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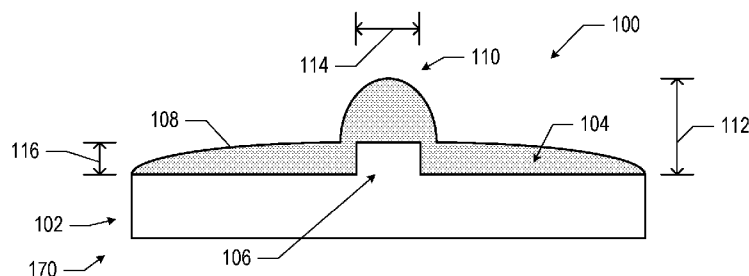
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(54) Title: CONDITIONING DISKS FOR CHEMICAL MECHANICAL POLISHING

**FIG. 1**

(57) Abstract: Disclosed herein are chemical mechanical polishing (CMP) conditioning disks, systems, and techniques. For example, in some embodiments, a CMP conditioning disk may include: a support having a surface; a projection secured to the support and extending away from the surface; and an abrasive material disposed on the surface and on the projection.

CONDITIONING DISKS FOR CHEMICAL MECHANICAL POLISHINGTechnical Field

[0001] The present disclosure relates generally to chemical mechanical polishing (CMP), and more particularly, to CMP conditioning disks.

Background

[0002] Chemical mechanical polishing (CMP) typically includes rotating and translating a polishing pad on a wafer to remove material from the wafer and achieve a flat wafer surface. For example, a wafer may be polished to remove an oxide layer prior to a lithography step. The polishing process may degrade the polishing surface of CMP polishing pads; to "refurbish" a CMP polishing pad and mitigate a degradation in polishing performance, the polishing surface may be abraded using a CMP conditioning disk.

Brief Description of the Drawings

[0003] Embodiments will be readily understood by the following detailed description in conjunction with the accompanying drawings. To facilitate this description, like reference numerals designate like structural elements. Embodiments are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

[0004] FIG. 1 is a side cross-sectional view of a portion of a chemical mechanical polishing (CMP) conditioning disk, in accordance with various embodiments.

[0005] FIG. 2 is a side view of a CMP system including the CMP conditioning disk of FIG. 1, in accordance with various embodiments.

[0006] FIG. 3 is a side cross-sectional view of a portion of a CMP polishing pad having a groove formed by a nodule of the CMP conditioning disk of FIG. 1, in accordance with various embodiments.

[0007] FIGS. 4-7 are side cross-sectional views of portions of examples of the CMP conditioning disk of FIG. 1, in accordance with various embodiments.

[0008] FIGS. 8-11 are top views of base structures that may be included in the CMP conditioning disk of FIG. 1, in accordance with various embodiments.

[0009] FIGS. 12-15 illustrate various example stages in the manufacture of the CMP conditioning disk of FIG. 1, in accordance with various embodiments.

[0010] FIG. 16 is a flow diagram of a method of manufacturing a CMP conditioning disk, in accordance with various embodiments.

[0011] FIG. 17 is a flow diagram of a method of using a CMP conditioning disk, in accordance with various embodiments.

[0012] FIGS. 18A and 18B are top views of a wafer and dies that may be processed using CMP systems and techniques in accordance with any of the embodiments disclosed herein.

[0013] FIG. 19 is a cross-sectional side view of an integrated circuit device that may be processed using CMP systems and techniques in accordance with any of the embodiments disclosed herein.

[0014] FIG. 20 is a cross-sectional side view of an IC device assembly that may have components that may be processed using CMP systems and techniques in accordance with any of the embodiments disclosed herein.

[0015] FIG. 21 is a block diagram of an example computing device that may have components that may be processed using CMP systems and techniques in accordance with any of the embodiments disclosed herein.

Detailed Description

[0016] Disclosed herein are chemical mechanical polishing (CMP) conditioning disks, systems, and techniques. For example, in some embodiments, a CMP conditioning disk may include: a support having a surface; a projection secured to the support and extending away from the surface; and an abrasive material disposed on the surface and on the projection. The projection and the abrasive material disposed on the projection may form a nodule.

[0017] Conventional CMP conditioning disks can only be used to recondition CMP polishing pads for a limited period of time before the conventional abrasive diamond field has been smoothed away and the CMP conditioning disk can no longer effectively condition a polishing pad. The short disk life of conventional CMP conditioning disks not only leads to the expense of purchasing new disks but also incurs costs due to tool downtime (e.g., during conditioning disk changes and during periods in which a new conditioning disk is not available). Attempts to improve the life of CMP conditioning disks have not been successful. For example, attempts to form an organized distribution of individual abrasive diamonds in a diamond-embedded substrate (e.g., by sintering) have results in wafer defects due to diamonds "lost" from the CMP conditioning disk.

[0018] Various ones of the CMP conditioning disks disclosed herein may have a significantly longer disk life than conventional CMP conditioning disks. The use of these disks may facilitate the CMP removal rate of wafer material for an extended period of time, while reducing process variability and maintaining low defect levels. Various ones of the embodiments disclosed herein may include one or more nodules that may range in size and number across the surface of a CMP conditioning disk. These nodules may generate, in a controlled manner, small grooves on the surface of the CMP conditioning pad. These grooves may serve as channels for slurry delivery to wafers under polish. Moreover, the inclusion of such nodules may dramatically increase the lifespan of the CMP conditioning disks disclosed herein relative to conventional CMP conditioning disks. These nodules may wear slower than the conventional abrasive diamond fields used in existing CMP conditioning disks, and thus increase the useful life of the CMP conditioning disks disclosed herein.

[0019] In the following detailed description, reference is made to the accompanying drawings that form a part hereof wherein like numerals designate like parts throughout, and in which is shown, by way of illustration, embodiments that may be practiced. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present disclosure. Therefore, the following detailed description is not to be taken in a limiting sense.

[0020] Various operations may be described as multiple discrete actions or operations in turn, in a manner that is most helpful in understanding the claimed subject matter. However, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations may not be performed in the order of presentation. Operations described may be performed in a different order from the described embodiment. Various additional operations may be performed, and/or described operations may be omitted in additional embodiments.

[0021] For the purposes of the present disclosure, the phrase "A and/or B" means (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B, and C). The term "between," when used with reference to measurement ranges, is inclusive of the ends of the measurement ranges.

[0022] The description uses the phrases "in an embodiment" or "in embodiments," which may each refer to one or more of the same or different embodiments. Furthermore, the terms "comprising," "including," "having," and the like, as used with respect to embodiments of the present disclosure, are synonymous. The disclosure may use perspective-based descriptions such as "above," "below," "top," "bottom," and "side"; such descriptions are used to facilitate the discussion and are not intended to restrict the application of disclosed embodiments. The accompanying drawings are not necessarily drawn to scale.

[0023] FIG. 1 is a side cross-sectional view of a portion of a chemical mechanical polishing (CMP) conditioning disk 100, in accordance with various embodiments. The CMP conditioning disk 100 may include a support 102 having a surface 104. The CMP conditioning disk 100 may further include a projection 106 secured to the support 102 and extending away from the surface 104. In some embodiments, the projection 106 and the support 102 may be integrally formed (e.g., by molding, as discussed below with reference to FIGS. 12-14, or by machining the projection 106 and the support 102 from a single block of material). In other embodiments, the projection 106 may be secured to the support 102 using an adhesive, a mechanical fastener, a friction fit, or any other suitable technique. The support 102 and the projection 106 may together form a base structure 170.

[0024] The projection 106 may have a height 116 measured relative to the surface 104 of the support 102. In some embodiments, the height 116 may be between 5 and 25 μm . In some embodiments, the height 116 may be between 10 and 20 μm . The projection 106 may have a footprint on the support 102, and that footprint may have a maximum dimension 114. For example, when the projection 106 has a circular footprint (e.g., as discussed below with reference to FIGS. 8 and 9), the maximum dimension 114 may be the diameter of the circular footprint. When the projection 106 has a square footprint (e.g., as discussed below with reference to FIG. 11), the maximum dimension 114 may be the distance between two opposing diagonal corners of the square. In some embodiments, the maximum dimension 114 of the footprint of the projection 106 may be between 10 and 300 μm . In some embodiments, the maximum dimension 114 of the footprint of the projection 106 may be between 50 and 150 μm . In some embodiments, the maximum dimension 114 of the footprint of the projection 106 may be between 20 and 100 μm . The shape of the footprint of the projection 106 may be any desired shape, such as circular (e.g., for a substantially cylindrical, conical, or semispherical projection 106), a polygon (e.g., a triangle, rectangle, or higher order polygon), or any other desired shape.

[0025] An abrasive material 108 may be disposed on the surface 104 and on the projection 106. The abrasive material 108 may be any abrasive material suitable for conditioning the surface of the CMP polishing pad (e.g., as discussed below with reference to FIG. 2). In some embodiments, the abrasive material 108 may include diamond, alumina, sapphire, carbon or silicon composites, industrial ceramics (e.g., silicon ceramics or silicon nitride ceramics), or tungsten carbide films, for example. In such embodiments, the diamond film may be formed by chemical vapor deposition (CVD).

[0026] The projection 106 and the abrasive material 108 disposed on the projection 106 may form a nodule 110. In some embodiments, when a CVD process is used to grow the abrasive material 108 on the base structure 170, the projection 106 may serve as a nucleation point for the formation of the abrasive material 108, resulting in particular growth of the abrasive material 108 around the projection 106 to form the nodule 110. As discussed below with reference to FIG. 2, when the CMP conditioning disk 100 is used to condition a CMP polishing pad, the nodule 110 may form a groove in the CMP polishing pad. The nodule 110 may have a height 112 measured relative to the surface 104 of the support 102. In some embodiments, the height of the nodule 110 may be between 10 and 100 μm . In some embodiments, the height of the nodule 110 may be between 20 and 100 μm . In some embodiments, the height of the nodule 110 may be between 20 and 50 μm .

[0027] The base structure 170 may be formed from any suitable material or materials, such as an industrial ceramic, stainless steel, or any metal or ceramic material compatible with the abrasive

material 108. In some embodiments, the base structure 170 may be formed of a material that may be used as a substrate for growing an abrasive material 108 using CVD. For example, when the abrasive material 108 is CVD-grown diamond, the base structure 170 may be formed of a suitable silicon or carbon composite. In some embodiments, a projection 106 may be formed of diamond, and the abrasive material 108 may be a diamond film grown on the projection 106 and the surface 104 by CVD.

[0028] Although a single projection 106 (and single corresponding nodule 110) is depicted in FIG. 1, a CMP conditioning disk 100 may include one or more projections 106/nodules 110. In some embodiments, the number of nodules 110 included in a CMP conditioning disk 100 may be correlated with the lifespan of the CMP conditioning disk 100 (characterized by, e.g., the number of hours of useful conditioning provided by the CMP conditioning disk 100). In particular, the more nodules 110 included in the CMP conditioning disk 100, the longer the life span of the CMP conditioning disk 100. In some embodiments, the number of nodules 110 included in a CMP conditioning disk 100 may be correlated with the PCR of the CMP conditioning disk 100. In particular, the more nodules 110 included in the CMP conditioning disk 100, the higher the PCR of the CMP conditioning disk 100. The relationship between the number of nodules 110 and the PCR of the CMP conditioning disk 100 may be approximately linear, in some implementations. Different ones of the projections 106/nodules 110 may have different heights, footprints, and shapes, and may be arranged in any desired arrangement on the support 102. In some embodiments, the height of the nodules 110 included in a CMP conditioning disk 100 may be correlated with the lifespan of the CMP conditioning disk 100. In particular, the taller the nodules 110 (e.g., in a height range between 10 and 100 microns), the longer the life span of the CMP conditioning disk 100. Examples of various configurations and arrangements of projections 106/nodules 110 are discussed below with reference to FIGS. 4-11.

[0029] FIG. 2 is a side view of a CMP system 150 including a CMP conditioning disk 100, in accordance with various embodiments. The CMP system 150 may include a CMP conditioning disk 100 disposed on a first arm 152. The CMP conditioning disk 100 of the CMP system 150 may take the form of any of the CMP conditioning disks disclosed herein. The CMP conditioning disk 100 may be secured to the first arm 152 using any suitable mechanism, such as vacuum, a clamp, a frame, or mechanical fasteners, for example. The first arm 152 may include mechanical linkages to allow the CMP conditioning disk 100 to translate "up and down" to bring the CMP conditioning disk 100 into contact with the CMP polishing pad 158 (discussed below). In some embodiments, the first arm 152 may include mechanical linkages to allow the CMP conditioning disk 100 to translate "side to side" while in contact with the CMP polishing pad 158. In some embodiments, the first arm 152 may

include a rotor to allow the CMP conditioning disk 100 to rotate while in contact with the CMP polishing pad 158. The first arm 152 may include, for example, a head, as known in the art. In various embodiments, the CMP system 150 may include control circuitry (not shown) to allow a user to control the rotation rate of the CMP conditioning disk 100, the downward force exerted by the CMP conditioning disk 100 on the CMP polishing pad 158, the "side to side" translation of the CMP conditioning disk 100, and/or other operational properties of the CMP system 150.

[0030] The CMP system 150 may include a CMP polishing pad 158 disposed on a second arm 154. The CMP polishing pad 158 may be formed from a porous material, such as a hard elastomer or a polyurethane-based material. The CMP polishing pad 158 may include other additives to achieve a desired porosity, as known in the art. Different CMP polishing pads 158 may have different mechanical properties, such as hardness (e.g., with "soft" pads having a hardness between 10 and 20 MPa, and "hard" pads having a hardness between 200 and 1500 MPa). The CMP polishing pad 158 may be secured to the second arm 154 using any suitable mechanism, such as vacuum, a clamp, a frame, or mechanical fasteners, for example. The second arm 154 may include mechanical linkages to allow the CMP polishing pad 158 to translate "up and down" to bring the CMP polishing pad 158 into contact with the CMP conditioning disk 100 and/or the wafer 160 (discussed below). In some embodiments, the second arm 154 may include mechanical linkages to allow the CMP polishing pad 158 to translate "side to side" while in contact with the CMP conditioning disk 100 and/or the wafer 160. In some embodiments, the second arm 154 may include a rotor to allow the CMP polishing pad 158 to rotate while in contact with the CMP conditioning disk 100 and/or the wafer 160. The second arm 154 may be, for example, a platen, as known in the art. In various embodiments, the CMP system 150 may include control circuitry (not shown) to allow a user to control the rotation rate of the CMP polishing pad 158, the "side to side" translation of the CMP polishing pad 158, and/or other operational properties of the CMP system 150, as noted above. The amount of conditioning performed by the CMP conditioning disk 100 on the CMP polishing pad 158 may be quantified by the pad cut rate (PCR), the amount of material removed from the CMP polishing pad 158 by the CMP conditioning disk 100 (normalized by time of conditioning).

[0031] The CMP system 150 may include a wafer 160 disposed on a third arm 156. The wafer 160 may have any suitable dimensions (e.g., 200, 300, or 450 mm in diameter). The wafer 160 may be secured to the third arm 156 using any suitable mechanism, such as vacuum, a clamp, a frame, or mechanical fasteners, for example. In some embodiments, the wafer 160 may be disposed in a retainer ring to control the "side to side" movement of the wafer 160, and vacuum force may be used to hold the wafer 160 against the third arm 156 to control the "up-and-down" movement of the wafer 160. The third arm 156 may include mechanical linkages to allow the wafer 160 to

translate "up-and-down" to bring the wafer 160 into contact with the CMP polishing pad 158. In some embodiments, the third arm 156 may include mechanical linkages to allow the wafer 160 to translate "side to side" while in contact with the CMP polishing pad 158. In some embodiments, the third arm 156 may include a rotor to allow the wafer 160 to rotate while in contact with the CMP polishing pad 158. In various embodiments, the CMP system 150 may include control circuitry (not shown) to allow a user to control the rotation rate of the wafer 160, the "side to side" translation of the wafer 160, the downward force exerted by the third arm 156 on the CMP conditioning pad 158, and/or other operational properties of the CMP system 150, as noted above.

[0032] When the CMP conditioning disk 100 is brought into contact with the CMP polishing pad 158, and the two are rotated (and/or translated) relative to one another, the nodule 110 of the CMP conditioning disk 100 may "dig" into the surface of the CMP polishing pad 158 and create a groove in the CMP polishing pad 158. FIG. 3 illustrates a groove 164 in the CMP polishing pad 158 created by movement of the nodule 110 of the CMP conditioning disk 100 along the surface of the CMP polishing pad 158. In some embodiments, during use, the nodules 110 of the CMP conditioning disks 100 disclosed herein may be the only active "cutting" contact points between the CMP conditioning disks 100 and the CMP polishing pads 158.

[0033] Returning to FIG. 2, when the wafer 160 is brought into contact with the CMP polishing pad 158, and the two are rotated (and/or translated) relative to one another, the CMP polishing pad 158 may remove material from the wafer 160 and thereby polish the wafer 160. A slurry 162 may be disposed on the CMP polishing pad 158. When the wafer 160 is brought into contact with the CMP polishing pad 158, and the two are rotated (and/or translated) relative to one another, the slurry 162 may flow between the CMP polishing pad 158 and the wafer 160 to facilitate the polishing of the wafer 160. In some embodiments, a retainer ring holding the wafer 160 on the third arm 156 may include grooves to allow the slurry 162 to flow to the wafer 160 and away from the wafer 160 during polishing. The slurry 162 may also flow through grooves in the CMP polishing pad 158 formed by the nodule 110 of the CMP conditioning disk 100 (e.g., the groove 164 of FIG. 3). The slurry 162 may take any suitable form known in the art (e.g., an oxide slurry). Control circuitry (not shown) included in the CMP system 150 may control the rate of flow of the slurry 162 from a slurry source (not shown), in some embodiments.

[0034] In some embodiments, the CMP conditioning disk 100 may be used to condition the CMP polishing pad 158 simultaneously with the CMP polishing pad 158 polishing the wafer 160. That is, the CMP conditioning disk 100 may be in contact with (and rotated relative to) the CMP polishing pad 158 at the same time that the wafer 160 may be in contact with (and rotated relative to) the CMP polishing pad 158. In other embodiments, the CMP polishing pad 158 may be conditioned by

the CMP conditioning disk 100 before and/or after (but not simultaneously with) polishing the wafer 160 using the CMP polishing pad 158.

[0035] A CMP conditioning disk 100 may include one or more projections 106, having any desired shape and arranged in any desired manner. For example, FIGS. 4-7 are side cross-sectional views of portions of examples of the CMP conditioning disk 100, in accordance with various embodiments. FIG. 4 illustrates a portion of a CMP conditioning disk 100 having multiple projections 106 all having the same shape. As discussed above with reference to FIG. 1, the projections 106 may be secured to a support 102 (forming a base structure 170), and may extend away from the surface 104 of the support 102. An abrasive material 108 may be disposed on the surface 104 and on the projections 106 (forming corresponding nodules 110). The projections 106 of FIG. 4 may take the form of any of the projections disclosed herein (e.g., shape, dimensions, relation to the support 102, etc.). In some embodiments, the projections 106 of the embodiment of FIG. 4 may be regularly spaced. Although three projections 106 are illustrated in FIG. 4, a CMP conditioning disk 100 may include two projections having the same shape, or more than three projections having the same shape, as desired. Additionally, although FIG. 4 illustrates a continuous mass of the abrasive material 108, in some embodiments, different portions of the abrasive material 108 may be disposed on different projections 106 and/or different areas of the surface 104.

[0036] FIG. 5 illustrates a portion of a CMP conditioning disk 100 having a projection 106 with a cross-section having a rounded profile. The profile illustrated in FIG. 5 (and any other cross-sectional views herein) is simply illustrative, and projections 106 may have any desired profile (e.g., rectangular, rounded, concave, convex, pyramidal, or any combination thereof). Additionally, in embodiments in which a CMP conditioning disk 100 includes multiple projections 106, different ones of the projections 106 may have different profiles. As discussed above with reference to FIG. 1, the projection 106 of FIG. 5 may be secured to a support 102 (forming a base structure 170), and may extend away from the surface 104 of the support 102. An abrasive material 108 may be disposed on the surface 104 and on the projection 106 (forming a corresponding nodule 110). The projection 106 of FIG. 5 may take the form of any of the projections disclosed herein (e.g., shape, dimensions, relation to the support 102, etc.).

[0037] FIG. 6 illustrates a portion of a CMP conditioning disk 100 having multiple projections 106 having different shapes. In particular, the projections 106-1 may have the same shape, the projections 106-2 may have the same shape (different from the shape of the projections 106-1), and the projection 106-3 may have a shape that is different from the shape of the projections 106-1 and 106-2. As discussed above with reference to FIG. 1, the projections 106 of FIG. 6 may be secured to a support 102 (forming a base structure 170), and may extend away from the surface 104 of the

support 102. An abrasive material 108 may be disposed on the surface 104 and on the projections 106 (forming corresponding nodules 110). The projections 106 of FIG. 6 may take the form of any of the projections disclosed herein (e.g., shape, dimensions, relation to the support 102, etc.).

Although five projections 106 are illustrated in FIG. 6, the CMP conditioning disk 100 may include fewer than or more than five projections having different combinations of shapes, as desired.

Additionally, although FIG. 6 illustrates a continuous mass of the abrasive material 108, in some embodiments, different portions of the abrasive material 108 may be disposed on different projections 106 and/or different areas of the surface 104.

[0038] FIG. 7 illustrates a portion of the CMP conditioning disk 100 in which the support 102 includes a substrate 166 and a pedestal 168 extending away from the substrate 166. The surface 104 is a surface of the pedestal 168, and the projection 106 is disposed on the pedestal 168. As discussed above with reference to FIG. 1, the projection 106 of FIG. 7 may be secured to the support 102 (forming a base structure 170), and may extend away from the surface 104. An abrasive material 108 may be disposed on the surface 104 and on the projection 106 (forming a corresponding nodule 110). As illustrated in FIG. 7, in some embodiments, the abrasive material 108 may not be disposed on the substrate 166, but may be confined to the pedestal 168. In some embodiments, the pedestal 168 may be integrally formed with the substrate 166, or the pedestal 168 may be otherwise secured to the substrate 166 (e.g., in accordance with any of the embodiments discussed above with reference to the relation between the projection 106 and the support 102). Although a single pedestal 168 is illustrated in FIG. 7, a CMP conditioning disk 100 may include any desired number of pedestals 168. Additionally, although a single projection 106 is shown disposed on the pedestal 168 in FIG. 7, multiple projections 106 may be disposed on a single pedestal 168. Various arrangements of pedestals 168 and projections 106 are discussed below with reference to FIGS. 9-11.

[0039] FIGS. 8-11 are top views of base structures 170 that may be included in a CMP conditioning disk 100 in accordance with various embodiments. These base structures 170 may include a support 102 having a surface 104, and one or more projections 106 secured to the support 102 and extending away from the surface 104. In a CMP conditioning disk 100, an abrasive material 108 may be disposed on the surface 104 and on the one or more projections 106 of the base structures 170 illustrated in FIGS. 8-11. As discussed above, a projection 106 and the abrasive material 108 disposed on the projection 106 may form a nodule 110.

[0040] FIG. 8 depicts an embodiment of a base structure 170 having a first set of projections 106-1, a second set of projections 106-2, and a third set of projections 106-3, all disposed in a regular arrangement. The base structure 170 of FIG. 8 has a circular footprint (corresponding to the

footprint of the CMP conditioning disk 100), and each set of projections 106 may be arranged at predetermined radial distances from a center 180 of the circular footprint of the base structure 170. For example, the projections 106-1 may be disposed at a distance 172-1 from the center 180, the projections 106-2 may be disposed at a distance 172-2 from the center 180, and the projections 106-3 may be disposed at a distance 172-3 from the center 180. Analogously, each set of projections 106 may be arranged at a predetermined radial distance from an edge 182 of the circular footprint of the base structure 170. For example, the projections 106-1 may be disposed at a distance 174-1 from the edge 182, the projections 106-2 may be disposed at a distance 174-2 from the edge 182, and the projections 106-3 may be disposed at a distance 174-3 from the edge 182. In FIG. 8, each set of projections 106 includes four projections 106, and the sets of projections 106 are arranged in a particular spacing; these are illustrative, and any number and spacing of the projections 106 may be used. Also, FIG. 8 depicts projections 106 having circular footprints with maximum dimensions 114. The projections 106 may have footprints of any desired shape and any maximum dimension 114, in accordance with the present disclosure.

[0041] FIG. 9 depicts an embodiment of a base structure 170 having multiple projections 106 disposed on pedestals 168 in a regular arrangement. Each of these pedestals 168 may have the shape of a vane or ridge, as shown, and may extend away from a substrate 166, as discussed above with reference to FIG. 7. In some embodiments, abrasive material 108 (not shown) may be disposed only on the pedestals 168 of the embodiment of FIG. 9, and not on the substrate 166. The base structure 170 of FIG. 9 has a circular footprint (corresponding to the footprint of the CMP conditioning disk 100) and each projection 106 may be disposed at a same distance 174 from an edge 182 of the circular footprint. In some embodiments, the distance 174 may be between 1 and 4 cm. In some embodiments, the distance 174 may be between 1 and 3 cm. In some embodiments, the distance 174 may be between 2 and 3 cm. For example, in one embodiment of the base structure 170 of FIG. 9, cylindrically shaped projections 106 may be disposed on each of eight pedestals 168 at a distance 174 of 2.54 cm, with heights 116 between 10 and 20 microns. Although a single projection 106 is shown as disposed on each of the pedestals 168 in the embodiment of FIG. 9, multiple projections 106 may be included in a single pedestal 168, and/or some pedestals 168 may not include any projections 106. In FIG. 9, eight pedestals 168 are illustrated, but this is simply illustrative, and any number of pedestals 168 may be used. Also, FIG. 9 depicts projections 106 having circular footprints with maximum dimensions 114. The projections 106 may have footprints of any desired shape, and any maximum dimension 114, in accordance with the present disclosure.

[0042] FIG. 10 depicts an embodiment of a base structure 170 having multiple projections 106 disposed on pedestals 168 in a regular arrangement. Each of the pedestals 168 may have a shape

similar to a trapezoid, as shown, and may extend away from a substrate 166, as discussed above with reference to FIG. 7. In some embodiments, abrasive material 108 (not shown) may be disposed only on the pedestals 168 of the embodiment of FIG. 10, and not on the substrate 166. The base structure 170 of FIG. 10 has a circular footprint (corresponding to the footprint of the CMP conditioning disk 100). Two projections 106 are shown as disposed on each pedestal 168 in the embodiment of FIG. 10; in other embodiments, fewer or more projections 106 may be disposed on each pedestal 168, and fewer or more pedestals 168 may be included. FIG. 10 depicts projections 106 having triangular footprints with a maximum dimension 114. The projections 106 may have footprints of any desired shape, and any maximum dimension 114, in accordance with the present disclosure.

[0043] FIG. 11 depicts an embodiment of a base structure 170 having multiple projections 106 disposed on pedestals 168 in a regular arrangement. Each of the pedestals 168 may have a circular footprint, as shown, and may extend away from the substrate 166, as discussed above with reference to FIG. 7. In some embodiments, abrasive material 108 (not shown) may be disposed only on the pedestals 168 of the embodiment of FIG. 11, and not on the substrate 166. The base structure 170 of FIG. 11 has a circular footprint (corresponding to the footprint of the CMP conditioning disk 100). One projection 106 is shown as disposed on each pedestal 168 in the embodiment of FIG. 11; in other embodiments, fewer or more projections 106 may be disposed on each pedestal 168, and fewer or more pedestals 168 may be included. FIG. 11 depicts projections 106 having square footprints with a maximum dimension 114. The projections 106 may have footprint of any desired shape, and any maximum dimension 114, in accordance with the present disclosure.

[0044] The CMP conditioning disks 100 disclosed herein may be manufactured using any suitable techniques. As noted above, in some embodiments, the projection 106 and the support 102 may be formed separately and secured together to provide the base structure 170. In other embodiments, the projection 106 and the support 102 may be integrally formed. For example, the projection 106 and the support 102 may be integrally formed by three-dimensional printing, and/or by laser engraving or otherwise machining an existing block of material. In some embodiments, the projection 106 of the support 102 may be integrally formed by molding.

[0045] FIGS. 12-15 illustrate various example stages in a molding-based manufacturing process for the CMP conditioning disk 100, in accordance with various embodiments. FIG. 12 depicts a mold 1200 having an inlet 1202 and the cavity 1204. The cavity 1204 may be shaped so that the base structure 170 (including the projection 106 and the support 102) may be formed simultaneously.

[0046] FIG. 13 depicts an assembly 1300 subsequent to providing a fluid mold compound 1302 to the cavity 1204 of the mold 1200 via the inlet 1202.

[0047] FIG. 14 depicts an assembly 1400 subsequent to curing the fluid mold compound 1302 in the mold 1200 of the assembly 1300 (FIG. 13) to form a structure 1402 in the mold 1200. The structure 1402 may have a form that is substantially similar to the base structure 170, but may include molding artifacts, such as a tail 1404 arising from cured mold compound in the inlet 1202 of the mold 1200.

[0048] FIG. 15 depicts a CMP conditioning disk 100 subsequent to removing the structure 1402 from the mold 1200 (FIG. 14), removing the tail 1404, and providing an abrasive material 108 to the base structure 170 (in particular, to a surface 104 of the support 102 and to the projection 106). In some embodiments, the abrasive material 108 may be provided by CVD. For example, the abrasive material 108 may be a CVD-deposited diamond film.

[0049] FIG. 16 is a flow diagram of a method 1600 of manufacturing a CMP conditioning disk, in accordance with various embodiments. Although various operations are arranged in particular order and illustrated once each, various ones of the operations may be repeated or performed in any suitable order.

[0050] At 1602, a base structure may be formed. The base structure may include a support and a projection, and the projection may be secured to the support. For example, the base structure 170 may include a support 102 and a projection 106, with the projection 106 secured to the support 102. In some embodiments, a base structure may be formed at 1602 in accordance with any of the techniques disclosed herein (e.g., molding, three-dimensional printing, machining, etc.). The base structure formed at 1602 may take any suitable form, such as any of the forms disclosed herein.

[0051] At 1604, an abrasive material may be provided on the projection and the support of the base structure formed at 1602. For example, an abrasive material 108 may be provided on the support 102 and the projection 106 of the base structure 170. In some embodiments, an abrasive material may be provided at 1604 in accordance with any of the techniques disclosed herein (e.g., CVD). The abrasive material provided at 1604 may take any suitable form, such as any of the forms disclosed herein.

[0052] FIG. 17 is a flow diagram of a method 1700 of using a CMP conditioning disk, in accordance with various embodiments. Although various operations are arranged in particular order and illustrated once each, various ones of the operations may be repeated or performed in any suitable order.

[0053] At 1702, a CMP conditioning disk may be brought into contact with a CMP polishing pad. The CMP conditioning disk may include a support having a surface, a projection secured to the

support and extending away from the surface, and an abrasive material disposed on the surface and on the projection. The projection and the abrasive material disposed on the projection may form a nodule. For example, the CMP conditioning disk 100 may be brought into contact with the CMP polishing pad 158 of the CMP system 150 (FIG. 2). The CMP conditioning disk 100 may include a support 102 having a surface 104, a projection 106 secured to the support 102 and extending away from the surface 104, and the abrasive material 108 disposed on the surface 104 and on the projection 106. The projection 106 and the abrasive material 108 disposed on the projection 106 may form a nodule 110. The CMP conditioning disk of 1702 may take any suitable form, such as any of the forms disclosed herein.

[0054] At 1704, the CMP conditioning disk and the CMP polishing pad may be rotated and translated relative to one another to cause the formation of a groove, by the nodule, in the CMP polishing pad. For example, the CMP conditioning disk 100 and the CMP polishing pad 158 of the CMP system 150 may be rotated and translated relative to one another (e.g., using the first arm 152 and the second arm 154) to cause the formation of a groove 164 (FIG. 3), by the nodule 110, in the CMP polishing pad 158.

[0055] Devices processed using the CMP systems and techniques disclosed herein (e.g., polished by CMP polishing pads conditioned by the CMP conditioning disks disclosed herein) may be included in any suitable electronic device. FIGS. 18-21 illustrate various examples of apparatuses that may include devices processed using the CMP systems and techniques disclosed herein.

[0056] FIGS. 18A-B are top views of a wafer 1800 and dies 1802 that may be processed using CMP systems and techniques in accordance with any of the embodiments disclosed herein. In particular, the wafer 1800 may be the wafer 160 polished in the CMP system 150 of FIG. 2. The wafer 1800 may be composed of semiconductor material and may include one or more dies 1802 having IC structures formed on a surface of the wafer 1800. Each of the dies 1802 may be a repeating unit of a semiconductor product that includes any suitable IC. After the fabrication of the semiconductor product is complete (e.g., after the semiconductor product is polished in accordance with any of the techniques disclosed herein), the wafer 1800 may undergo a singulation process in which each of the dies 1802 is separated from one another to provide discrete "chips" of the semiconductor product. In particular, devices processed using the CMP systems and techniques disclosed herein may take the form of the wafer 1800 (e.g., not singulated) or the form of the die 1802 (e.g., singulated). The die 1802 may include one or more transistors (e.g., some of the transistor(s) 1940 of FIG. 19, discussed below) and/or supporting circuitry to route electrical signals to the transistors, as well as any other IC components. In some embodiments, the wafer 1800 or the die 1802 may include a memory device (e.g., a static random access memory (SRAM) device), a logic device (e.g., an AND,

OR, NAND, or NOR gate), or any other suitable circuit element. Multiple ones of these devices may be combined on a single die 1802. For example, a memory array formed by multiple memory devices may be formed on a same die 1802 as a processing device (e.g., the processing device 2102 of FIG. 21) or other logic that is configured to store information in the memory devices or execute instructions stored in the memory array.

[0057] FIG. 19 is a cross-sectional side view of an IC device 1900 that may be processed using CMP systems and techniques in accordance with any of the embodiments disclosed herein. The IC device 1900 may be formed on a substrate 1902 (e.g., the wafer 1800 of FIG. 18A) and may be included in a die (e.g., the die 1802 of FIG. 18B). The substrate 1902 may be a semiconductor substrate composed of semiconductor material systems including, for example, N-type or P-type materials systems. The substrate 1902 may include, for example, a crystalline substrate formed using a bulk silicon or a silicon-on-insulator substructure. In some embodiments, the semiconductor substrate 1902 may be formed using alternative materials, which may or may not be combined with silicon, that include but are not limited to germanium, indium antimonide, lead telluride, indium arsenide, indium phosphide, gallium arsenide, or gallium antimonide. Further materials classified as group II-VI, III-V, or IV may also be used to form the substrate 1902. Although a few examples of materials from which the substrate 1902 may be formed are described here, any material that may serve as a foundation for an IC device 1900 may be used. The substrate 1902 may be part of a singulated die (e.g., the dies 1802 of FIG. 18B) or a wafer (e.g., the wafer 1800 of FIG. 18A).

[0058] The IC device 1900 may include one or more device layers 1904 disposed on the substrate 1902. The device layer 1904 may include features of one or more transistors 1940 (e.g., metal oxide semiconductor field-effect transistors (MOSFETs)) formed on the substrate 1902. The device layer 1904 may include, for example, one or more source and/or drain (S/D) regions 1920, a gate 1922 to control current flow in the transistors 1940 between the S/D regions 1920, and one or more S/D contacts 1924 to route electrical signals to/from the S/D regions 1920. The transistors 1940 may include additional features not depicted for the sake of clarity, such as device isolation regions, gate contacts, and the like. The transistors 1940 are not limited to the type and configuration depicted in FIG. 19 and may include a wide variety of other types and configurations such as, for example, planar transistors, non-planar transistors, or a combination of both. Non-planar transistors may include FinFET transistors, such as double-gate transistors or tri-gate transistors, and wrap-around or all-around gate transistors, such as nanoribbon and nanowire transistors.

[0059] Each transistor 1940 may include a gate 1922 formed of at least two layers, a gate dielectric layer and a gate electrode layer. The gate dielectric layer may include one layer or a stack of layers. The one or more layers may include silicon oxide, silicon dioxide, and/or a high-k dielectric material.

The high-k dielectric material may include elements such as hafnium, silicon, oxygen, titanium, tantalum, lanthanum, aluminum, zirconium, barium, strontium, yttrium, lead, scandium, niobium, and zinc. Examples of high-k materials that may be used in the gate dielectric layer include, but are not limited to, hafnium oxide, hafnium silicon oxide, lanthanum oxide, lanthanum aluminum oxide, zirconium oxide, zirconium silicon oxide, tantalum oxide, titanium oxide, barium strontium titanium oxide, barium titanium oxide, strontium titanium oxide, yttrium oxide, aluminum oxide, lead scandium tantalum oxide, and lead zinc niobate. In some embodiments, an annealing process may be carried out on the gate dielectric layer to improve its quality when a high-k material is used.

[0060] The gate electrode layer may be formed on the gate dielectric layer and may include at least one P-type work function metal or N-type work function metal, depending on whether the transistor 1940 is to be a PMOS or an NMOS transistor. In some implementations, the gate electrode layer may consist of a stack of two or more metal layers, where one or more metal layers are work function metal layers and at least one metal layer is a fill metal layer. Further metal layers may be included for other purposes, such as a barrier layer. For a PMOS transistor, metals that may be used for the gate electrode include, but are not limited to, ruthenium, palladium, platinum, cobalt, nickel, and conductive metal oxides (e.g., ruthenium oxide). For an NMOS transistor, metals that may be used for the gate electrode include, but are not limited to, hafnium, zirconium, titanium, tantalum, aluminum, alloys of these metals, and carbides of these metals (e.g., hafnium carbide, zirconium carbide, titanium carbide, tantalum carbide, and aluminum carbide).

[0061] In some embodiments, when viewed as a cross-section of the transistor 1940 along the source-channel-drain direction, the gate electrode may consist of a U-shaped structure that includes a bottom portion substantially parallel to the surface of the substrate and two sidewall portions that are substantially perpendicular to the top surface of the substrate. In other embodiments, at least one of the metal layers that form the gate electrode may simply be a planar layer that is substantially parallel to the top surface of the substrate and does not include sidewall portions substantially perpendicular to the top surface of the substrate. In other embodiments, the gate electrode may consist of a combination of U-shaped structures and planar, non-U-shaped structures. For example, the gate electrode may consist of one or more U-shaped metal layers formed atop one or more planar, non-U-shaped layers.

[0062] In some embodiments, a pair of sidewall spacers may be formed on opposing sides of the gate stack to bracket the gate stack. The sidewall spacers may be formed from a material such as silicon nitride, silicon oxide, silicon carbide, silicon nitride doped with carbon, and silicon oxynitride. Processes for forming sidewall spacers are well known in the art and generally include deposition and etching process steps. In some embodiments, a plurality of spacer pairs may be used; for

instance, two pairs, three pairs, or four pairs of sidewall spacers may be formed on opposing sides of the gate stack.

[0063] The S/D regions 1920 may be formed within the substrate 1902 adjacent to the gate 1922 of each transistor 1940. The S/D regions 1920 may be formed using either an implantation/diffusion process or an etching/deposition process, for example. In the former process, dopants such as boron, aluminum, antimony, phosphorous, or arsenic may be ion-implanted into the substrate 1902 to form the S/D regions 1920. An annealing process that activates the dopants and causes them to diffuse farther into the substrate 1902 may follow the ion implantation process. In the latter process, the substrate 1902 may first be etched to form recesses at the locations of the S/D regions 1920. An epitaxial deposition process may then be carried out to fill the recesses with material that is used to fabricate the S/D regions 1920. In some implementations, the S/D regions 1920 may be fabricated using a silicon alloy such as silicon germanium or silicon carbide. In some embodiments, the epitaxially deposited silicon alloy may be doped in situ with dopants such as boron, arsenic, or phosphorous. In some embodiments, the S/D regions 1920 may be formed using one or more alternate semiconductor materials such as germanium or a group III-V material or alloy. In further embodiments, one or more layers of metal and/or metal alloys may be used to form the S/D regions 1920.

[0064] Electrical signals, such as power and/or input/output (I/O) signals, may be routed to and/or from the transistors 1940 of the device layer 1904 through one or more interconnect layers disposed on the device layer 1904 (illustrated in FIG. 19 as interconnect layers 1906-1910). For example, electrically conductive features of the device layer 1904 (e.g., the gate 1922 and the S/D contacts 1924) may be electrically coupled with the interconnect structures 1928 of the interconnect layers 1906-1910. The one or more interconnect layers 1906-1910 may form an interlayer dielectric (ILD) stack 1919 of the IC device 1900.

[0065] The interconnect structures 1928 may be arranged within the interconnect layers 1906-1910 to route electrical signals according to a wide variety of designs (in particular, the arrangement is not limited to the particular configuration of interconnect structures 1928 depicted in FIG. 19). Although a particular number of interconnect layers 1906-1910 is depicted in FIG. 19, embodiments of the present disclosure include IC devices having more or fewer interconnect layers than depicted.

[0066] In some embodiments, the interconnect structures 1928 may include trench structures 1928a (sometimes referred to as "lines") and/or via structures 1928b (sometimes referred to as "holes") filled with an electrically conductive material such as a metal. The trench structures 1928a may be arranged to route electrical signals in a direction of a plane that is substantially parallel with a surface of the substrate 1902 upon which the device layer 1904 is formed. For example, the

trench structures 1928a may route electrical signals in a direction in and out of the page from the perspective of FIG. 19. The via structures 1928b may be arranged to route electrical signals in a direction of a plane that is substantially perpendicular to the surface of the substrate 1902 upon which the device layer 1904 is formed. In some embodiments, the via structures 1928b may electrically couple trench structures 1928a of different interconnect layers 1906-1910 together.

[0067] The interconnect layers 1906-1910 may include a dielectric material 1926 disposed between the interconnect structures 1928, as shown in FIG. 19. In some embodiments, the dielectric material 1926 disposed between the interconnect structures 1928 in different ones of the interconnect layers 1906-1910 may have different compositions; in other embodiments, the composition of the dielectric material 1926 between different interconnect layers 1906-1910 may be the same.

[0068] A first interconnect layer 1906 (referred to as Metal 1 or "M1") may be formed directly on the device layer 1904. In some embodiments, the first interconnect layer 1906 may include trench structures 1928a and/or via structures 1928b, as shown. The trench structures 1928a of the first interconnect layer 1906 may be coupled with contacts (e.g., the S/D contacts 1924) of the device layer 1904.

[0069] A second interconnect layer 1908 (referred to as Metal 2 or "M2") may be formed directly on the first interconnect layer 1906. In some embodiments, the second interconnect layer 1908 may include via structures 1928b to couple the trench structures 1928a of the second interconnect layer 1908 with the trench structures 1928a of the first interconnect layer 1906. Although the trench structures 1928a and the via structures 1928b are structurally delineated with a line within each interconnect layer (e.g., within the second interconnect layer 1908) for the sake of clarity, the trench structures 1928a and the via structures 1928b may be structurally and/or materially contiguous (e.g., simultaneously filled during a dual-damascene process) in some embodiments.

[0070] A third interconnect layer 1910 (referred to as Metal 3 or "M3") (and additional interconnect layers, as desired) may be formed in succession on the second interconnect layer 1908 according to similar techniques and configurations described in connection with the second interconnect layer 1908 or the first interconnect layer 1906.

[0071] The IC device 1900 may include a solder resist material 1934 (e.g., polyimide or similar material) and one or more bond pads 1936 formed on the interconnect layers 1906-1910. The bond pads 1936 may be electrically coupled with the interconnect structures 1928 and configured to route the electrical signals of the transistor(s) 1940 to other external devices. For example, solder bonds may be formed on the one or more bond pads 1936 to mechanically and/or electrically couple a chip including the IC device 1900 with another component (e.g., a circuit board). The IC device 1900 may have other alternative configurations to route the electrical signals from the interconnect layers

1906-1910 than depicted in other embodiments. For example, the bond pads 1936 may be replaced by or may further include other analogous features (e.g., posts) that route the electrical signals to external components.

[0072] FIG. 20 is a cross-sectional side view of an IC device assembly 2000 that may include components processed using any of the CMP systems and techniques disclosed herein. The IC device assembly 2000 includes a number of components disposed on a circuit board 2002 (which may be, e.g., a motherboard). The IC device assembly 2000 includes components disposed on a first face 2040 of the circuit board 2002 and an opposing second face 2042 of the circuit board 2002; generally, components may be disposed on one or both faces 2040 and 2042.

[0073] In some embodiments, the circuit board 2002 may be a printed circuit board (PCB) including multiple metal layers separated from one another by layers of dielectric material and interconnected by electrically conductive vias. Any one or more of the metal layers may be formed in a desired circuit pattern to route electrical signals (optionally in conjunction with other metal layers) between the components coupled to the circuit board 2002. In other embodiments, the circuit board 2002 may be a non-PCB substrate.

[0074] The IC device assembly 2000 illustrated in FIG. 20 includes a package-on-interposer structure 2036 coupled to the first face 2040 of the circuit board 2002 by coupling components 2016. The coupling components 2016 may electrically and mechanically couple the package-on-interposer structure 2036 to the circuit board 2002, and may include solder balls (as shown in FIG. 20), male and female portions of a socket, an adhesive, an underfill material, and/or any other suitable electrical and/or mechanical coupling structure.

[0075] The package-on-interposer structure 2036 may include an IC package 2020 coupled to an interposer 2004 by coupling components 2018. The coupling components 2018 may take any suitable form for the application, such as the forms discussed above with reference to the coupling components 2016. Although a single IC package 2020 is shown in FIG. 20, multiple IC packages may be coupled to the interposer 2004; indeed, additional interposers may be coupled to the interposer 2004. The interposer 2004 may provide an intervening substrate used to bridge the circuit board 2002 and the IC package 2020. The IC package 2020 may be or include, for example, a die (the die 1802 of FIG. 18B), an IC device (e.g., the IC device 1900 of FIG. 19), or any other suitable component. Generally, the interposer 2004 may spread a connection to a wider pitch or reroute a connection to a different connection. For example, the interposer 2004 may couple the IC package 2020 (e.g., a die) to a ball grid array (BGA) of the coupling components 2016 for coupling to the circuit board 2002. In the embodiment illustrated in FIG. 20, the IC package 2020 and the circuit board 2002 are attached to opposing sides of the interposer 2004; in other embodiments, the IC

package 2020 and the circuit board 2002 may be attached to a same side of the interposer 2004. In some embodiments, three or more components may be interconnected by way of the interposer 2004.

[0076] The interposer 2004 may be formed of an epoxy resin, a fiberglass-reinforced epoxy resin, a ceramic material, or a polymer material such as polyimide. In some implementations, the interposer 2004 may be formed of alternate rigid or flexible materials that may include the same materials described above for use in a semiconductor substrate, such as silicon, germanium, and other group III-V and group IV materials. The interposer 2004 may include metal interconnects 2008 and vias 2010, including but not limited to through-silicon vias (TSVs) 2006. The interposer 2004 may further include embedded devices 2014, including both passive and active devices. Such devices may include, but are not limited to, capacitors, decoupling capacitors, resistors, inductors, fuses, diodes, transformers, sensors, electrostatic discharge (ESD) devices, and memory devices. More complex devices such as radio-frequency (RF) devices, power amplifiers, power management devices, antennas, arrays, sensors, and microelectromechanical systems (MEMS) devices may also be formed on the interposer 2004. The package-on-interposer structure 2036 may take the form of any of the package-on-interposer structures known in the art.

[0077] The IC device assembly 2000 may include an IC package 2024 coupled to the first face 2040 of the circuit board 2002 by coupling components 2022. The coupling components 2022 may take the form of any of the embodiments discussed above with reference to the coupling components 2016, and the IC package 2024 may take the form of any of the embodiments discussed above with reference to the IC package 2020.

[0078] The IC device assembly 2000 illustrated in FIG. 20 includes a package-on-package structure 2034 coupled to the second face 2042 of the circuit board 2002 by coupling components 2028. The package-on-package structure 2034 may include an IC package 2026 and an IC package 2032 coupled together by coupling components 2030 such that the IC package 2026 is disposed between the circuit board 2002 and the IC package 2032. The coupling components 2028 and 2030 may take the form of any of the embodiments of the coupling components 2016 discussed above, and the IC packages 2026 and 2032 may take the form of any of the embodiments of the IC package 2020 discussed above. The package-on-package structure 2034 may be configured in accordance with any of the package-on-package structures known in the art.

[0079] FIG. 21 is a block diagram of an example computing device 2100 that may include one or more components processed using the CMP systems and techniques disclosed herein. For example, any suitable ones of the components of the computing device 2100 may include a die (e.g., the die 1802 (FIG. 18B)) processed using the CMP systems and techniques disclosed herein. A number of

components are illustrated in FIG. 21 as included in the computing device 2100, but any one or more of these components may be omitted or duplicated, as suitable for the application. In some embodiments, some or all of the components included in the computing device 2100 may be attached to one or more motherboards. In some embodiments, some or all of these components are fabricated onto a single system-on-a-chip (SoC) die.

[0080] Additionally, in various embodiments, the computing device 2100 may not include one or more of the components illustrated in FIG. 21, but the computing device 2100 may include interface circuitry for coupling to the one or more components. For example, the computing device 2100 may not include a display device 2106, but may include display device interface circuitry (e.g., a connector and driver circuitry) to which a display device 2106 may be coupled. In another set of examples, the computing device 2100 may not include an audio input device 2124 or an audio output device 2108, but may include audio input or output device interface circuitry (e.g., connectors and supporting circuitry) to which an audio input device 2124 or audio output device 2108 may be coupled.

[0081] The computing device 2100 may include a processing device 2102 (e.g., one or more processing devices). As used herein, the term "processing device" or "processor" may refer to any device or portion of a device that processes electronic data from registers and/or memory to transform that electronic data into other electronic data that may be stored in registers and/or memory. The processing device 2102 may include one or more digital signal processors (DSPs), application-specific integrated circuits (ASICs), central processing units (CPUs), graphics processing units (GPUs), cryptoprocessors (specialized processors that execute cryptographic algorithms within hardware), server processors, or any other suitable processing devices. The computing device 2100 may include a memory 2104, which may itself include one or more memory devices such as volatile memory (e.g., dynamic random access memory (DRAM)), nonvolatile memory (e.g., read-only memory (ROM)), flash memory, solid state memory, and/or a hard drive. In some embodiments, the memory 2104 may include memory that shares a die with the processing device 2102. This memory may be used as cache memory and may include embedded dynamic random access memory (eDRAM) or spin transfer torque magnetic random-access memory (STT-MRAM).

[0082] In some embodiments, the computing device 2100 may include a communication chip 2112 (e.g., one or more communication chips). For example, the communication chip 2112 may be configured for managing wireless communications for the transfer of data to and from the computing device 2100. The term "wireless" and its derivatives may be used to describe circuits, devices, systems, methods, techniques, communications channels, etc., that may communicate data through the use of modulated electromagnetic radiation through a nonsolid medium. The term

does not imply that the associated devices do not contain any wires, although in some embodiments they might not.

[0083] The communication chip 2112 may implement any of a number of wireless standards or protocols, including but not limited to Institute for Electrical and Electronic Engineers (IEEE) standards including Wi-Fi (IEEE 802.11 family), IEEE 802.16 standards (e.g., IEEE 802.16-2005 Amendment), Long-Term Evolution (LTE) project along with any amendments, updates, and/or revisions (e.g., advanced LTE project, ultra mobile broadband (UMB) project (also referred to as "3GPP2"), etc.). IEEE 802.16 compatible Broadband Wireless Access (BWA) networks are generally referred to as WiMAX networks, an acronym that stands for Worldwide Interoperability for Microwave Access, which is a certification mark for products that pass conformity and interoperability tests for the IEEE 802.16 standards. The communication chip 2112 may operate in accordance with a Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS), High Speed Packet Access (HSPA), Evolved HSPA (E-HSPA), or LTE network. The communication chip 2112 may operate in accordance with Enhanced Data for GSM Evolution (EDGE), GSM EDGE Radio Access Network (GERAN), Universal Terrestrial Radio Access Network (UTRAN), or Evolved UTRAN (E-UTRAN). The communication chip 2112 may operate in accordance with Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Digital Enhanced Cordless Telecommunications (DECT), Evolution-Data Optimized (EV-DO), and derivatives thereof, as well as any other wireless protocols that are designated as 3G, 4G, 5G, and beyond. The communication chip 2112 may operate in accordance with other wireless protocols in other embodiments. The computing device 2100 may include an antenna 2122 to facilitate wireless communications and/or to receive other wireless communications (such as AM or FM radio transmissions).

[0084] In some embodiments, the communication chip 2112 may manage wired communications, such as electrical, optical, or any other suitable communication protocols (e.g., the Ethernet). As noted above, the communication chip 2112 may include multiple communication chips. For instance, a first communication chip 2112 may be dedicated to shorter-range wireless communications such as Wi-Fi or Bluetooth, and a second communication chip 2112 may be dedicated to longer-range wireless communications such as GPS, EDGE, GPRS, CDMA, WiMAX, LTE, EV-DO, or others. In some embodiments, a first communication chip 2112 may be dedicated to wireless communications, and a second communication chip 2112 may be dedicated to wired communications.

[0085] The computing device 2100 may include battery/power circuitry 2114. The battery/power circuitry 2114 may include one or more energy storage devices (e.g., batteries or capacitors) and/or

circuitry for coupling components of the computing device 2100 to an energy source separate from the computing device 2100 (e.g., AC line power).

[0086] The computing device 2100 may include a display device 2106 (or corresponding interface circuitry, as discussed above). The display device 2106 may include any visual indicators, such as a heads-up display, a computer monitor, a projector, a touchscreen display, a liquid crystal display (LCD), a light-emitting diode display, or a flat panel display, for example.

[0087] The computing device 2100 may include an audio output device 2108 (or corresponding interface circuitry, as discussed above). The audio output device 2108 may include any device that generates an audible indicator, such as speakers, headsets, or earbuds, for example.

[0088] The computing device 2100 may include an audio input device 2124 (or corresponding interface circuitry, as discussed above). The audio input device 2124 may include any device that generates a signal representative of a sound, such as microphones, microphone arrays, or digital instruments (e.g., instruments having a musical instrument digital interface (MIDI) output).

[0089] The computing device 2100 may include a global positioning system (GPS) device 2118 (or corresponding interface circuitry, as discussed above). The GPS device 2118 may be in communication with a satellite-based system and may receive a location of the computing device 2100, as known in the art.

[0090] The computing device 2100 may include an other output device 2110 (or corresponding interface circuitry, as discussed above). Examples of the other output device 2110 may include an audio codec, a video codec, a printer, a wired or wireless transmitter for providing information to other devices, or an additional storage device.

[0091] The computing device 2100 may include an other input device 2120 (or corresponding interface circuitry, as discussed above). Examples of the other input device 2120 may include an accelerometer, a gyroscope, a compass, an image capture device, a keyboard, a cursor control device such as a mouse, a stylus, a touchpad, a bar code reader, a Quick Response (QR) code reader, any sensor, or a radio frequency identification (RFID) reader.

[0092] The computing device 2100 may have any desired form factor, such as a hand-held or mobile computing device (e.g., a cell phone, a smart phone, a mobile internet device, a music player, a tablet computer, a laptop computer, a netbook computer, an ultrabook computer, a personal digital assistant (PDA), an ultra-mobile personal computer, etc.), a desktop computing device, a server or other networked computing component, a printer, a scanner, a monitor, a set-top box, an entertainment control unit, a vehicle control unit, a digital camera, a digital video recorder, or a wearable computing device. In some embodiments, the computing device 2100 may be any other electronic device that processes data.

[0093] The following paragraphs provide various examples of the embodiments disclosed herein.

[0094] Example 1 is a chemical mechanical polishing (CMP) conditioning disk, including: a support having a surface; a projection secured to the support and extending away from the surface; and an abrasive material disposed on the surface and on the projection.

[0095] Example 2 may include the subject matter of Example 1, and may further specify that the support comprises a substrate and a pedestal extending away from the substrate, and wherein the surface is a surface of the pedestal.

[0096] Example 3 may include the subject matter of any of Examples 1-2, and may further specify that the projection and the support are integrally formed.

[0097] Example 4 may include the subject matter of any of Examples 1-2, and may further specify that the projection is secured to the support by an adhesive disposed between the projection and the support.

[0098] Example 5 may include the subject matter of any of Examples 1-4, and may further specify that the projection and the abrasive material disposed on the projection form a nodule, the nodule has a height measured from the surface, and the height of the nodule is between 10 and 100 microns.

[0099] Example 6 may include the subject matter of Example 5, and may further specify that the height of the nodule is between 20 and 100 microns.

[0100] Example 7 may include the subject matter of any of Examples 1-6, and may further specify that the projection has a footprint with a maximum dimension, and the maximum dimension is between 10 and 300 microns.

[0101] Example 8 may include the subject matter of Example 7, and may further specify that the maximum dimension is between 50 and 150 microns.

[0102] Example 9 may include the subject matter of any of Examples 1-8, and may further specify that the abrasive material includes a diamond film.

[0103] Example 10 may include the subject matter of any of Examples 1-9, and may further specify that the projection has a height measured from the surface, and the height is between 5 and 25 microns.

[0104] Example 11 may include the subject matter of any of Examples 1-10, and may further specify that: the projection is a first projection; the CMP conditioning disk further includes a second projection secured to the support and extending away from the surface; and the abrasive material is disposed on the second projection.

[0105] Example 12 may include the subject matter of Example 11, and may further specify that the first and second projections have the same shape.

[0106] Example 13 may include the subject matter of any of Examples 11-12, and may further specify that the support includes a substrate and first and second pedestals, the first projection is secured to the first pedestal, and the second projection is secured to the second pedestal.

[0107] Example 14 may include the subject matter of any of Examples 1-13, and may further specify that the projection is one of a plurality of projections secured to the support and extending away from the surface, and the plurality of projections are disposed in a regular arrangement.

[0108] Example 15 may include the subject matter of Example 14, and may further specify that the CMP conditioning disk is circular, and the plurality of projections are spaced at equal radial distances from a center of the CMP conditioning disk.

[0109] Example 16 may include the subject matter of any of Examples 14-15, and may further specify that the support includes a substrate and a plurality of pedestals, and each of the plurality of projections is disposed on a different one of the plurality of pedestals.

[0110] Example 17 may include the subject matter of any of Examples 1-16, and may further specify that the projection has a cylindrical shape.

[0111] Example 18 is a chemical mechanical polishing (CMP) system, including: a CMP conditioning disk disposed on a first arm, wherein the CMP conditioning disk includes a support having a surface, a projection secured to the support and extending away from the surface, and an abrasive material disposed on the surface and on the projection; and a CMP polishing pad disposed on a second arm; wherein the first and second arms allow the CMP conditioning disk to come into contact with, and rotate relative to, the CMP polishing pad.

[0112] Example 19 may include the subject matter of Example 18, and may further include a wafer disposed on a third arm, wherein the second and third arms allow the wafer to come into contact with the CMP polishing pad.

[0113] Example 20 may include the subject matter of any of Examples 18-19, and may further include slurry disposed on the CMP polishing pad, wherein the projection and the abrasive material disposed on the projection form a nodule of the CMP conditioning disk, the nodule is to create a groove in the CMP polishing pad when the nodule and the CMP polishing pad are in contact and rotating relative to one another, and the groove is to transport the slurry across the CMP polishing pad.

[0114] Example 21 may include the subject matter of any of Examples 18-20, and may further specify that the projection and the support are integrally formed.

[0115] Example 22 may include the subject matter of any of Examples 18-21, and may further specify that the projection has a footprint with a maximum dimension, and the maximum dimension is between 10 and 300 microns.

[0116] Example 23 may include the subject matter of any of Examples 18-22, and may further specify that the abrasive material includes a diamond film.

[0117] Example 24 may include the subject matter of any of Examples 18-23, and may further specify that the projection has a circular footprint.

[0118] Example 25 is a method of manufacturing a chemical mechanical polishing (CMP) conditioning disk, including: forming a base structure including a support and a projection, wherein the projection is secured to the support, and the projection has a footprint with a maximum dimension between 10 and 300 microns; and providing an abrasive material on the projection and the support.

[0119] Example 26 may include the subject matter of Example 25, and may further specify that forming the base structure comprises forming the base structure in a mold.

[0120] Example 27 may include the subject matter of any of Examples 25-26, and may further specify that forming the base structure comprises forming the base structure by three-dimensional printing or laser engraving.

[0121] Example 28 may include the subject matter of any of Examples 25-27, and may further specify that providing the abrasive material comprises performing chemical vapor deposition (CVD).

[0122] Example 29 may include the subject matter of Example 28, and may further specify that providing the abrasive material comprises depositing diamond using CVD.

[0123] Example 30 may include the subject matter of any of Examples 25-29, and may further specify that the base structure comprises a silicon or carbon composite.

[0124] Example 31 is a method, including: bringing a chemical mechanical polishing (CMP) conditioning disk into contact with a CMP polishing pad, wherein the CMP conditioning disk includes a support having a surface, a projection secured to the support and extending away from the surface, and an abrasive material disposed on the surface and on the projection, the projection and the abrasive material disposed on the projection form a nodule, and the nodule is in contact with the CMP polishing pad; and rotating and translating the CMP conditioning disk and the CMP polishing pad relative to one another to cause the formation of a groove, by the nodule, in the CMP polishing pad.

[0125] Example 32 may include the subject matter of Example 31, and may further specify that the support comprises a base and a pedestal, and wherein the surface is a surface of the pedestal.

[0126] Example 33 may include the subject matter of any of Examples 31-32, and may further specify that the nodule has a height measured from the surface, and the height of the nodule is between 20 and 100 microns.

[0127] Example 34 may include the subject matter of any of Examples 31-33, and may further specify that the projection has a footprint with a maximum dimension, and the maximum dimension is between 10 and 300 microns.

[0128] Example 35 may include the subject matter of any of Examples 31-34, and may further specify that: the projection is a first projection; the nodule is a first nodule; the CMP conditioning disk further includes a second projection secured to the support and extending away from the surface; the abrasive material is disposed on the second projection; the second projection and the abrasive material disposed on the second projection form a second nodule; the second nodule is in contact with the CMP polishing pad; the groove is a first groove; and rotating and translating the CMP conditioning disk and the CMP polishing pad relative to one another is to cause the formation of a second groove, by the second nodule, in the CMP polishing pad.

[0129] Example 36 may include the subject matter of any of Examples 31-35, and may further specify that the projection is one of a plurality of projections secured to the support and extending away from the surface, and the plurality of projections are disposed in a regular arrangement.

[0130] Example 37 may include the subject matter of any of Examples 31-36, and may further include using the CMP polishing pad to polish a wafer.

[0131] Example 38 may include the subject matter of Example 37, and may further specify that using the CMP polishing pad to polish the wafer occurs simultaneously with rotating and translating the CMP conditioning disk and the CMP polishing pad relative to one another.

[0132] Example 39 may include the subject matter of any of Examples 37-38, and may further specify that using the CMP polishing pad to polish the wafer occurs after rotating and translating the CMP conditioning disk and the CMP polishing pad relative to one another.

Claims:

1. A chemical mechanical polishing (CMP) conditioning disk, comprising:
a support having a surface;
a projection secured to the support and extending away from the surface; and
an abrasive material disposed on the surface and on the projection.
2. The CMP conditioning disk of claim 1, wherein the support comprises a substrate and a pedestal extending away from the substrate, and wherein the surface is a surface of the pedestal.
3. The CMP conditioning disk of claim 1, wherein the projection and the support are integrally formed.
4. The CMP conditioning disk of claim 1, wherein the projection and the abrasive material disposed on the projection form a nodule, the nodule has a height measured from the surface, and the height of the nodule is between 10 and 100 microns.
5. The CMP conditioning disk of claim 1, wherein the projection has a footprint with a maximum dimension, and the maximum dimension is between 50 and 150 microns.
6. The CMP conditioning disk of claim 1, wherein the abrasive material includes a diamond film.
7. The CMP conditioning disk of claim 1, wherein the projection has a height measured from the surface, and the height is between 5 and 25 microns.
8. The CMP conditioning disk of any of claims 1-7, wherein:
the projection is a first projection;
the CMP conditioning disk further includes a second projection secured to the support and extending away from the surface; and
the abrasive material is disposed on the second projection.
9. The CMP conditioning disk of claim 8, wherein the first and second projections have the same shape.
10. The CMP conditioning disk of claim 8, wherein the support includes a substrate and first and second pedestals, the first projection is secured to the first pedestal, and the second projection is secured to the second pedestal.
11. The CMP conditioning disk of any of claims 1-8, wherein the projection is one of a plurality of projections secured to the support and extending away from the surface, and the plurality of projections are disposed in a regular arrangement.
12. The CMP conditioning disk of claim 11, wherein the CMP conditioning disk is circular, and the plurality of projections are spaced at equal radial distances from a center of the CMP conditioning disk.

13. The CMP conditioning disk of claim 11, wherein the support includes a substrate and a plurality of pedestals, and each of the plurality of projections is disposed on a different one of the plurality of pedestals.

14. The CMP conditioning disk of any of claims 1-8, wherein the projection has a cylindrical shape.

15. A chemical mechanical polishing (CMP) system, comprising:

a CMP conditioning disk disposed on a first arm, wherein the CMP conditioning disk includes a support having a surface, a projection secured to the support and extending away from the surface, and an abrasive material disposed on the surface and on the projection; and

a CMP polishing pad disposed on a second arm;

wherein the first and second arms allow the CMP conditioning disk to come into contact with, and rotate relative to, the CMP polishing pad.

16. The CMP system of claim 15, wherein the projection and the support are integrally formed.

17. The CMP system of claim 15, wherein the projection has a footprint with a maximum dimension, and the maximum dimension is between 10 and 300 microns.

18. The CMP system of any of claims 15-17, wherein the abrasive material includes a diamond film.

19. A method of manufacturing a chemical mechanical polishing (CMP) conditioning disk, comprising:

forming a base structure including a support and a projection, wherein the projection is secured to the support, and the projection has a footprint with a maximum dimension between 10 and 300 microns; and

providing an abrasive material on the projection and the support.

20. The method of claim 19, wherein providing the abrasive material comprises performing chemical vapor deposition (CVD).

21. The method of any of claims 19-20, wherein the base structure comprises a silicon or carbon composite.

22. A method, comprising:

bringing a chemical mechanical polishing (CMP) conditioning disk into contact with a CMP polishing pad, wherein:

the CMP conditioning disk includes a support having a surface, a projection secured to the support and extending away from the surface, and an abrasive material disposed on the surface and on the projection,

the projection and the abrasive material disposed on the projection form a nodule, and

the nodule is in contact with the CMP polishing pad; and

rotating and translating the CMP conditioning disk and the CMP polishing pad relative to one another to cause the formation of a groove, by the nodule, in the CMP polishing pad.

23. The method of claim 22, wherein the support comprises a base and a pedestal, and wherein the surface is a surface of the pedestal.

24. The method of claim 22, wherein the nodule has a height measured from the surface, and the height of the nodule is between 20 and 100 microns.

25. The method of any of claims 22-24, further comprising:
using the CMP polishing pad to polish a wafer.

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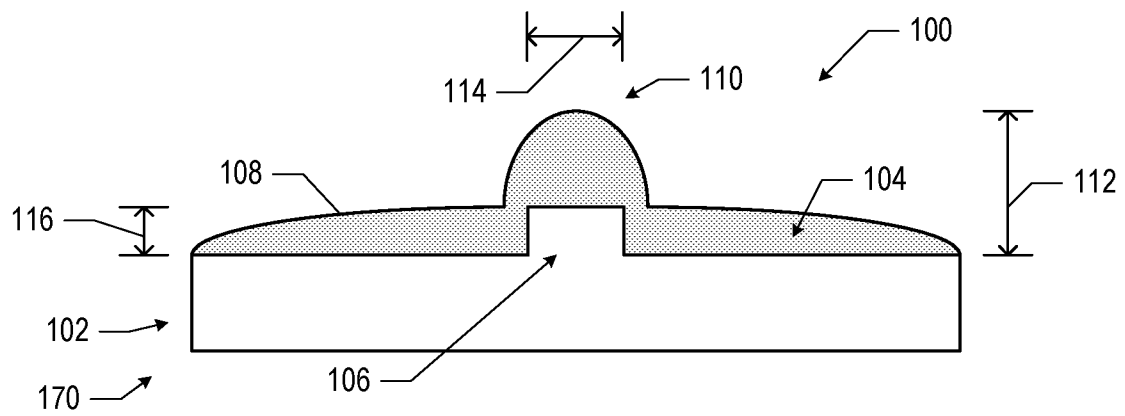


FIG. 1

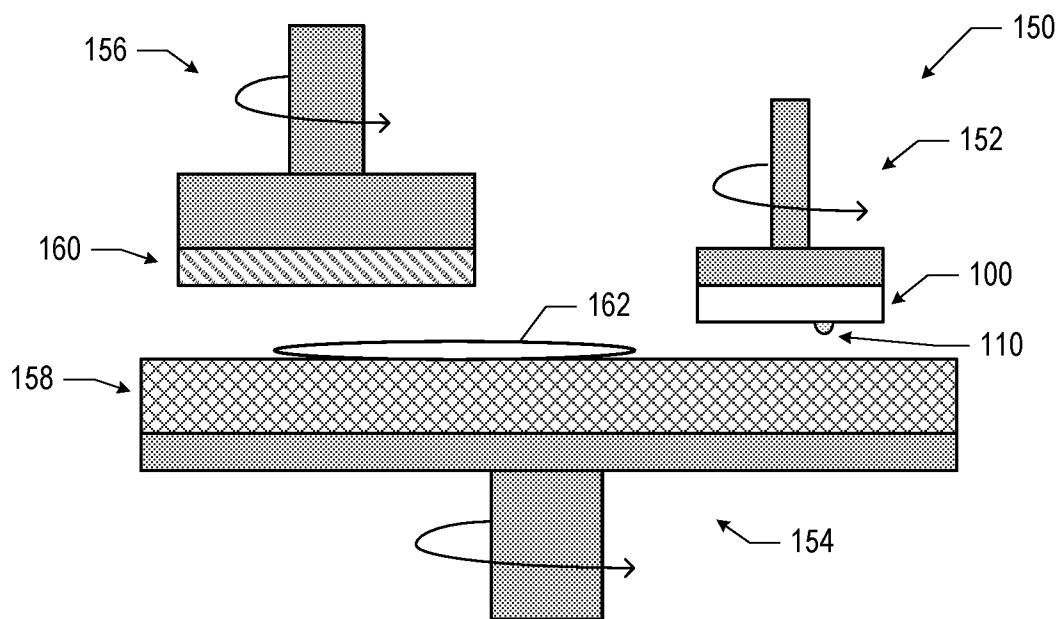


FIG. 2

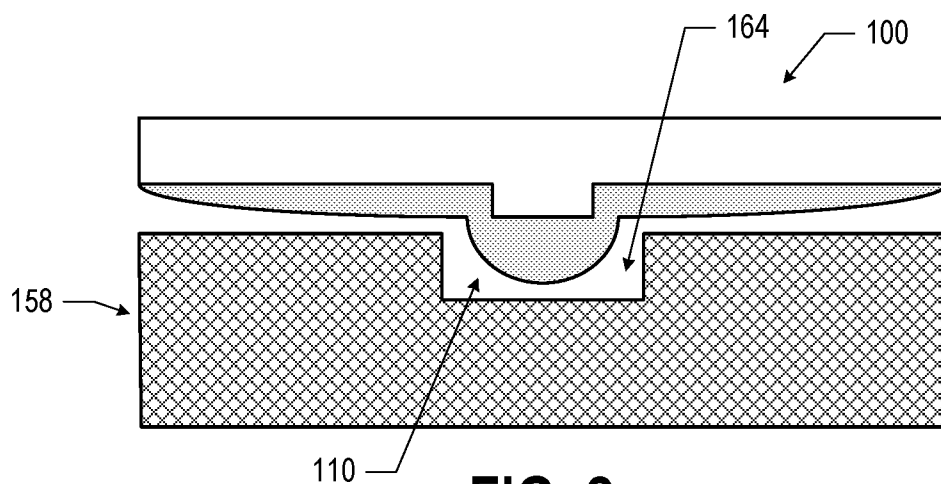


FIG. 3

FIG. 4

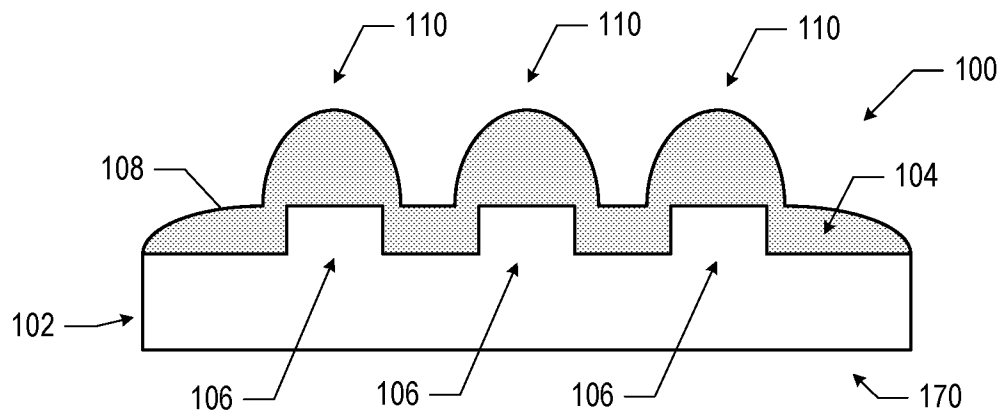


FIG. 5

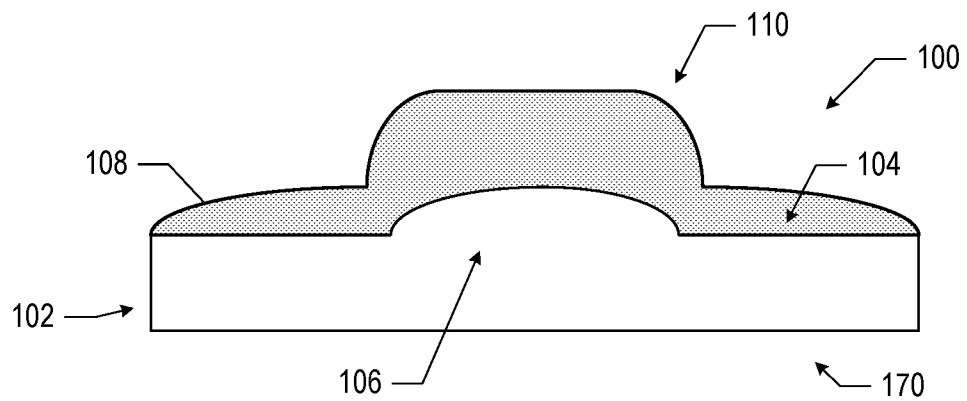


FIG. 6

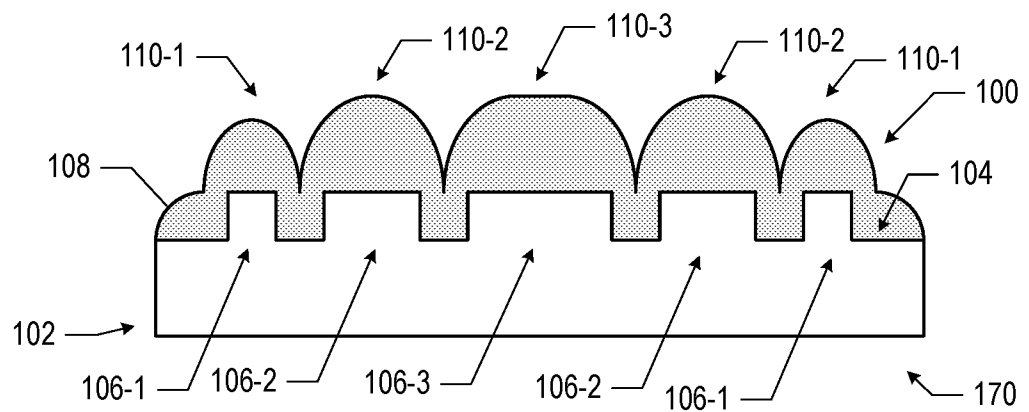
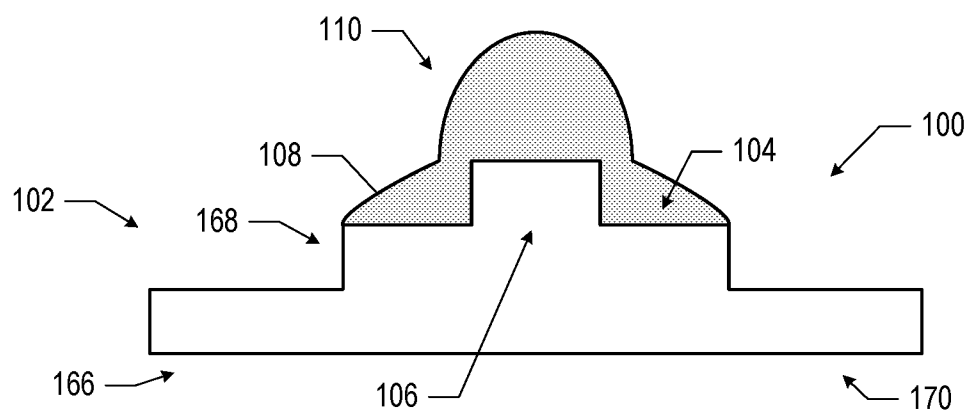


FIG. 7



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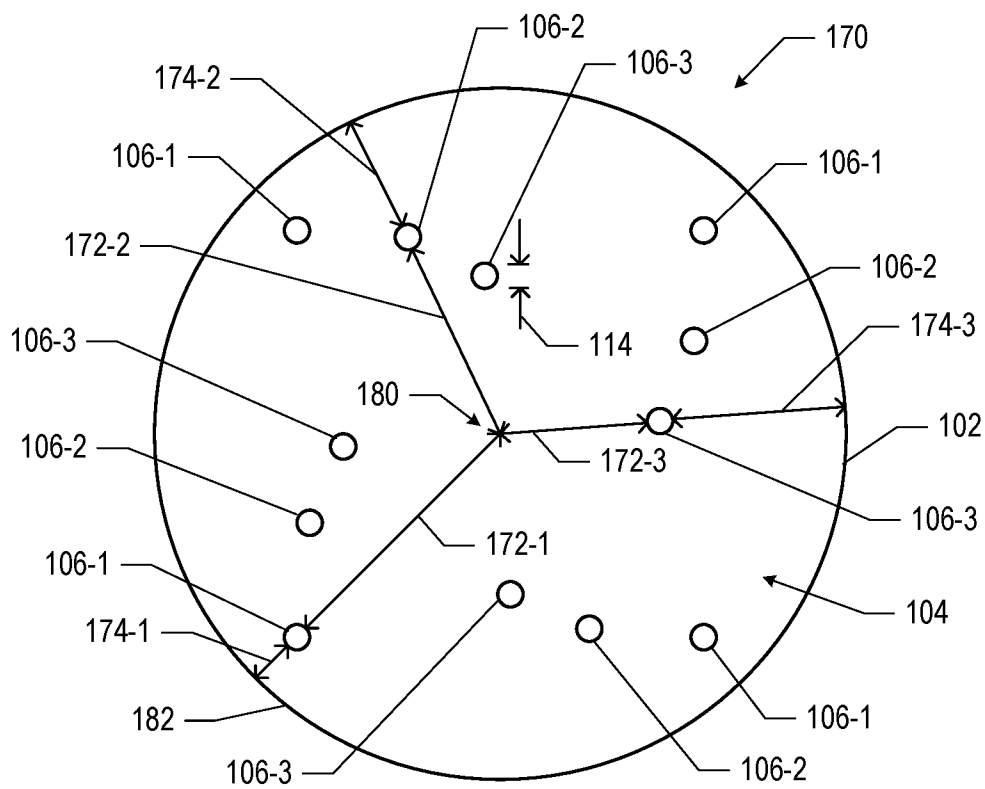


FIG. 8

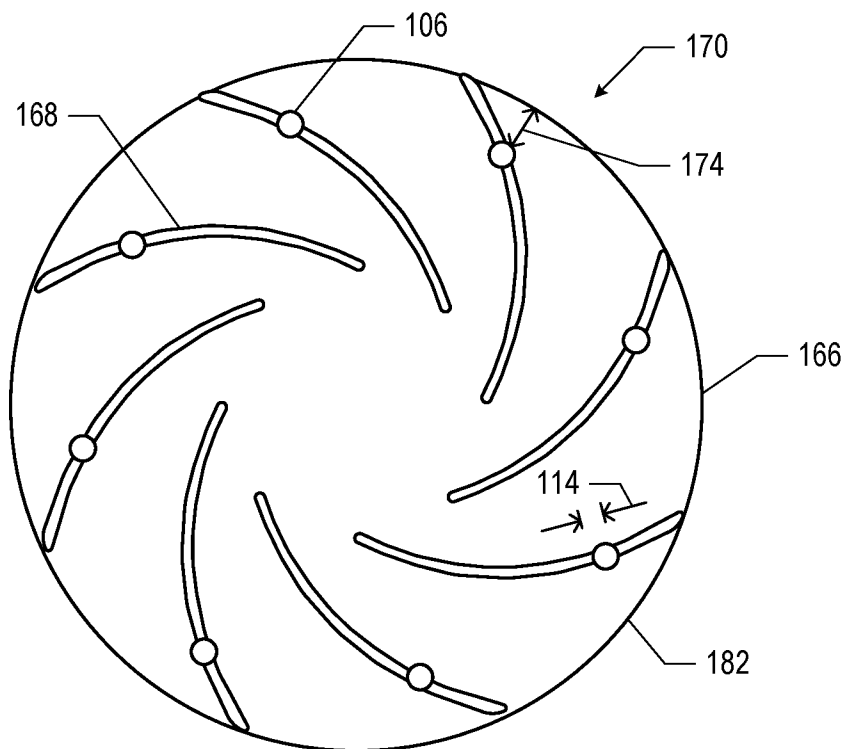


FIG. 9

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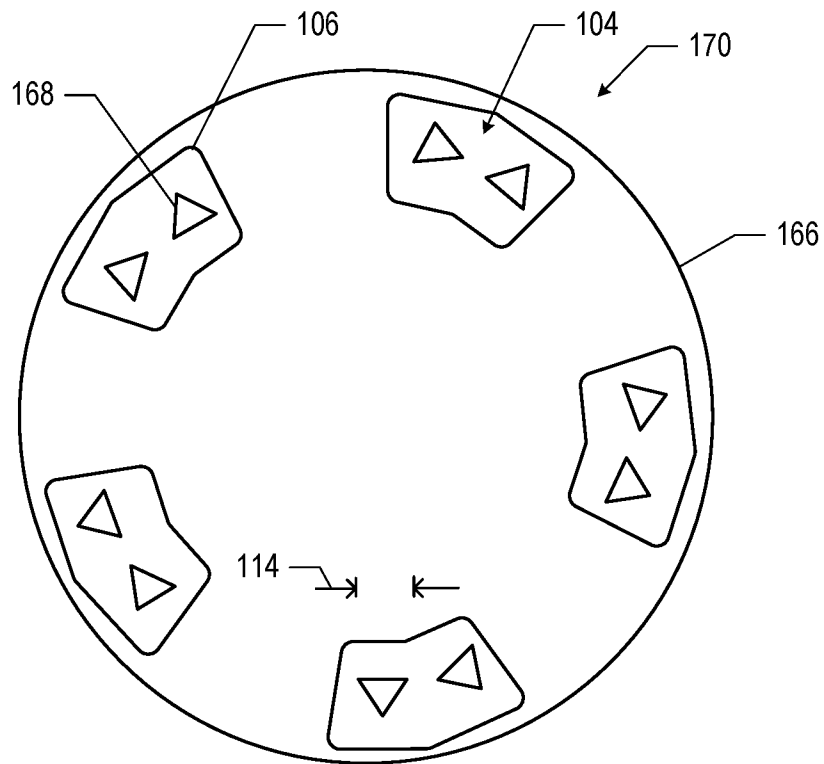


FIG. 10

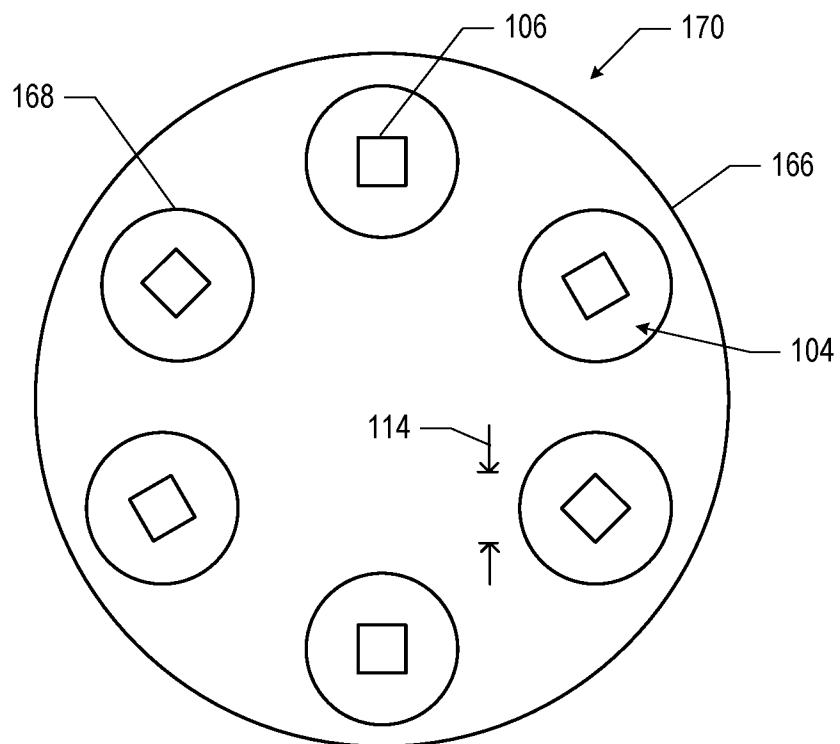


FIG. 11

FIG. 12

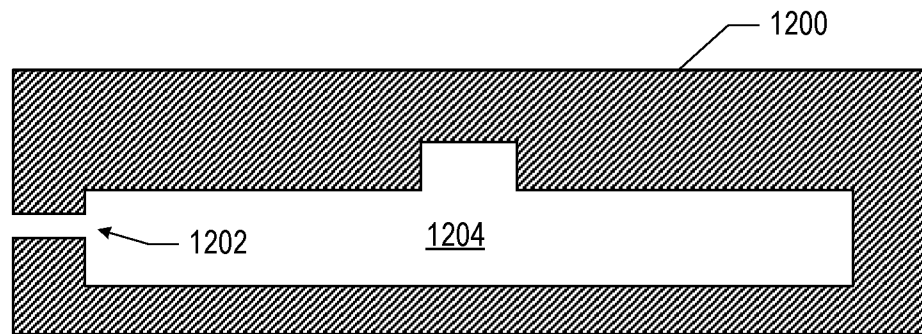


FIG. 13

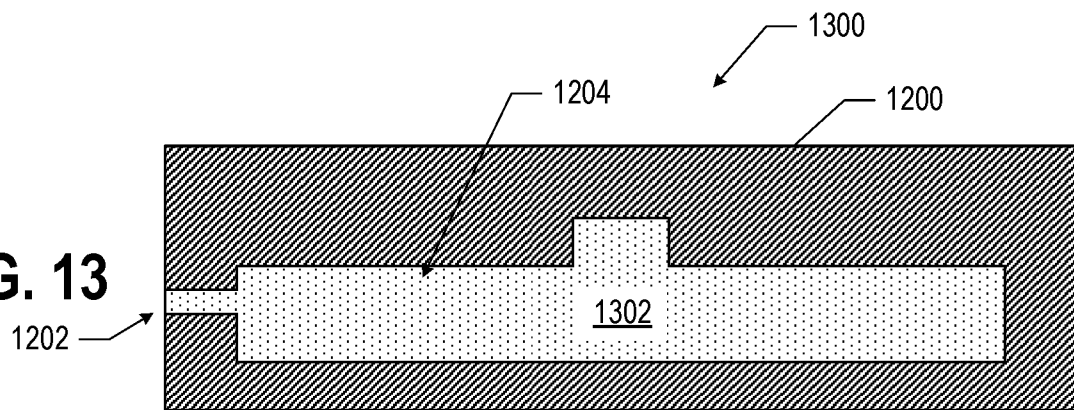


FIG. 14

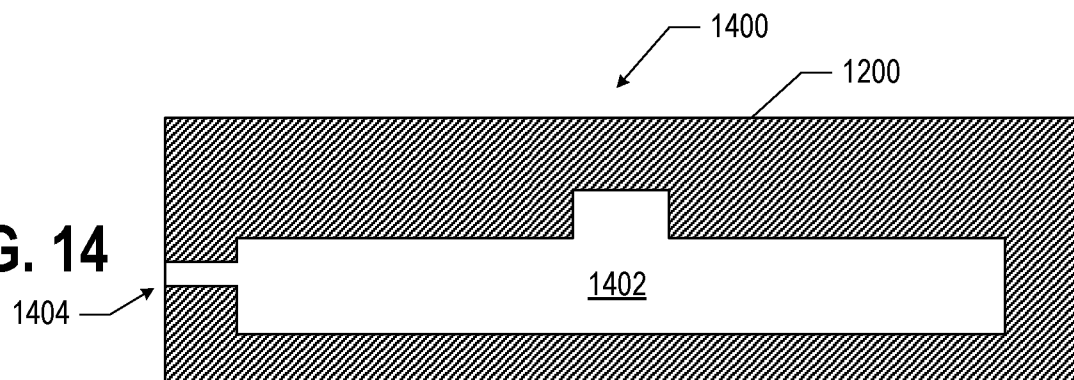
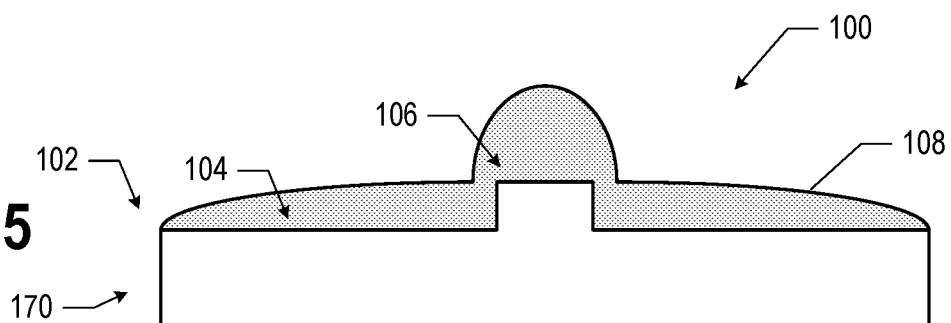
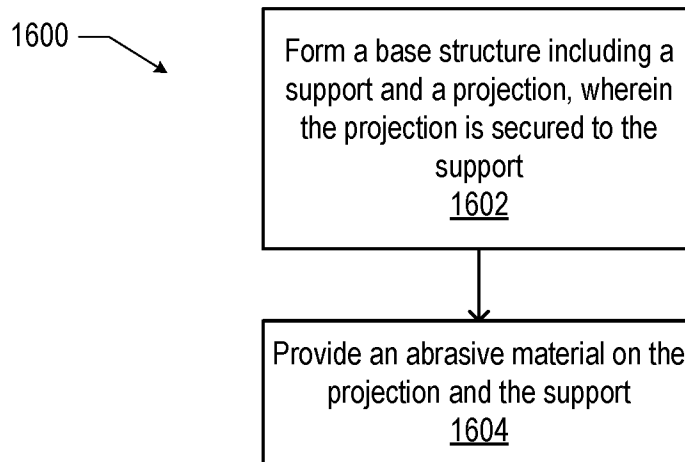
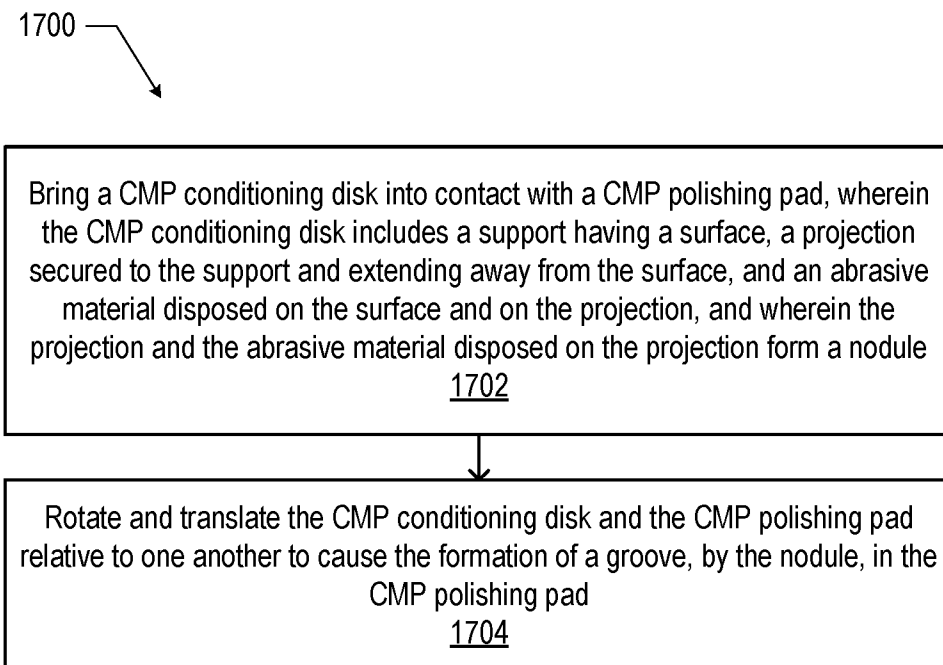


FIG. 15



**FIG. 16****FIG. 17**

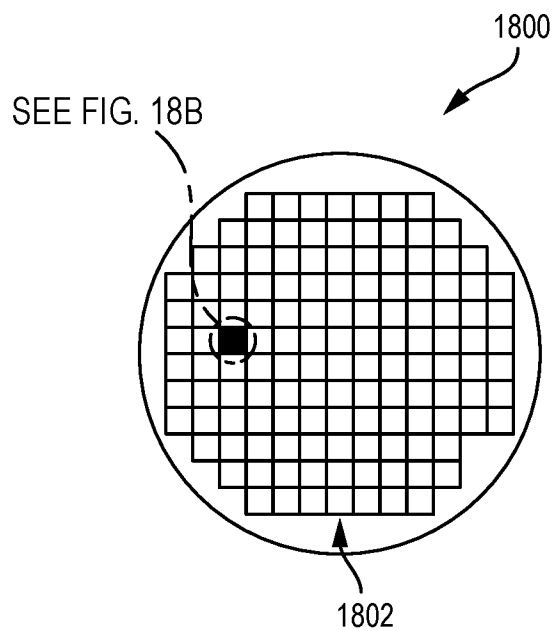


FIG. 18A

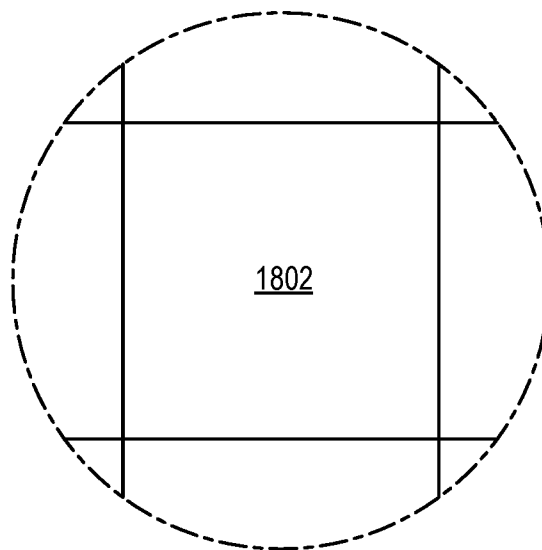


FIG. 18B

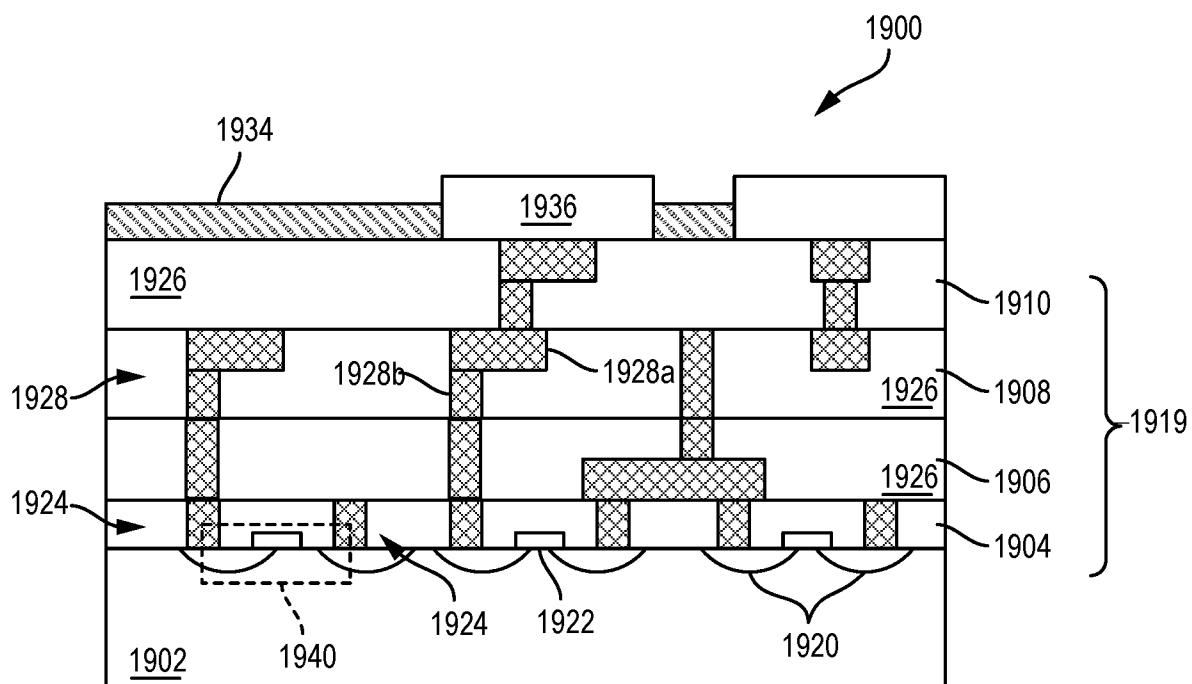


FIG. 19

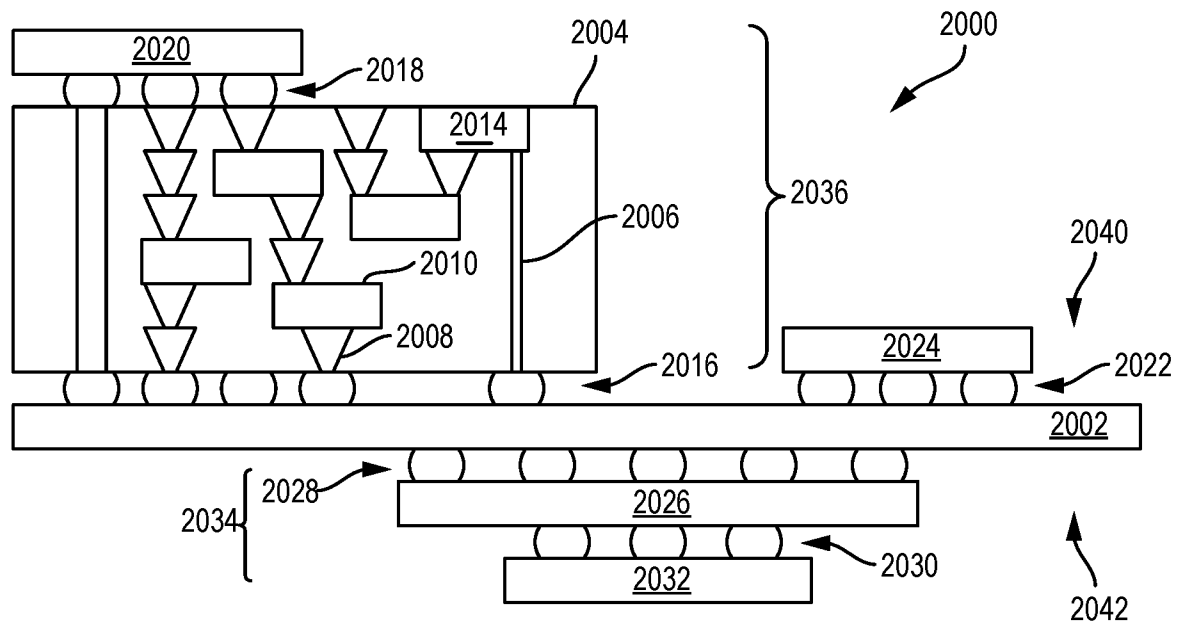


FIG. 20

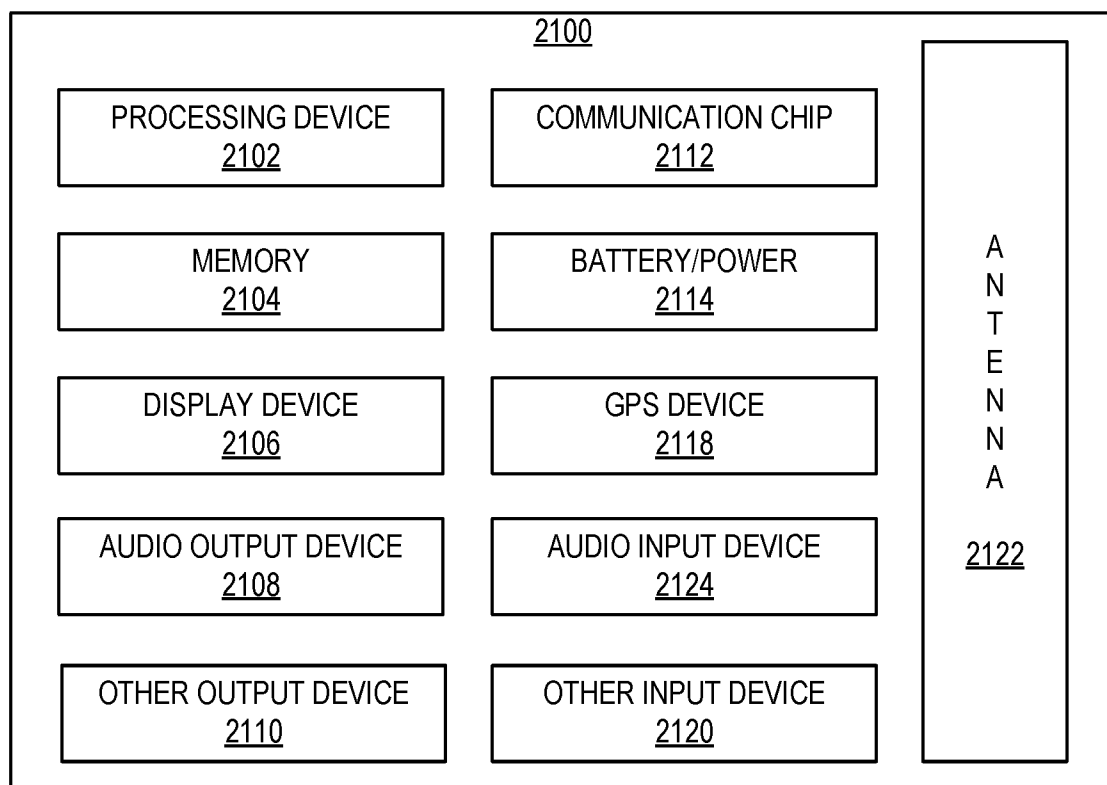


FIG. 21

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/019008**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 53/017; B24B 53/00; H01L 21/306; B24B 53/12

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: CMP, conditioner, pad, head, projection, pedestal, abrasive material

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0113532 A1 (JOSEPH SMITH et al.) 24 April 2014 See paragraphs [0003]-[0007], [0059]-[0087], [0123]-[0129], claims 1-14, 16, 17 and figures 1, 4A-4D, 7A-7F, 10, 17.	1, 3-9, 11, 12, 14-22 , 24, 25
A		2, 10, 13, 23
A	US 6361414 B1 (MIKE RAVKIN et al.) 26 March 2002 See column 3, line 9- column 5, line 7, claim 1 and figure 1.	1-25
A	US 2014-0148008 A1 (TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY, LTD.) 29 May 2014 See paragraphs [0012]-[0023], claim 1 and figure 1.	1-25
A	KR 10-2015-0095364 A (SAESOL DIAMOND IND. CO., LTD.) 21 August 2015 See paragraphs [0037]-[0046], claims 1, 17 and figure 1.	1-25
A	KR 10-2012-0031729 A (SHINHAN DIAMOND INDUSTRIAL CO., LTD.) 04 April 2012 See paragraphs [0020]-[0042], claims 1-14 and figures 1-4.	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 November 2016 (17.11.2016)

Date of mailing of the international search report

17 November 2016 (17.11.2016)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/019008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014-0113532 A1	24/04/2014	CN 103688343 A EP 2684211 A2 JP 2014-510645 A KR 10-2014-0036160 A TW 201249595 A US 2016-0074993 A1 US 9132526 B2 WO 2012-122186 A2 WO 2012-122186 A3	26/03/2014 15/01/2014 01/05/2014 25/03/2014 16/12/2012 17/03/2016 15/09/2015 13/09/2012 08/11/2012
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KR 10-2012-0031729 A	04/04/2012	KR 10-1201259 B1 WO 2012-043964 A1	14/11/2012 05/04/2012