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(54) **Polishing apparatus**

(57) A chemical mechanical polishing system having a dual position slurry/rinse arm for moving between a polishing position in which slurry is supplied to a polishing pad from a location remote from the polishing pad's center, and a rinsing position in which rinsing fluid is supplied from a location above or adjacent the polishing pad's center. The rinsing fluid is preferably sprayed from one or more nozzles that extend from the edge of the polishing pad to the center of the polishing pad. Preferably, in the polishing position, the slurry/rinse arm is positioned horizontally remote from the polishing pad's center and supplies slurry to the polishing pad via a horizontally angled slurry supply line. The slurry/rinse arm may include a gimbled brush for contacting the polishing pad when the slurry/rinse arm is in the rinsing position, and may further include brush nozzles positioned to direct rinsing fluid to the brush so as to rinse particles therefrom. Rinsing fluid nozzles may also be angled to spray rinsing fluid in front of the brush, so as to prewet the polishing pad.

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Description

[0001] During formation of a semiconductor device, various layers (e.g. oxides) require planarization to remove steps or undulations prior to formation of subsequent layers. Planarization is typically performed mechanically by forcing the semiconductor substrate S face down against a semi-porous polishing pad which is saturated with an abrasive compound (i.e., a slurry) and by rotating the polishing pad relative to the substrate S. The slurry reacts with the substrate Surface making the surface easier to remove, and the rotary motion between the polishing pad and the substrate S mechanically removes layers of the intermediate oxide and is continued until the oxide steps or undulations are removed. This process is generally referred to as chemical mechanical polishing (CMP).

[0002] FIG. 1 is a schematic top plan view of a conventional chemical mechanical polishing device 11. The polishing device 11 comprises a rotatable platen 15 on which a grooved polishing pad 17 for polishing semiconductor substrate S is mounted. The polishing pad 17 has at least one groove 19 and typically has a plurality of concentric circumferential grooves 19 which are disposed along the outer portion of the polishing pad 17.

[0003] The polishing device 11 further comprises a pivot arm 21, a holder or conditioning head 23 mounted to one end of the pivot arm 21, a slurry source such as a slurry/rinse arm 25, a pad conditioner 27a, such as a pad embedded with diamond crystals, mounted to the underside of the conditioning head 23, and a substrate mounting head 29 operatively coupled to the platen 15 so as to press a substrate S against the grooves 19 of the polishing pad 17.

[0004] The pivot arm 21 is operatively coupled to the platen 15, and holds the conditioning head 23 against the polishing pad 17, as the pivot arm 21 sweeps back and forth across the polishing pad 17's radius, in an arcing motion, as further described below. The slurry/rinse arm 25 is stationarily positioned outside the sweep of the pivot arm 21 and the conditioning head 23 coupled thereto.

[0005] In operation, the substrate S is placed face down beneath the substrate mounting head 29, and the substrate mounting head 29 presses the substrate S firmly against the grooved portion of the polishing pad 17. Slurry is introduced to the polishing pad 17 via the slurry/rinse arm 25, and the platen 15 rotates as indicated by the arrow R_1. The pivot arm 21 scans from side to side in an arcing motion as indicated by the arrow S_1 and the conditioning head 23 rotates as indicated by the arrow R_2.

[0006] The grooves 19 channel the slurry (not shown) between the substrate S and the polishing pad 17. The semi-porous surface of the polishing pad 17 becomes saturated with slurry which, with the downward force of the substrate mounting head 29 and the rotation of the platen 15, abrades and planarizes the surface of the substrate S. The diamond crystals (not shown) embedded in the rotating conditioner 27a continually roughen the surface of the polishing pad 17 to ensure consistent polishing rates.

[0007] As the slurry filled grooves travel beneath the substrate mounting head 29, the downward force of the substrate mounting head 29 and the substrate S thereunder, in addition to other factors such as the pH, the temperature, and the act of polishing itself, tend to compact and/or dry the slurry particles within the grooves 19, forming hard chunks which may dislodge and scratch the substrate S. Accordingly, a pad cleaning step must be performed frequently to rinse debris and compacted slurry from the polishing pad 17.

[0008] To rinse the polishing pad 17, the substrate mounting head 29 is removed from contact with the polishing pad 17, the supply of slurry from the slurry/rinse arm 25 is turned off, and a rinsing fluid such as deionized water is supplied via the slurry/rinse arm 25. To achieve maximum defect reduction the pad cleaning step preferably is performed after each substrate S is polished. However, such frequent rinsing increases rinsing fluid consumption costs, and reduces the overall throughput of the polishing device 11.

[0009] Accordingly a need exists for an improved polishing system that provides more efficient, more cost-effective pad cleaning.

[0010] The present invention provides an apparatus for polishing semiconductor substrates S. The apparatus comprises a rotatable platen, a polishing pad mounted on the rotatable platen, and a dual position slurry/rinse arm. The slurry/rinse arm has a slurry supply line with a slurry outlet, and a rinsing fluid supply line with a rinsing fluid outlet. The slurry/rinse arm is operatively coupled to the rotatable platen via a mechanism for moving the arm between a polishing position wherein the slurry/rinse arm is positioned to supply slurry to the polishing pad from a location remote from the polishing pad's center, and a rinsing position wherein the slurry rinse arm is positioned to supply rinsing fluid to the polishing pad is center. Preferably in the rinsing position the slurry/rinse arm is located above or adjacent the polishing pad's center such that the rinsing fluid is sprayed onto the polishing pad's center (i.e. is positioned to supply rinsing fluid directly to the polishing pad's center). Preferably, the slurry supply line is angled horizontally, and the arm is positioned a horizontal distance from the polishing pad's center when in the polishing position.

[0011] The slurry/rinse arm's dual position capability allows the arm to be configured and positioned for optimal rinsing, without constraint by the path of either the conditioning head or the substrate mounting head. Thus, the slurry/rinse arm of the inventive polishing apparatus is configured to supply rinsing fluid across the entire radius of the polishing pad, and provides superior rinsing as compared to conventional polishing apparatuses whose stationary slurry/rinse arms cannot

extend to the polishing pad's center.

[0012] In a first embodiment the rinsing fluid outlet comprises either a line type nozzle which outputs a spray that extends from the edge of the polishing pad to at least the center of the polishing pad, or a plurality of rinsing fluid nozzles whose spray extends, preferably uniformly, from the edge of the polishing pad to at least the center of the polishing pad. Thus, the entire polishing pad is rinsed as the polishing pad rotates. In alternative embodiments, the rinsing nozzles may extend across the entire diameter of the polishing pad to reduce rinsing time, or the rinsing fluid outlet maybe scanned between the polishing pad's edge and center.

[0013] In a second embodiment the slurry/rinse arm comprises a pad brush coupled to the arm so as to contact the polishing pad when the arm is in the rinsing position. The arm thus is lower when in the rinsing position than when in the polishing position. The pad brush speeds the rate of particle removal and loosens compacted particles from polishing pad grooves where rinsing nozzles alone either can not remove the particles or would require considerably longer rinsing times and/or greater rinsing fluid volumes to remove the particles. In order, despite wear, to maintain uniform contact with the substrate, the pad brush preferably is coupled to the arm via a gimble.

[0014] Further embodiments employ one or more rinsing fluid nozzles that are positioned either to direct rinsing fluid into the pad brush (i.e., brush nozzles), thereby deterring particles from undesirably collecting in the pad brush or to direct rinsing fluid in front of the pad brush (i.e., prewetting nozzles), thereby prewetting the pad surface to facilitate cleaning by the pad brush. The brush nozzles and prewetting nozzles are preferably angled respectively toward or away from the pad brush at an angle of 70 degrees from normal, and the brush bristles are preferably sized to fit within the smallest grooves (e.g., the grooves created by the conditioning head). A dense nylon brush having .005 inch diameter bristle is presently preferred for its cleaning performance.

[0015] Accordingly, the inventive semiconductor polishing apparatus with its dual position slurry/rinse arm, its optional pad brush and optional brush nozzles removes particles both from the center of the pad and from pad grooves, more quickly, more thoroughly and with less rinsing fluid than conventional semiconductor polishing apparatuses.

[0016] Other objects, features and advantages of the present invention will become more fully apparent from the following detailed description of the preferred embodiments, the appended claims and the accompanying drawings.

FIG. 1 is a schematic top plan view of a conventional chemical mechanical polishing device, as previously described;

FIGS. 2A and 2B are a front and a side elevational view, respectively, of an inventive dual position slurry/rinse arm;

FIG. 2C is a top plan view of the inventive slurry/rinse arm of FIGS. 2A and 2B;

FIG 3A and 3B are schematic top plan views of an apparatus for polishing semiconductor substrates S which employs the inventive slurry/rinse arm of FIGS. 2A-C, respectively showing the slurry/rinse arm in a polishing position and in a rinsing position; and

FIG. 4 is a side elevational view of an embodiment of the inventive slurry/rinse arm that employs prewetting nozzles.

[0017] FIGS. 2A and 2B are a front and a side elevational view, respectively, and FIG. 2C is a top plan view of a preferred, inventive, dual-position slurry/rinse arm 211. The slurry/rinse arm 211 comprises an arm 213 through which a first slurry supply line 215a and a second slurry supply line 215b extend. The first slurry supply line 215a has a first slurry outlet 217a and the second slurry supply line 215b has a second slurry outlet 217b. Both the first and second slurry supply lines are angled horizontally so as to direct slurry inward to the center of the polishing pad 17, as shown in FIGS. 3A and 3B. A rinsing fluid supply line 219 having a rinsing fluid outlet such as a rinsing fluid nozzles 221 is also coupled to the arm 213. An optional brush 223 is coupled so as to extend along the bottom of the arm 213. Preferably the optional brush 223 is coupled to the arm 213 via a gimble 224. The gimble 224 allows the brush to pivot so that the surface of the brush maintains uniform contact with the pad 17 (FIG. 1) irrespective of variations in the contour of the pad or in the contour of the brush. Optional rinsing fluid nozzles 225 are coupled to the arm 213 so as to direct rinsing fluid into the optional brush 223 (i.e., are brush nozzles).

[0018] The arm 213 is coupled to a base 227 via an automatically controlled hinge 229 which in operation, moves the arm 213 between the polishing position and the rinsing position. Preferably, as further described below, the polishing position is horizontally adjacent the rinsing position, thus, placing the arm 213 a horizontal distance from the polishing pad's center (preferably above or adjacent the center of the polishing pad's radius) during polishing, as further described below with reference to FIGS. 3A and 3B.

[0019] FIGS. 3A and 3B are top plan views of a polishing apparatus 231, such as a chemical mechanical polisher which employs the inventive slurry/rinse arm 211 of FIGS. 2A - 2C. FIGS. 3A and 3B respectively show the slurry/rinse arm 211 in a polishing position and in a rinsing position. The polishing apparatus 231, with the exception of the slurry/rinse arm 211, is configured the same as, and operates the same as the conventional polishing apparatus 11 of FIG. 1. Therefore, components like those of FIG. 1 are identified with the reference numerals of FIG. 1, and the details of their

configuration are not repeated.

[0020] In operation, the automated hinge 229 rotates, placing the arm 213 in the polishing position. When in the polishing position, the arm 213 is remote from the center of the polishing pad 17. Thus, the substrate mounting head 29 and the conditioning head 23 can freely scan between the edge and center of the polishing pad 17 without obstruction by the arm 213. Preferably in the polishing position, the arm 213 provides both the substrate mounting head 29 and conditioning head 23 with maximum scanning freedom yet positions the slurry/rinse arm 211 so as to provide slurry to the grooves 19. The first slurry supply line 215a and the second slurry supply line 215b are angled horizontally inward toward the polishing pad 17's center so as to place slurry farther from the edge of the polishing pad 17. Preferably slurry is delivered to the center region of the grooves 19.

[0021] The platen 15 and the polishing pad 17 positioned thereon then begin to rotate, and a substrate S is mounted to the underside of the substrate mounting head 29 and pressed against the rotating polishing pad 17. Slurry is introduced to the polishing pad 17 via the first slurry outlet 217a and/or the second slurry outlet 217b as the substrate mounting head 29 scans between the edge and center of the polishing pad 17, carrying the substrate S back and forth over the grooves 19 and the slurry channeled therein. The combination of the slurry and the rotating surface of the polishing pad 17 abrades material from the surface of the substrate S, thereby planarizing or polishing the substrate S. Meanwhile, the pivot arm 21 scans back and forth in an arcing motion re-roughening the surface of the polishing pad 17.

[0022] Material removed from the substrate S, and slurry that compacts under the pressure applied by the substrate mounting head 29 must be periodically cleaned from the polishing pad 17, to prevent these particles from scratching the surface of the substrate S. Accordingly, the polishing pad 17 preferably is rinsed after each substrate S is polished. Such frequent rinsing is possible because, in the rinsing position, the inventive slurry/rinse arm 211 extends across the entire radius of the substrate S, and preferably includes the optional brush 223, allowing more thorough cleaning in a shorter period of time, and with less rinsing fluid consumption.

[0023] After polishing is complete, both the pivot arm 21 and the substrate mounting head 29 are elevated from the surface of the polishing pad 17 and the hinge 229 rotates, positioning the arm 213 in the rinsing position such that the arm 213 extends from the edge of the polishing pad 17 to the center of the polishing pad 17. The hinge 229 then lowers the arm 213 such that the optional brush 223 contacts the polishing pad 17. If the surface of the pad 17 and the surface of the optional brush 223 are not parallel, the optional brush 223 pivots about the gimble 224. Thus the optional brush 223 maintains uniform contact from the edge to the center of the pad 17.

[0024] Rinsing fluid is supplied to the polishing pad 17 from the rinsing fluid supply line 219 coupled to the slurry/ rinse arm 211. Preferably the platen 15 rotates toward the slurry/rinse arm 211 so that the surface of the polishing pad 17 is wet from rinsing fluid supplied by the rinsing fluid nozzles 221 when the polishing pad surface reaches the brush 223. The energy of the rinsing fluid sprayed from the slurry/rinse arm 211 and the energy from the optional brush 223 sweeps particles and compacted slurry from the entire surface (edge to center) of the polishing pad 17 and from the grooves 19 as the platen 15 rotates.

[0025] The brush nozzles 225 direct rinsing fluid from the rinsing fluid supply line 219, or from an additional supply line, into the brush 223. The rinsing fluid from the brush nozzles 225 cleans the brush 223 of particles and slurry which may collect therein. The particles and slurry freed from the brush 223, flow off of the polishing pad 17 via centripetal force. The entire surface of the polishing pad 17 is therefore quickly and efficiently cleaned of undesirable particles and slurry chunks. An alternative embodiment which has been proven to provide superior defect levels is shown in FIG. 4.

[0026] FIG. 4 is a side elevational view of an embodiment of the inventive slurry rinse arm 211 that employs prewetting nozzles 233. The prewetting nozzles 233 replace the brush nozzles 225 of FIGS. 2A-3B, and preferably are angled (e.g., 70°) so as to point away from/in front of the slurry rinse arm 211. In operation the prewetting nozzles 233 are engaged while the slurry/rinse arm 211 is in the polishing position. The prewetting nozzles 233 spray rinsing fluid on the pad 17 for a short period of time (e.g., 5 seconds) and then are turned off as the slurry/rinse arm 211 moves to the rinsing position wherein the rinsing fluid nozzles 221 are engaged. By prewetting the pad in this manner, fewer defects have been found to occur in the subsequently polished wafers.

[0027] The foregoing description discloses only the preferred embodiments of the invention, modifications of the above disclosed apparatus and method which fall within the scope of the invention will be readily apparent to those of ordinary skill in the art. For instance, the slurry/rinse arm's configuration may vary considerably while still implementing the invention. The slurry/rinse arm could rotate vertically to assume a vertical position during polishing with slurry supplied to the polishing pad from a lower portion of the arm. The rinsing outlet could comprise one or more nozzles which are scanned across the radius of the polishing pad during the rinsing step, or the arm could be longer extending across the entire diameter of the polishing pad during rinsing, and thus further reducing the rinsing cycle time. Additionally, instead of a hinged coupling between the slurry/rinse arm's base and arm portions, the base and arm portions could be stationarily coupled and the base portion itself could rotate, lift and lower the arm portion. Any

type of nozzle that provides sufficient spray to uniformly rinse the pad or brush may be used (e.g., a line type nozzle, a plurality of fan type nozzles) and may be designed for straight or angled spray, as described above. Finally, the polisher described herein is merely exemplary, other polisher configurations (e.g., those employing a polishing pad in the form of a translating band, etc.) may also benefit from the invention.

Claims

1. A slurry/rinse arm comprising:

an arm;
at least one slurry supply line coupled to the arm, the slurry supply line having a slurry outlet;
a rinsing fluid supply line coupled to the arm, the rinsing supply line having a rinsing fluid outlet; and
a mechanism for moving the arm between a polishing position, and a rinsing position.

2. The slurry/rinse arm of claim 1 wherein the slurry supply line has an angled bend.

3. The slurry/rinse arm of claim 1 or claim 2 wherein the rinsing fluid outlet comprises one or more nozzles.

4. The slurry/rinse arm of any of the preceding claims further comprising a brush, coupled to the arm, adapted to contact a polishing pad.

5. The slurry/rinse arm of claim 4 wherein the rinsing fluid outlet comprises at least one nozzle angled to direct fluid in front of the brush, so as to prewet the pad.

6. The slurry/rinse arm of claim 4 or claim 5 further comprising one or more nozzles adapted to direct rinsing fluid into the brush.

7. The slurry/rinse are of any one of claims 4 to 6 further comprising a gimble coupled between the arm and the brush so as to facilities uniform contact between the brush and a polishing pad.

8. An apparatus for polishing semiconductor substrates comprising;

a rotatable platen;
a polishing pad mounted on the rotatable platen; and
the slurry/rinse arm of any preceding claim, wherein in the polishing position, the arm is remote from the centre of the polishing pad, and in the rinsing position the arm is positioned to supply rinsing fluid to the centre of the polishing pad.

9. The apparatus of claim 8 when dependent on claim 2, wherein the angled bend is in a plane parallel to the plane of the polishing pad.

10. The apparatus of claim 8 or claim 9 wherein the rinsing fluid outlet extends from the edge of the polishing pad to at least the centre of the polishing pad, when the slurry/rinse arm is in the rinsing position.

11. The apparatus of any one of claims 8 to 10 when dependent on any one of claims 5 to 7, wherein the brush extends from the edge of the polishing pad to at least the centre of the polishing pad.

12. The apparatus of any one of claims 8 to 11, wherein the brush has bristles sized to fit within the smallest polishing pad groove.

13. A method of polishing semiconductor substrates, comprising:

placing a semiconductor substrate on a polishing pad;
placing a slurry/rinse arm having a slurry supply line and a rinsing fluid supply line in a polishing position wherein the outlet of the slurry supply line is positioned to supply slurry to the polishing pad from a position remote from the polishing pad's centre;
supplying slurry to the polishing pad;
polishing the semiconductor substrate;
removing the semiconductor substrate from the polishing pad;
placing the slurry/rinse arm in a rinsing position wherein the outlet of the rinsing fluid supply line is positioned to supply rinsing fluid to the polishing pad centre; and
supplying rinsing fluid to the polishing pad via the slurry/rinse arm;
wherein placing the slurry/rinse arm in the polishing position and placing the slurry/rinse arm in the rinsing position is automated.

14. The method of claim 13 wherein supplying rinsing fluid to the polishing pad comprises simultaneously spraying rinsing fluid along a radius of the polishing pad.

15. The method of claim 13 wherein supplying rinsing fluid to the polishing pad comprises scanning the rinsing fluid outlet between the edge of the polishing pad and the centre of polishing pad.

16. The method of any one of claims 13 to 15 wherein

placing the slurry/rinse arm in a polishing position comprises rotating the slurry/rinse arm about an axis perpendicular to the plane of the polishing pad away from the polishing pad's centre.

17. The method of any one of the claims 13 to 16 wherein placing the slurry/rinse arm in a rinsing position comprises contacting the polishing pad with a brush, coupled to the slurry/rinse arm, while supplying rinsing fluid to the polishing pad.

18. The method of claim 17 further comprising directing a rinsing fluid spray into the brush.

19. The method of claim 17 further comprising rotating the rotatable platen such that rinsing fluid sprayed on the polishing pad is rotated toward the brush.

20. The method of any one of the claims 13 to 19 further comprising supplying rinsing fluid to the pad via the slurry/rinse arm, before placing the slurry/rinse arm in the rinsing position.

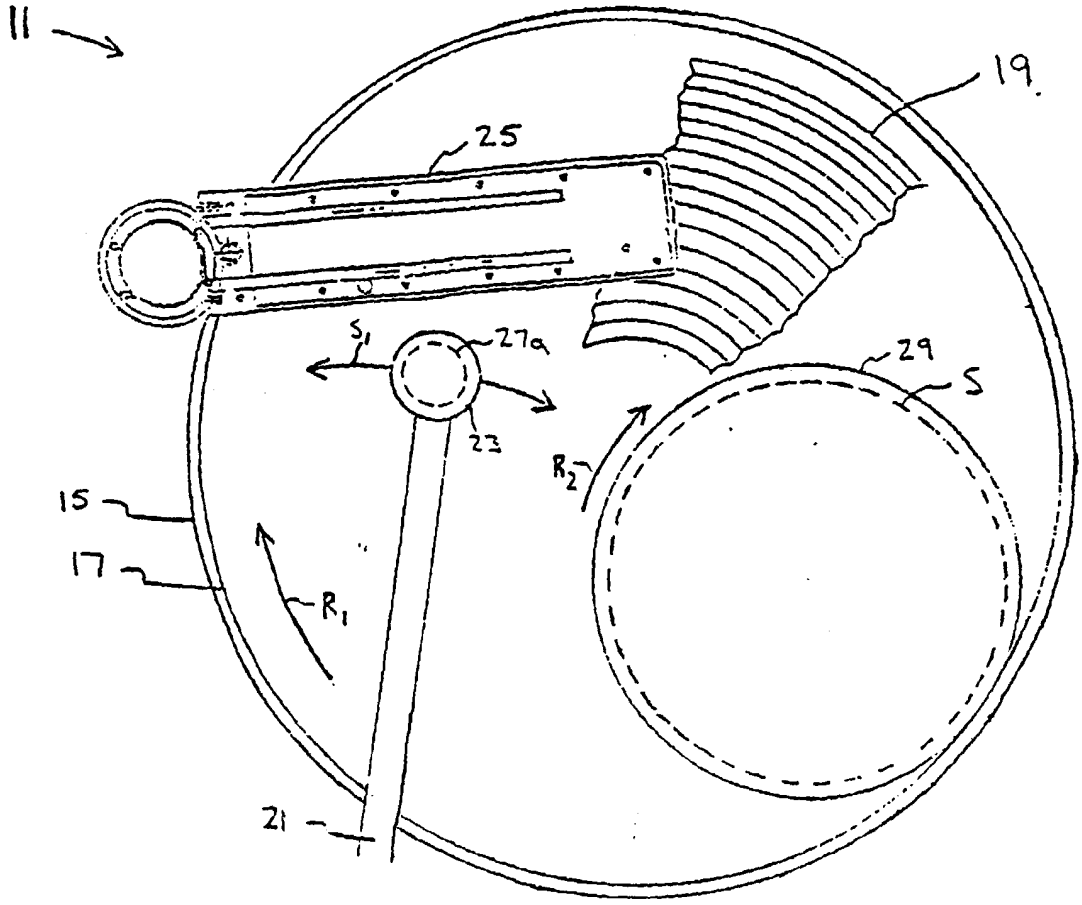

FIG. 1
(PRIOR ART)

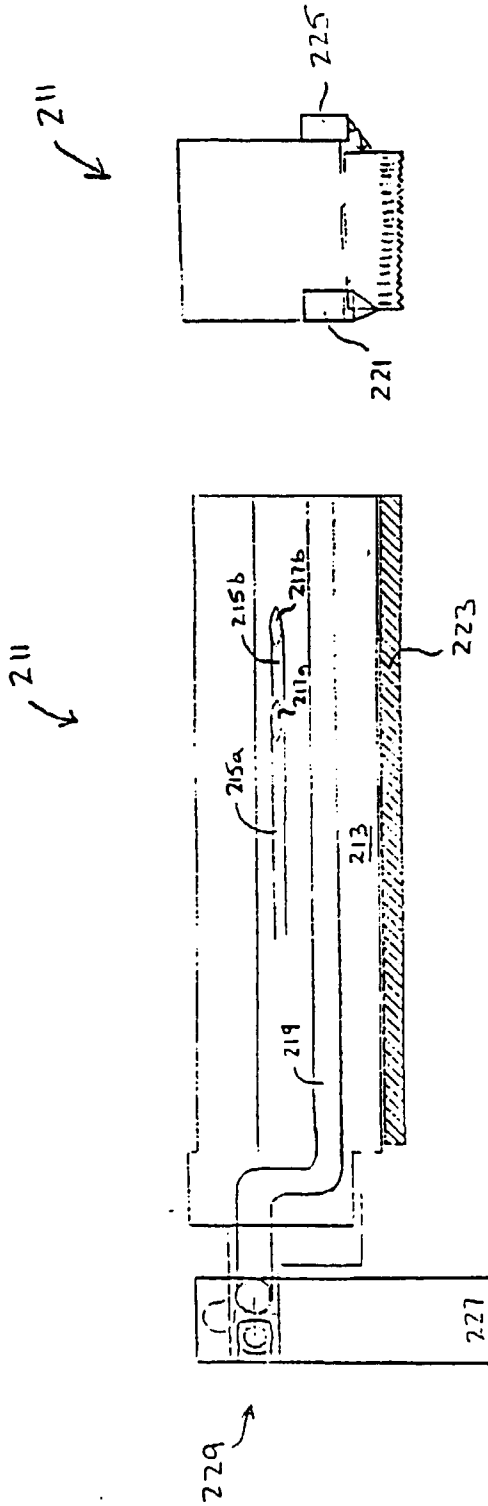

FIG. 2A

FIG. 2B

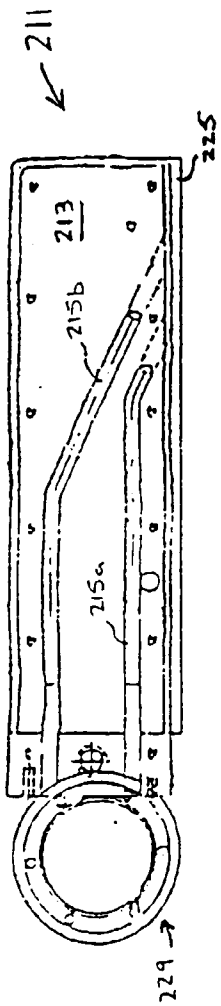

FIG. 2C

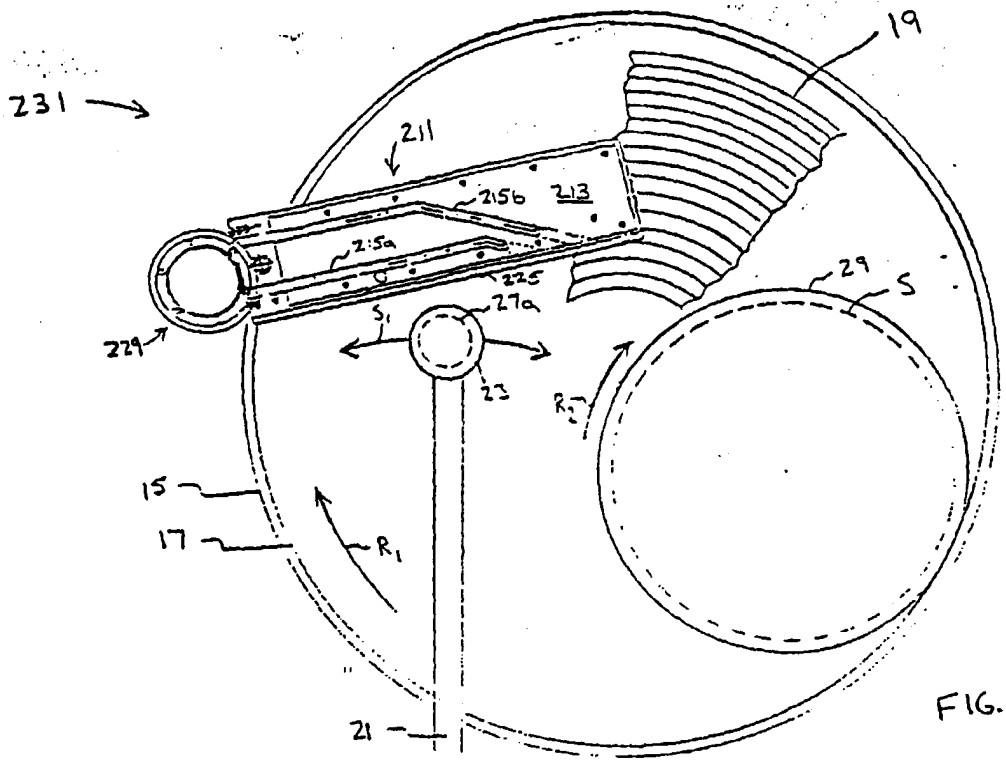
231
19
211
215b
213
215a
225
29
S
229
S_1
27a
23
R_2
15
17
R_1
21

FIG. 3A

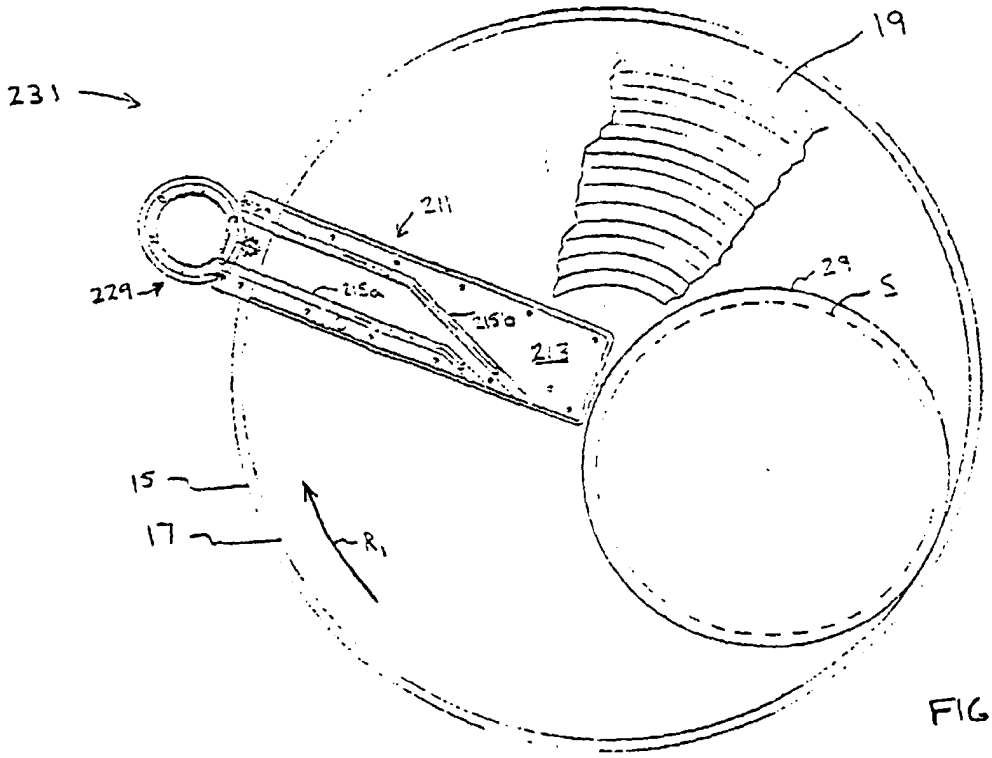
231
19
211
29
S
229
215a
215b
213
15
17
R_1

FIG. 3B

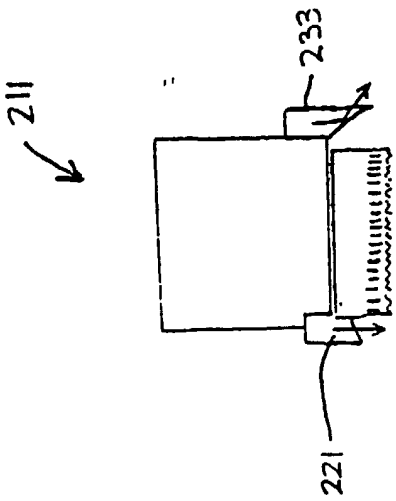

FIG. 4