slurry from outside the retaining ring to the substrate. The channels

the channel. The channels on the lower surface 114 extend partially into, not e
through, the lower portion 140. The retaining ring 110 can be replaced when l
portion 140 has been sufficiently worn. As ring wears, the total ring thickness
decreases and the membrane becomes more compressed, which can affect load
5 substrate edge. The retaining ring 110 can be replaced after a certain reduction
thickness, e.g., 0.09 inches of wear. In addition, the impact of the substrate can
damage or wear to the inner surface 116 of the retaining ring. Moreover, the r
ring 110 can be refurbished by removing the worn lower portion 140 and attach
new lower portion to the upper portion 142.

10 The flexural modulus of the material of the lower portion can be in the
of 0.5 to 1.5×10^6 psi. In some implementations, the flexural modulus of the n
of the lower portion can be in the range of 1.1 to 1.5×10^6 psi, e.g., about $1.2 \times$
psi. Although the lower portion can have a low wear rate, it is acceptable for t
lower portion 140 to be gradually worn away, as this appears to prevent the sul
15 edge from cutting a deep groove into the inner surface 144.

The plastic of the lower portion 140 may be (e.g., consist of) a “self-rei
plastic”, which is a polymer matrix reinforced by commonly oriented polymer
which can be derived from the same polymer as the matrix. The plastic can be
reinforced polyphenylene or polypropylene, e.g., PrimoSpire PR120 from Solv
20 Plastics. Other possible materials for the lower portion 140 include polypheny
sulfide (PPS), polyetheretherketone (PEEK), polyetherketoneketone (PEKK),
polyetherketone (PEK), or a similar material.

Adjacent the bottom surface 114, the inner surface 116 of the lower poi
140 of the retaining ring can have an inner diameter just larger than the substra
25 diameter, e.g., about 1-2 mm larger than the substrate diameter, so as to accom
positioning tolerances of the substrate loading system. The retaining ring 110
have a radial width of about half an inch to an inch. The inner surface 116 of t
lower portion 140 can be substantially vertical. Similarly, the inner surface 11
upper portion 140 can be substantially vertical.

30 The thickness of the lower portion 140 should be larger than the permis

to the flexible nature of the lower portion 140. The initial thickness T of the lower portion 140 may be about 25 to 100 mils, e.g., 50 mils. In some implementations, the initial thickness T of the lower portion 140 may be 25 to 45 mils.

In implementations with channels, the channels 144 can have a depth of about 90%, e.g., 80%, of the thickness of the lower portion 140, e.g., 25 to 45 mils. For example, for a 50 mil thick lower portion 140, the channels can be about 40 mils deep. Alternatively, the channels can extend entirely through the retaining ring, or even extend into the upper portion 142.

In operation, the frictional force of the polishing pad 20 against the substrate 10 forces the substrate 10 toward the “trailing edge” of the carrier head 100, i.e., in the same direction as the rotation of the polishing pad 20. This drives an edge of the substrate 10 against the inner surface 116 of the bottom portion 140. In addition, there is a frictional force from the polishing pad 20 on the lower surface 114 of the retaining ring 110. The combination of these forces tends to generate a local torque on the lower portion 140, causing the inner surface 116 and lower surface 114 to deform as shown in FIG. 2, the deformation and result in the inner surface 116 being sloped outwardly (relative to the center of the retaining ring) along a downward direction.

The deformation of the lower portion 140 of the retaining ring under the influence of the lateral forces during polishing creates a compression in the polishing pad 20, which affects the pressure on the a perimeter portion 14 of the lower surface of the substrate 10, and thus the polishing rate near the substrate edge 12. In general, the greater the deformation, the greater the polishing rate in the perimeter portion 14.

In general, the more rigid the material of the lower portion 140, the less the lower portion 140 will deform. In addition, the thinner the lower portion 140, the less the moment, and the less the lower portion 140 will deform.

By proper selection of the combination of the stiffness and thickness of the lower portion 140 of the retaining ring, the compression distribution within the polishing pad 20, and thus the pressure on the perimeter portion 14 of the substrate 10, can be tuned. In particular, by reducing the thickness of the lower portion 140, the moment of the lower portion 140 about the interface between the upper portion 142 and the lower portion 140 is reduced, and thus the lower portion 140 will deform less.

For a polishing process using a low-abrasive slurry, wear of the retaining ring will tend to decrease. However, low-abrasive slurries have a greater tendency to suffer from the edge effect. Thus, a polishing process using a low-abrasive slurry can particularly benefit from this technique, as the lower portion 140 can be thinned without significant loss of retaining ring lifetime, while improving polishing uniformity at the substrate edge.

In order to select the stiffness and thickness of the lower portion 140, a series of test substrates can be polished, with a first retaining ring with a first stiffness and a first thickness installed on the carrier head 100. Polishing of the first test substrate can otherwise be conducted using the same polishing recipe as is expected to be used on product substrates. The amount of material removed from the first test substrate can be measured at different radial positions, e.g., using a stand-alone metrology system. Whether the first test substrate perimeter is overpolished or underpolished relative to the center of the first test substrate can be determined.

A second retaining ring with a second stiffness and a second thickness is selected based on the measured degree of overpolishing or underpolishing of the first test substrate. For example, if the test substrate perimeter is overpolished, a second retaining ring with a stiffer and/or thinner lower portion 140 (relative to the first retaining ring) is selected. Similarly, if the test substrate perimeter is underpolished, a second retaining ring with a softer and/or thicker lower portion 140 (relative to the first retaining ring) is selected.

In some implementations, a second test substrate is polished with the second retaining ring. Whether the second test substrate perimeter is overpolished or underpolished relative to the center of the second test substrate can be determined. If the second test substrate has an acceptable polishing uniformity, polishing of additional substrates can be conducted using retaining rings with the second hardness and thickness. On the other hand, so long as a test substrate has unacceptable non-uniformity, the process of selecting another retaining ring and polishing another test substrate can be iterated until an acceptable or maximum degree of polishing uniformity is achieved.

into the annular recess. When the retaining ring 110 is secured to the carrier head 100, the O-ring is compressed between the rigid body to which the retaining ring is attached, e.g., the base 102, and the retaining ring 110. This can help prevent slurry from reaching the interior of the carrier head, thereby potentially reducing corrosion and associated defects.

In some implementations, the retaining ring 110 has one or more through-holes that extend horizontally or at a small angle from horizontal through the body of the retaining ring from the inner surface 116 to the outer surface 118 for allowing fluid, e.g., air or water, to pass from the interior to the exterior, or from the exterior to the interior, of the retaining ring during polishing. The through-holes can extend through the lower portion 140. The through holes can be evenly spaced around the retaining ring.

Rather than attaching the lower portion 140 to the upper portion 142 with mechanical fasteners or adhesive, the lower portion 140 could be a plastic coating sprayed on the upper portion 142. The coating can cover the lower surface and the side surface of the upper portion 142. The thickness of the lower portion 140 can be about 0.01 inches. Such an implementation may be suitable for some polishing recipes that use low abrasive slurries, e.g., with a low-abrasive slurry the ring may undergo very little wear of about 0.01 inches before wear or damage to the ring inner diameter becomes too severe and the retaining ring needs to be replaced.

The present invention has been described in terms of a number of embodiments. The invention, however, is not limited to the embodiments depicted and described. Rather, the scope of the invention is defined by the appended claims.

WHAT IS CLAIMED IS:

1. A retaining ring for holding a substrate below a carrier head during
5 chemical mechanical polishing, comprising:

an annular lower portion having a main body with a bottom surface for
contacting a polishing pad during polishing, the annular lower portion having a
thickness between 5 and 45 mils and being a first material having a flexural modulus
between 1.1 and 1.5×10^6 psi; and

10 an annular upper portion secured to the lower portion, a top surface of the
upper portion configured to be secured to the carrier head, the upper portion being a
second material that is more rigid than the first material.

2. The retaining ring of claim 1, wherein the annular lower portion
15 thickness between 10 and 20 mils.

3. The retaining ring of claim 1, wherein the annular lower portion
thickness between 25 and 45 mils.

20 4. A method of selecting a retaining ring, comprising:
polishing a first test substrate with the first test substrate held in a carrier head
having a first retaining ring having an upper portion and a lower portion with a
stiffness and a first thickness;

measuring polishing uniformity of the first test substrate;
25 selecting based on the polishing uniformity a second retaining ring with
upper portion and a lower portion with a second stiffness and a second thickness;
polishing a second test substrate with the second test substrate held in the
carrier head having the second retaining ring; and

polishing a plurality of device substrates using a plurality of carrier heads

5. The method of claim 4, wherein measuring polishing uniformity includes determining that a perimeter portion of the first test substrate is overpolished relative to a center portion of the first test substrate.

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6. The method of claim 5, wherein the second hardness is greater than the first hardness and/or the second thickness is less than the first thickness.

7. The method of claim 6, wherein the second hardness is greater than the first hardness.

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8. The method of claim 6, wherein the second thickness is less than the first thickness.

9. The method of claim 4, wherein measuring polishing uniformity includes determining that a perimeter portion of the first test substrate is underpolished relative to a center portion of the first test substrate.

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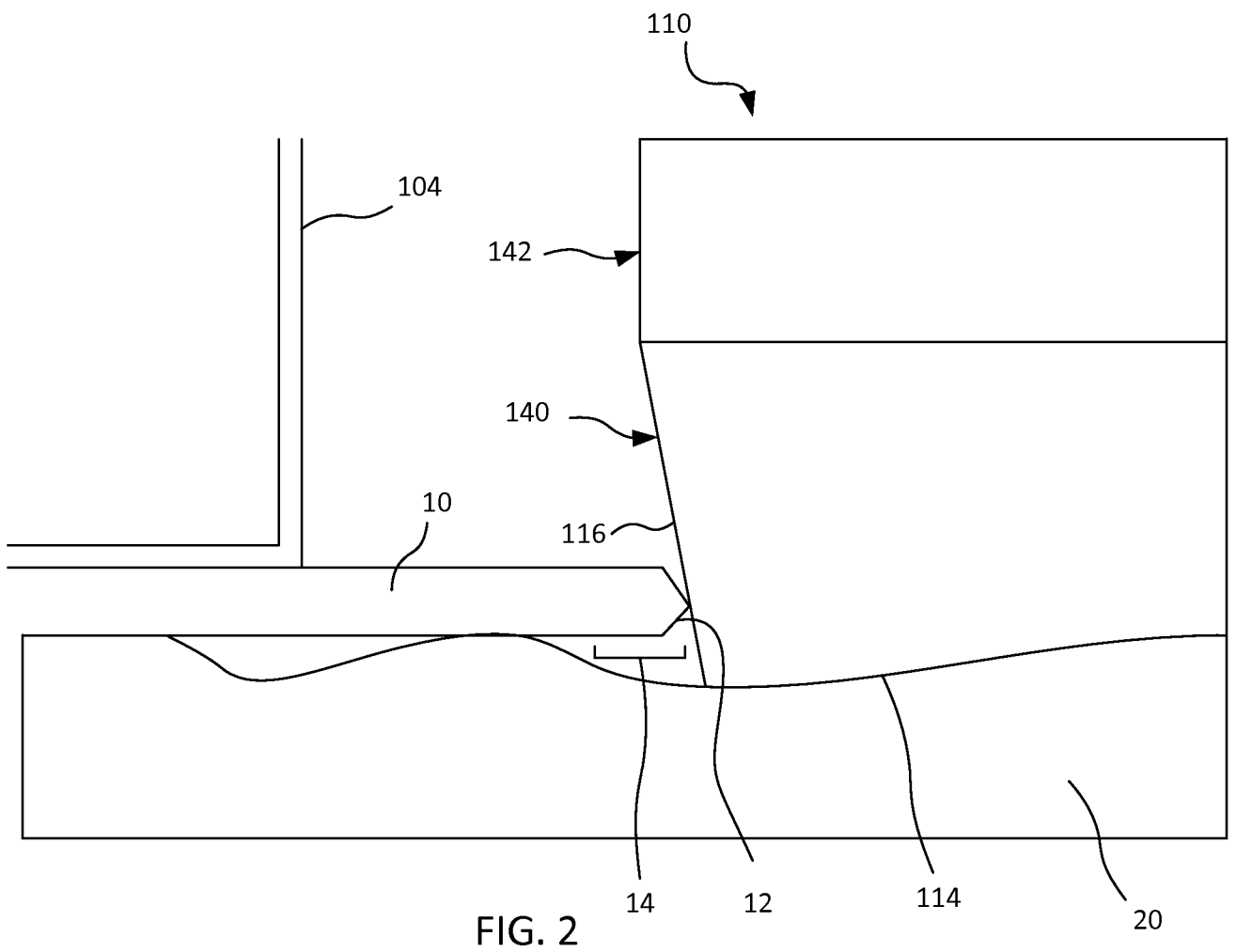
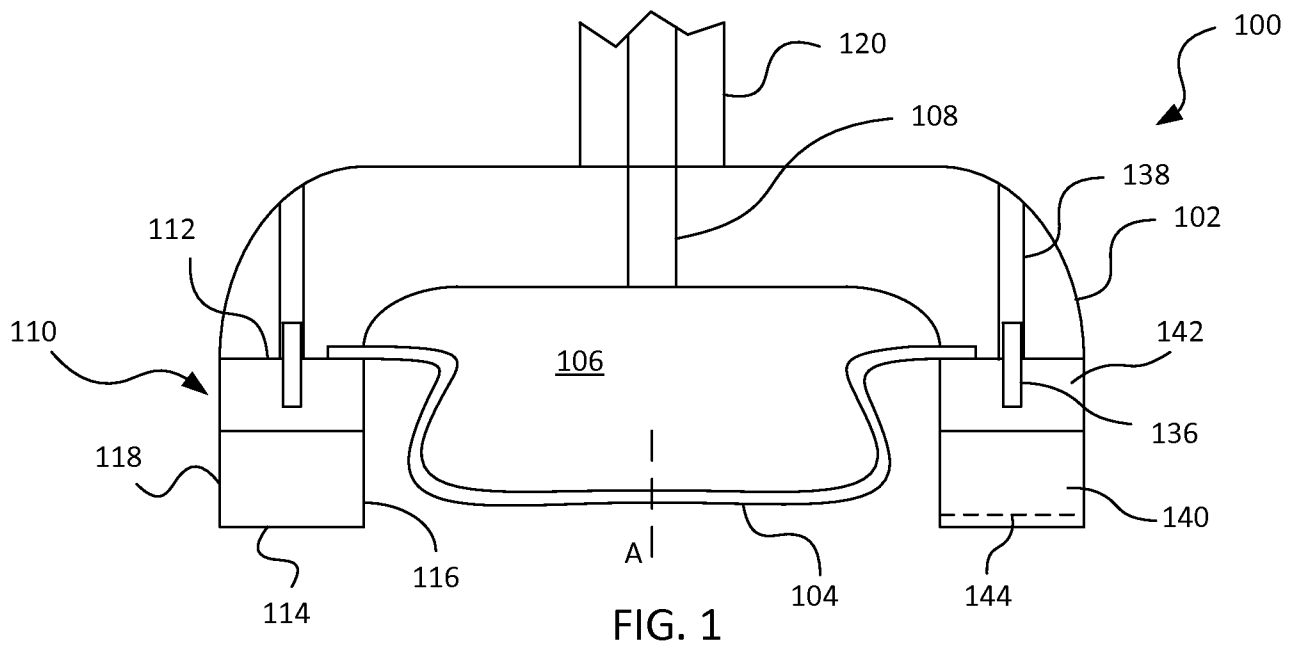
10. The method of claim 9, wherein the second hardness is less than the first hardness and/or the second thickness is greater than the first thickness.

20

11. The method of claim 10, wherein the second hardness is less than the first hardness.

12. The method of claim 10, wherein the second thickness is greater than the first thickness.

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A. CLASSIFICATION OF SUBJECT MATTER**H01L 21/304(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 21/304; B24B 41/06; B24B 29/00; B24B 7/19; B24B 1/00; C23F 1/08; C23C 16/00; H01L 21/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: retaining ring, snap ring, CMP, flexural, thickness, stiffness, uniformity

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0018093 A1 (STEVEN M. ZUNIGA et al.) 26 January 2012 See abstract, paragraphs [0028], [0038]-[0039], claims 1, 3 and figures 2-3.	1-3
A		4-12
A	US 2012-0071067 A1 (HUNG CHIH CHEN et al.) 22 March 2012 See abstract, paragraphs [0063]-[0067], claim 1 and figures 2-7, 16.	1-12
A	US 8088299 B2 (HUNG CHIH CHEN et al.) 03 January 2012 See abstract, column 5, lines 47-59, claim 1 and figure 2.	1-12
A	US 2004-0005842 A1 (HUNG CHIH CHEN et al.) 08 January 2004 See abstract, paragraphs [0029]-[0031], claims 1-3, 29 and figure 1.	1-12
A	US 7094133 B2 (TAKAYUKI MASUNAGA et al.) 22 August 2006 See abstract, column 4, line 62 - column 5, line 41, claims 1, 6 and figure 2.	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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