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(54) **RETAINING RING STRUCTURE FOR ENHANCED REMOVAL RATE DURING FIXED ABRASIVE CHEMICAL MECHANICAL POLISHING**

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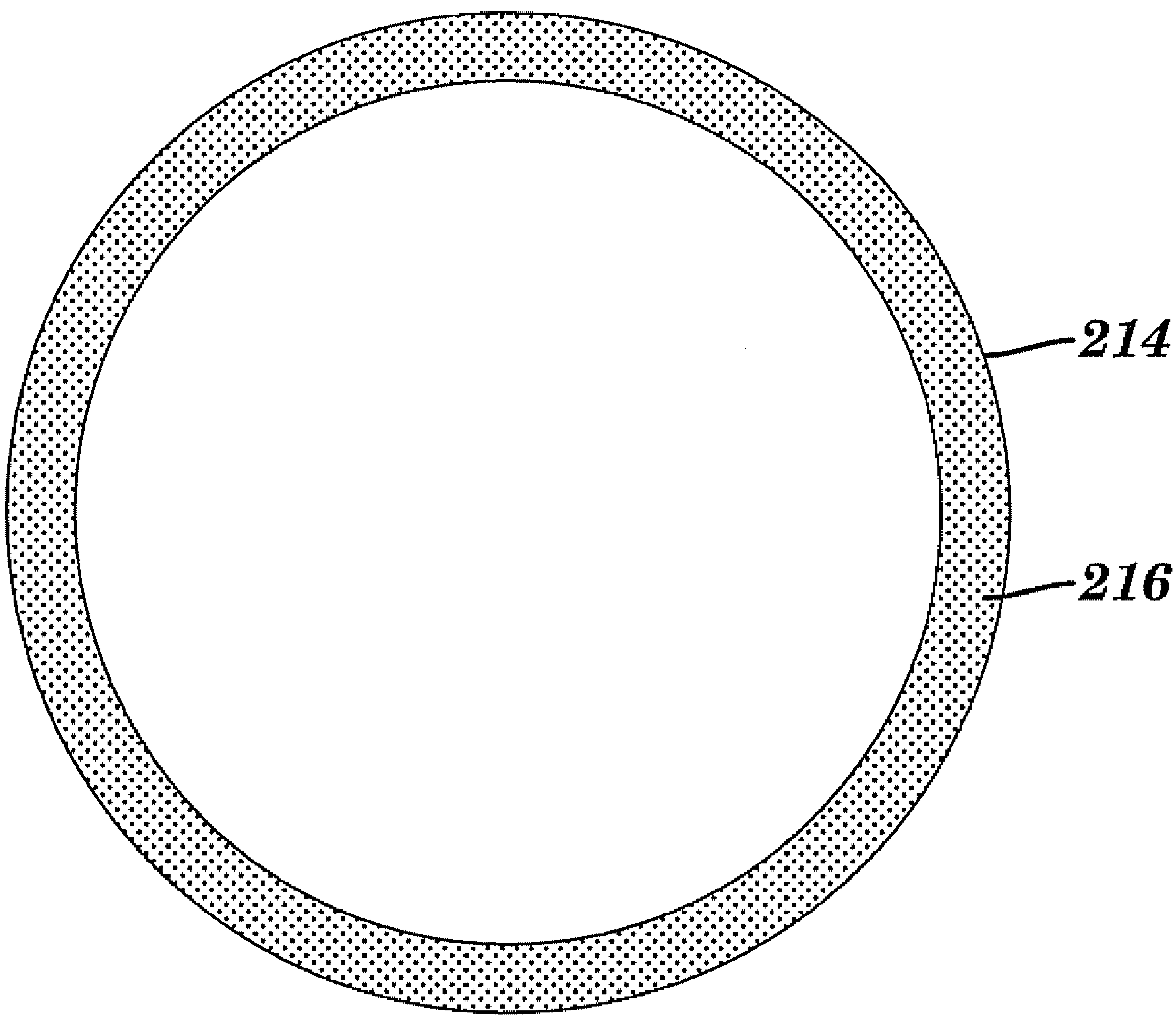
(57) **ABSTRACT**

A retaining ring structure for a chemical mechanical polishing (CMP) apparatus includes a plurality of protrusions formed on a bottom surface of a retaining ring configured for retaining a workpiece to be polished, the protrusions disposed so as to be in contact with a polishing pad during a polishing operation on the workpiece.



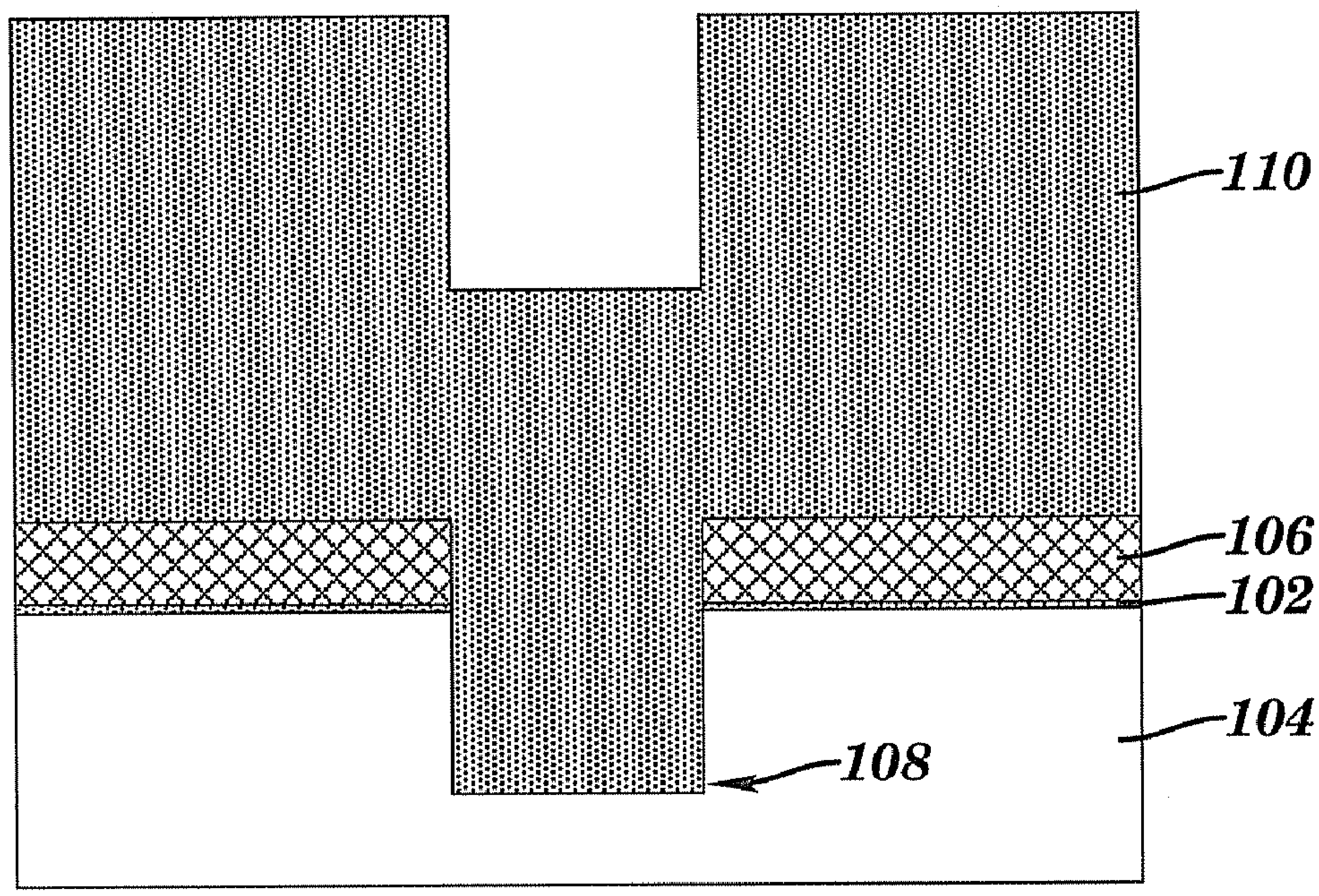


FIG. 1
PRIOR ART

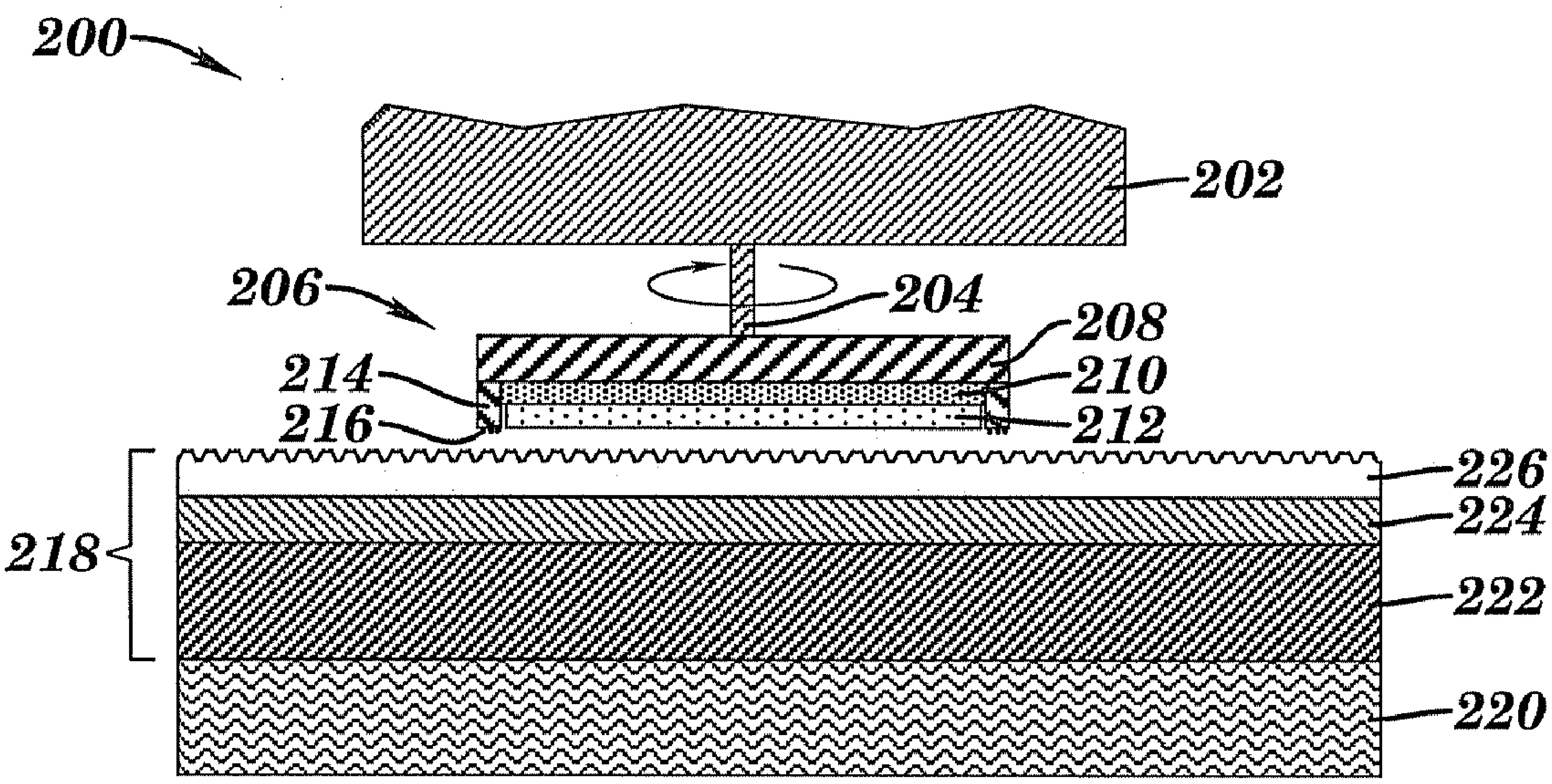


FIG. 2

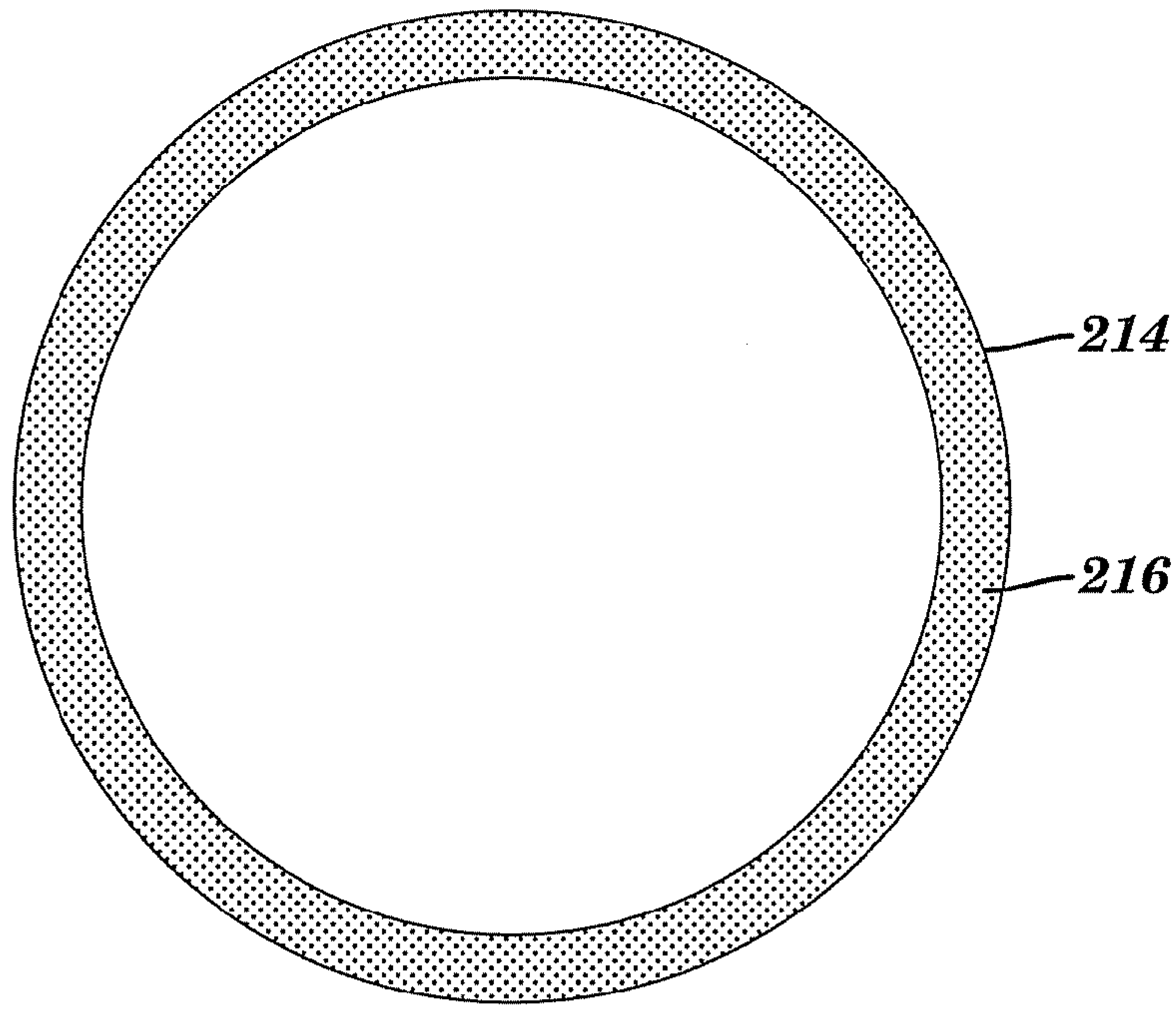


FIG. 3

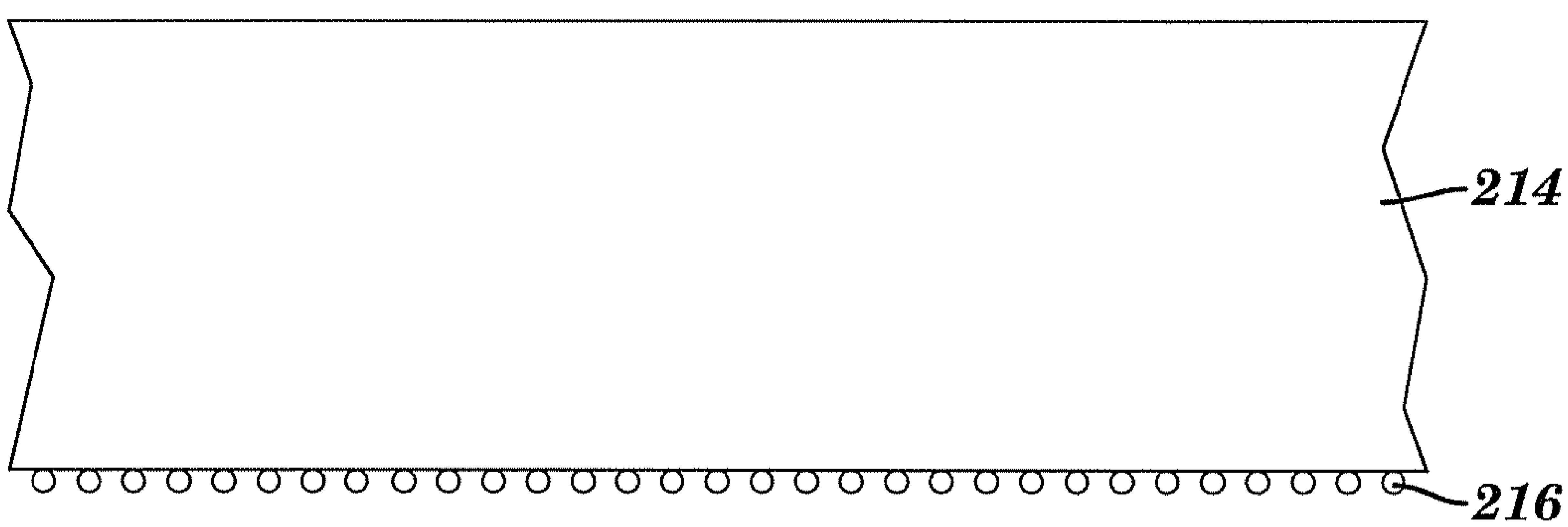


FIG. 4

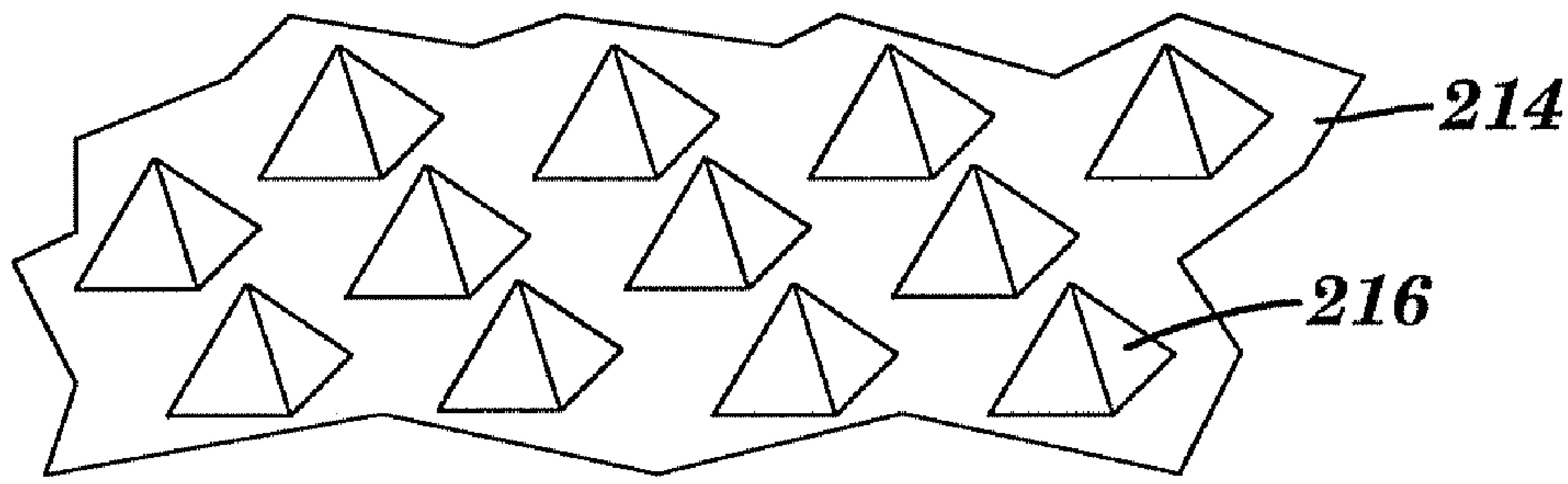


FIG. 5(a)

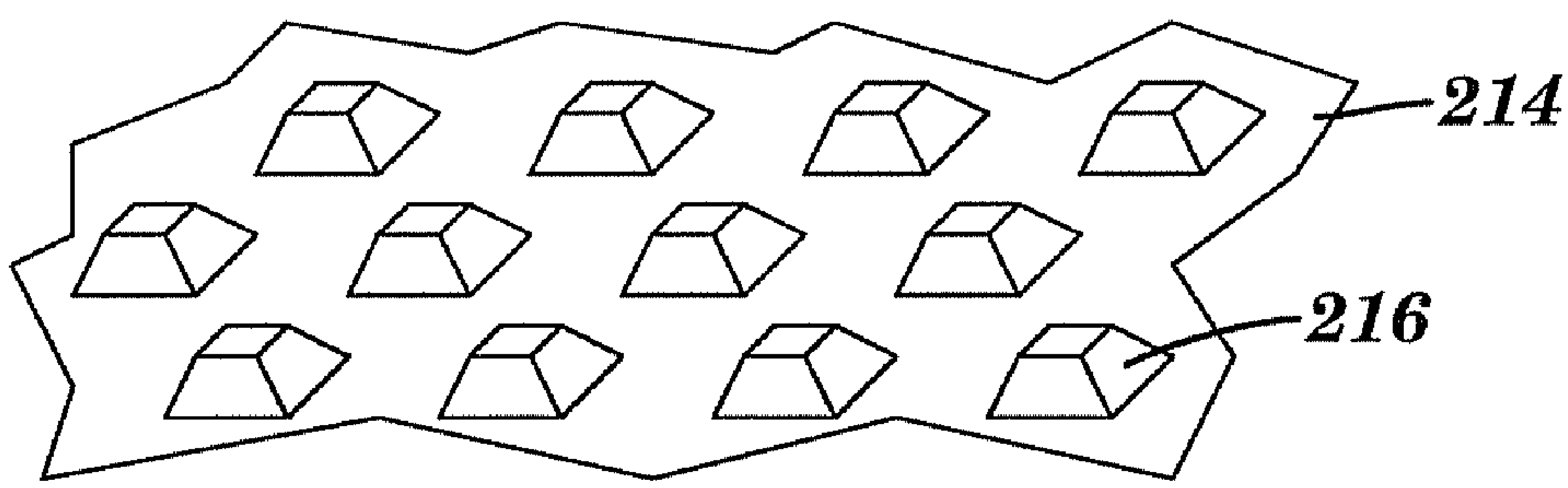


FIG. 5(b)

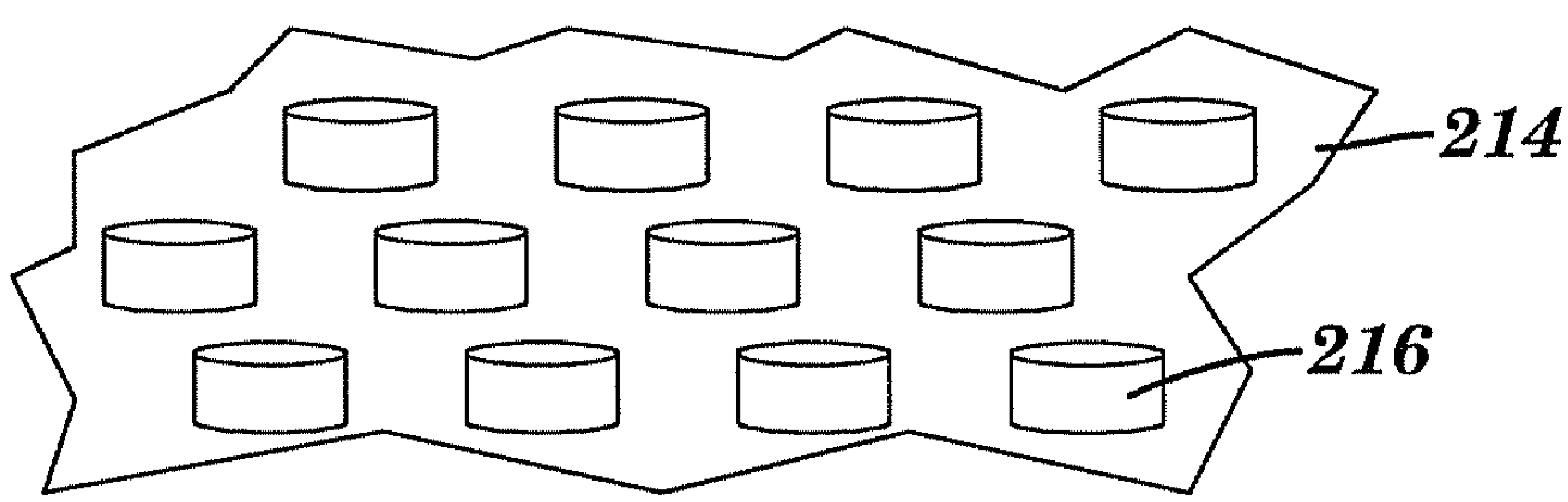


FIG. 5(c)

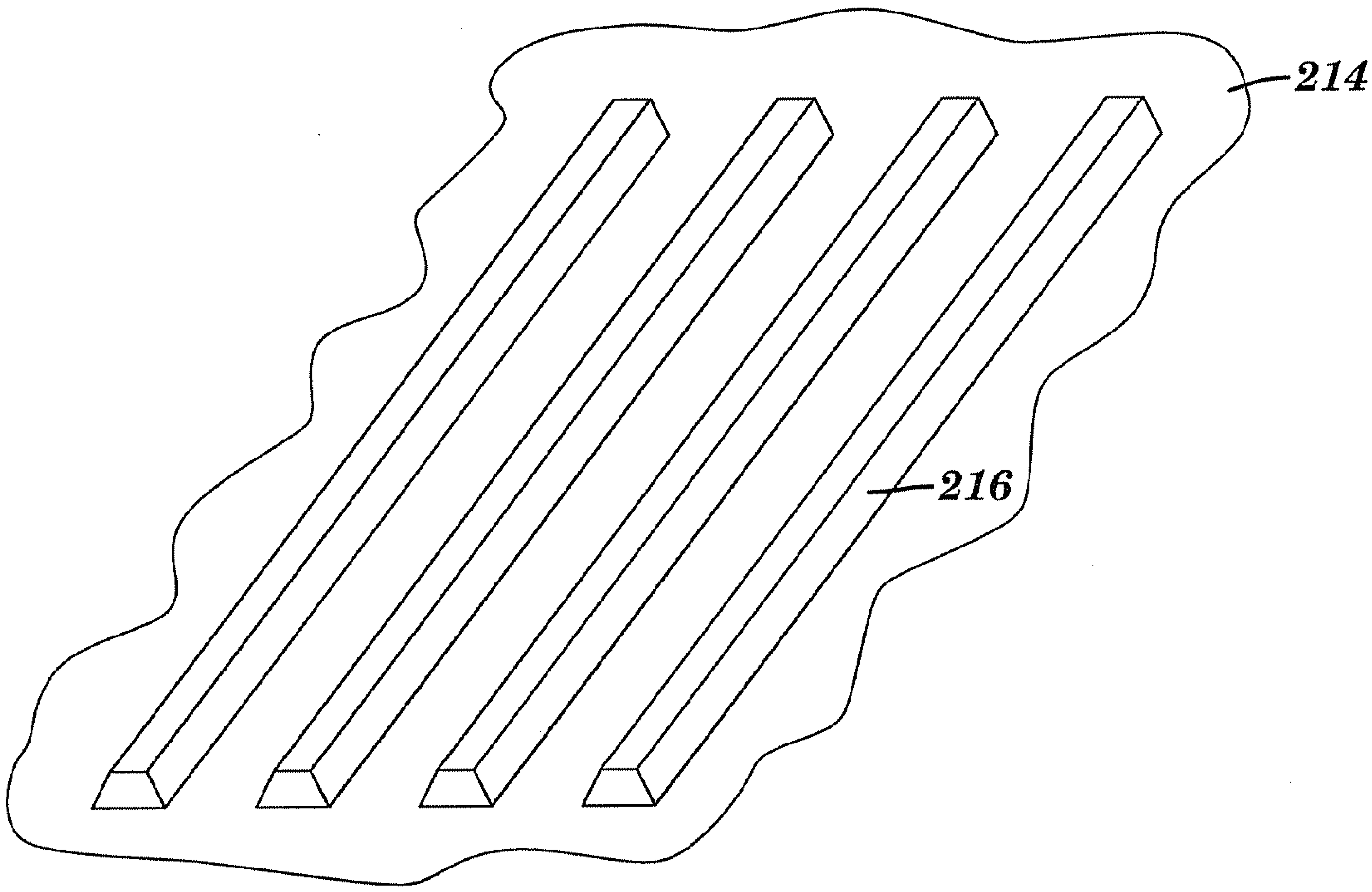


FIG. 5(d)

RETAINING RING STRUCTURE FOR ENHANCED REMOVAL RATE DURING FIXED ABRASIVE CHEMICAL MECHANICAL POLISHING

BACKGROUND

[0001] The present invention relates generally to semiconductor device processing techniques, and, more particularly, to a retaining ring structure for enhanced removal rate during fixed abrasive chemical mechanical polishing (CMP).

[0002] Integrated circuits are typically formed on substrates, particularly silicon wafers, by the sequential deposition of conductive, semiconductive or insulative layers. After each layer is deposited, it is etched to create circuitry features. As a series of layers are sequentially deposited and etched, the outer or uppermost surface of the substrate, i.e., the exposed surface of the substrate, becomes increasingly non-planar. This non-planar surface presents problems in the photolithographic steps of the integrated circuit fabrication process. Therefore, there is a need to periodically planarize the substrate surface.

[0003] Chemical mechanical polishing (CMP) is one accepted method of planarization. This planarization method typically requires that the substrate be mounted on a carrier or polishing head. The exposed surface of the substrate is placed against a rotating polishing pad. The polishing pad may be either a "standard" or a fixed-abrasive pad. A standard polishing pad has durable roughened surface, whereas a fixed-abrasive pad has abrasive, submicron particles (e.g., ceria (CeO_2)) embedded in a containment media. The carrier head provides a controllable load (i.e., pressure) on the substrate to push it against the polishing pad. A polishing slurry, including at least one chemically-reactive agent and abrasive particles (if a standard pad is used) is supplied to the surface of the polishing pad.

[0004] The effectiveness of a CMP process may be measured by its polishing rate, and by the resulting finish (absence of small-scale roughness) and flatness (absence of large-scale topography) of the substrate surface. The polishing rate, finish and flatness are determined by the pad and slurry combination, the relative speed between the substrate and pad, and the force pressing the substrate against the pad.

[0005] Fixed abrasive polishing is commonly used in conjunction with shallow trench isolation (STI) planarization. In a conventional STI process such as shown in FIG. **1**, a thin silicon dioxide (pad oxide) layer **102** is first grown on the substrate **104** of silicon wafer, followed by the deposition of a silicon nitride layer **106**. The thin oxide layer **102** relieves the stresses that could develop between the nitride wafer and the silicon wafer substrate **104**. Shallow trenches **108** are then etched into the wafer, cutting through the nitride film **106** and the thin oxide layer **102**. The trenches are then filled with silicon dioxide **110** to provide electrical isolation of active devices subsequently fabricated into the regions between the trenches. As a result of the trench oxide fill, the oxide material will also be present on the un-etched nitride layer **106**, resulting in topographic features of the oxide layer.

[0006] During fixed abrasive STI CMP of the oxide **110**, the polish rate decreases significantly once planarity is achieved and before the end point is reached (e.g., reaching the nitride layer **106**). More specifically, in the fixed abrasive process, the wafer presses and rubs against the structures holding the abrasive particles, which in turn can expose a significant number of fresh abrasive particles from inside the pad, further contributing to the polishing. This process is also referred to as pad activation. Accordingly, where topographic wafer features dig deeper into the pad structures (e.g., due to high pressure), increased pad activation and thus faster polishing may be the result. In contrast, once the wafer topography has been substantially removed, the newly flattened regions of the wafer simply press on the pad without activating it.

[0007] Although the overall polishing rate of a fixed abrasive CMP pad could be increased by increasing the abrasive content of the pad, for example, there would still be a significant drop in the polish rate once the topography on the wafer has been removed and the oxide overfill has begun to be polished. Accordingly, it would be desirable to be able to maintain an elevated polishing rate for a fixed abrasive CMP pad, even after initial planarity is reached.

SUMMARY

[0008] The above discussed drawbacks and deficiencies of the prior art are overcome or alleviated by a retaining ring structure for a chemical mechanical polishing (CMP) apparatus. In an exemplary embodiment, the structure includes a plurality of protrusions formed on a bottom surface of a retaining ring configured for retaining a workpiece to be polished, the protrusions disposed so as to be in contact with a polishing pad during a polishing operation on the workpiece.

[0009] In another embodiment, a carrier assembly for a chemical mechanical polishing (CMP) apparatus includes a polishing head, a carrier surface having a workpiece to be polished mounted thereon, and a retaining ring circumferentially disposed about the workpiece. The retaining ring further includes a plurality of protrusions formed on a bottom surface thereof, the protrusions disposed so as to be in contact with a polishing pad during a polishing operation on the workpiece.

[0010] In still another embodiment, a chemical mechanical polishing (CMP) apparatus includes a carrier assembly extending from a rotary chuck, the carrier assembly including a polishing head, a carrier surface having a workpiece to be polished mounted thereon, and a retaining ring circumferentially disposed about the workpiece. A platen has a CMP pad mounted thereon, and the retaining ring further includes a plurality of protrusions formed on a bottom surface thereof, the protrusions disposed so as to be in contact with the pad during a polishing operation on the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Referring to the exemplary drawings wherein like elements are numbered alike in the several Figures:

[0012] FIG. **1** is a cross sectional view of a shallow trench isolation (STI) structure following the oxide deposition and before planarization;

[0013] FIG. **2** is a schematic diagram of an exemplary CMP apparatus suitable for use in accordance with an embodiment of the invention;

[0014] FIG. 3 is a top view of a retaining ring for a CMP apparatus, configured with a plurality of protrusions on a bottom surface thereof;

[0015] FIG. 4 is a sectional side view of the retaining ring of FIG. 3; and

[0016] FIGS. 5(*a*) through 5(*d*) illustrate alternative embodiments of the protrusions formed on the retaining ring.

DETAILED DESCRIPTION

[0017] Disclosed herein is a retaining ring structure for enhanced removal rate during fixed abrasive chemical mechanical polishing (CMP). Briefly stated, a retaining ring for a CMP apparatus is configured in a manner that provides continuous pad activation even after the wafer topography has been substantially removed. More specifically, the retaining ring is provided with a plurality of protrusions on the surface thereof, which are in constant contact with the fixed abrasive CMP pad during polishing. Thus, even when the wafer topography is relatively flat, the pad will continue to be activated as a result of the retaining ring protrusions.

[0018] Referring initially to FIG. 2, there is shown a schematic diagram of an exemplary CMP apparatus **200** suitable for use in accordance with an embodiment of the invention. In the simplified schematic depicted, the apparatus **200** includes a head unit **202** coupled to a motor (not shown), and from which a rotary chuck **204** extends. A carrier assembly **206** is located at the end of the chuck, and includes (among other components not necessary for an understanding of the teachings of the present disclosure) a polishing head **208**, a carrier surface **210** upon which a workpiece **212** (e.g., a silicon wafer) to be polished is mounted, and a retaining ring **214** circumferentially disposed about the workpiece **212**. As will be described in further detail hereinafter, the retaining ring **214** is configured with a plurality of protrusions **216** or asperities on the bottom surface (facing the CMP pad) thereof, although the depiction of the protrusions should not be construed herein as being depicted to scale.

[0019] During a polishing operation, the rotating carrier assembly **206** and wafer **212** are brought into contact with a CMP pad assembly **218** that is supported by a platen **220**. The CMP apparatus **200** may be a belt assembly (i.e., a web-format type) in which the pad assembly **218** is laterally advanced along a plurality of rollers (not shown). Alternatively, the CMP apparatus **200** may be a rotary type in which a drive assembly (not shown) rotates and/or reciprocates the platen **220** and pad assembly **218**. For fixed abrasive CMP, the pad assembly **218** includes a resilient layer **222** supported by the platen **220**, a rigid layer **224** supported by the resilient layer **222**, and a fixed abrasive pad **226** supported by the rigid layer **224**. The fixed abrasive pad **226**, such as those available from 3M corporation for example, includes an abrasive surface **226** containing abrasive particles embedded therein.

[0020] As indicated above, topographic features on the surface of the wafer **212** to be polished activate the abrasive particles physically embedded within the fixed abrasive pad **226**. Once initial planarity is achieved on the surface of the wafer, the polishing rate of the pad **226** diminishes. With an HDP oxide deposition, however, it is still desirable to be able to maintain a substantial polishing rate to remove the remaining planarized oxide down to the applicable etch stop layer (e.g., the nitride layer **106** of FIG. **1**). Accordingly, by configuring the bottom surface of the retaining ring **214** with protrusions **216**, the ring **214** still provides topography in contact with the pad **226** to maintain activation of the pad **226**, thereby maintaining a desired polishing rate.

[0021] FIG. **3** is a plan view of the bottom surface of the retaining ring **214**, having the protrusions **216** formed thereon. In an exemplary embodiment, the protrusions may be spherical in shape, such as shown in the sectional view of FIG. **4**. Where the protrusions are specifically designed for fixed abrasive pad activation, the size of the protrusions should be selected so as not to exceed the size of the abrasive particles themselves. Furthermore, the protrusion dimensions will also take into consideration the relative mechanical strength thereof with respect to the posts on the fixed abrasive CMP pad containing the embedded fixed abrasive particles. Mechanically stronger protrusions will result in the protrusions being much smaller than the height of the posts containing the fixed abrasive material. Conversely, mechanically weaker protrusions will allow larger protrusion dimensions to be used for the purpose of pad activation.

[0022] Ultimately, the controlling factor for selecting the protrusion dimensions is the ability to activate the pad without also eroding and/or damaging the pad. A fixed abrasive pad is considered eroded or damaged if the structural integrity of the posts holding the fixed abrasive particles is compromised, and all the particles are lost during abrasion with the protrusions. Accordingly, for the fixed abrasive pads that presently are in use, the size of the protrusions **216** should preferably not exceed about 200 microns in height (i.e., the distance the protrusions extend away from the bottom surface of the ring **214**). On the other hand, in order for the protrusions to have effective activation capability of a fixed abrasive pad, the protrusion height should be at least about 0.01 microns.

[0023] Although the illustrated embodiments herein are presented in the context of fixed abrasive CMP, it will further be appreciated that the retaining ring with protrusions can also be configured for pad conditioning in standard CMP. After a period of time, the fibers of a standard CMP pad become glazed over and require conditioning of the fibers. Thus, by sizing the protrusions on the retaining ring to perform pad conditioning, a standard CMP apparatus may be configured in which the wafer retaining ring conditions the portions of the pad on the periphery of the wafer at the same time the wafer is being polished. For such an application, the protrusions **216** would generally be larger than with respect to those used in activating a fixed abrasive pad (e.g., on the order of about 30-500 microns in height), and would further have a mechanical strength comparable to that of industrial diamonds. It is noted that such an embodiment is generally not interchangeable for use with fixed abrasive CMP pads, as they are not conditioned.

[0024] Finally, FIGS. **5**(*a*) through **5**(*d*) illustrates various alternative shapes that may be embodied by the protrusions **216**. Such alternative shapes may include, but are not limited to: pyramidal protrusions shown in FIG. **5**(*a*), truncated pyramidal protrusions shown in FIG. **5**(*b*), conical/truncated conical protrusions, cylindrical protrusions shown in FIG. **5**(*c*), polygonal protrusions, as well as different combinations of shapes and sizes. In other words, the size and shape of the protrusions **216** need not be homogeneous throughout the entire bottom surface of the retaining ring. Moreover, as shown in FIG. **5**(*d*), the protrusions may also include elongated shapes that run along the width of the retaining ring (i.e., from the inside diameter to the outside diameter).

[0025] While the invention has been described with reference to a preferred embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

1. A retaining ring structure for a chemical mechanical polishing (CMP) apparatus, comprising:

a plurality of protrusions formed on a bottom surface of a retaining ring configured for retaining a workpiece to be polished, said protrusions disposed so as to be in contact with a polishing pad during a polishing operation on the workpiece;

wherein said plurality of protrusions are sized so as to activate abrasive particles of a fixed abrasive CMP pad.

2. (canceled)

3. The retaining ring structure of claim 1, wherein said plurality of protrusions have a height of about 0.01 microns to about 200 microns.

4. (canceled)

5. (canceled)

6. The retaining ring structure of claim 1, wherein said plurality of protrusions further comprise at least one or more of: spherical shapes, pyramidal shapes, conical shapes, and polygonal shapes.

7. A carrier assembly for a chemical mechanical polishing (CMP) apparatus, comprising:

a polishing head;

a carrier surface having a workpiece to be polished mounted thereon; and

a retaining ring circumferentially disposed about said workpiece, said retaining ring further comprising a plurality of protrusions formed on a bottom surface thereof, said protrusions disposed so as to be in contact with a polishing pad during a polishing operation on said workpiece;

wherein said plurality of protrusions are sized so as to activate abrasive particles of a fixed abrasive CMP pad.

8. (canceled)

9. The carrier assembly of claim 7, wherein said plurality of protrusions have a height of about 0.01 microns to about 200 microns.

10. (canceled)

11. (canceled)

12. The carrier assembly of claim 7, wherein said plurality of protrusions further comprise at least one or more of: spherical shapes, pyramidal shapes, conical shapes, and polygonal shapes.

13. A chemical mechanical polishing (CMP) apparatus, comprising:

a carrier assembly extending from a rotary chuck;

said carrier assembly including a polishing head, a carrier surface having a workpiece to be polished mounted thereon, and a retaining ring circumferentially disposed about said workpiece;

a platen having a CMP pad mounted thereon; and

said retaining ring further comprising a plurality of protrusions formed on a bottom surface thereof, said protrusions disposed so as to be in contact with said pad during a polishing operation on said workpiece;

wherein said plurality of protrusions are sized so as to activate abrasive particles of a fixed abrasive CMP pad.

14. (canceled)

15. The CMP apparatus of claim 13, wherein said plurality of protrusions have a height of about 0.01 microns to about 200 microns.

16. (canceled)

17. (canceled)

18. The CMP apparatus of claim 13, wherein said plurality of protrusions further comprise at least one or more of: spherical shapes, pyramidal shapes, conical shapes, and polygonal shapes.

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