

## ROTATIONAL SLURRY DISTRIBUTION SYSTEM FOR ROTARY CMP SYSTEM

## (1) Field of the Invention.

The present invention relates to the field of chemical mechanical polishing (CMP). More particularly, the present invention relates to methods and apparatus for chemical mechanical polishing of substrates, such as semiconductor substrates, on a rotating polishing pad in the presence of a chemically and/or physically abrasive slurry, and providing fresh supply of slurry onto the surface of the substrate which is mounted on the polishing pad while the substrate is being polished.

## (2) Description of the Prior Art.

Chemical Mechanical Polishing is a method of polishing materials, such as semiconductor substrates, to a high degree of planarity and uniformity. The process is used to planarize semiconductor slices prior to the fabrication of semiconductor circuitry thereon, and is also used to remove high elevation features created during the fabrication of the microelectronic circuitry on the substrate. One typical chemical mechanical polishing process uses a large polishing pad that is located on a rotating platen against which a substrate is positioned for polishing, and a

positioning member which positions and biases the substrate on the rotating polishing pad. Chemical slurry, which may also include abrasive materials therein, is maintained on the polishing pad to modify the polishing characteristics of the polishing pad in order to enhance the polishing of the substrate.

The use of chemical mechanical polishing to planarize semiconductor substrates has not met with universal acceptance, particularly where the process is used to remove high elevation features created during the fabrication of microelectronic circuitry on the substrate. One primary problem which has limited the use of chemical mechanical polishing in the semiconductor industry is the limited ability to predict, much less control, the rate and uniformity at which the process will remove material from the substrate. As a result, CMP is labor intensive process because the thickness and uniformity of the substrate must be constantly monitored to prevent overpolishing or inconsistent polishing of the substrate surface.

One factor, which contributes to the unpredictability and non-uniformity of the polishing rate of the CMP process, is the non-homogeneous replenishment of slurry at the surface

of the substrate and the polishing pad. The slurry is primarily used to enhance the rate at which selected materials are removed from the substrate surface. As a fixed volume of slurry in contact with the substrate reacts with the selected materials on the surface of the substrate, this fixed volume becomes less reactive and the polishing enhancing characteristics of that fixed volume of slurry is significantly reduced. One approach to overcoming this problem is to continuously provide fresh slurry onto the polishing pad.

This approach presents at least two problems. Because of the physical configuration of the polishing apparatus, introducing fresh slurry into the area of contact between the substrate and the polishing pad is difficult. Providing a fresh supply of slurry to all positions of the substrate is even more difficult. As a result, the uniformity and the overall rate of polishing are significantly affected as the slurry reacts with the substrate.

Current practice uses a straight line tubing arrangement to dispense the slurry directly into the center of the polishing pad. This leads to uneven distribution of the slurry onto the polishing pad while covering the entire

polishing pad with slurry requires a significant amount of time. Current practice therefore leads to higher usage of slurry and longer process time since the polishing process can only start after the entire polishing pad has been covered with slurry.

The polishing process is carried out until the surface of the wafer is ground to a highly planar state. During the polishing process, both the wafer surface and the polishing pad become abraded. After numerous wafers have been polished, the polishing pad becomes worn to the point where the efficiency of the polishing process is diminished and the rate of removal of material from the wafer surface is significantly decreased. It is usually at this point that the polishing pad is treated and restored to its initial state so that a high rate of uniform polishing can once again be obtained.

Fig. 1 shows a Prior Art CMP apparatus. A polishing pad 20 is affixed to a circular polishing table 22 which rotates in a direction indicated by arrow 24 at a rate in the order of 1 to 100m RPM. A wafer carrier 26 is used to hold wafer 18 face down against the polishing pad 20. The wafer 18 is held in place by applying a vacuum to the backside of the

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wafer (not shown). The wafer carrier 26 also rotates as indicated by arrow 32, usually in the same direction as the polishing table 22, at a rate on the order of 1 to 100 RPM. Due to the rotation of the polishing table 22, the wafer traverses a circular polishing path over the polishing pad 20. A force 28 is also applied in the downward vertical direction against wafer 18 and presses the wafer 18 against the polishing pad 20 as it is being polished. The force 28 is typically in the order of 0 to 15 pounds per square inch and is applied by means of a shaft 30 that is attached to the back of wafer carrier 26. Slurry 21 is provided to the top of the polishing pad to further enhance the polishing action of polishing pad 20.

US 5,775,893 (Shendon et al.) shows a conical roller pad.

US 5,783,573 (Yueh) shows a slurry distribution method with slurry distribution in the core. However, this reference differs from the present invention.

US 5,245,794 (Salusugan) shows a conventional slurry tube.

## SUMMARY OF THE INVENTION

The present invention teaches a gravity fed slurry distribution system. Slurry is fed to the polishing pad via a slurry tube. The slurry tube of the present invention rotates; this rotation of the slurry tube is caused by a special design of the outlet of the slurry tube that dispenses the slurry onto the polishing pad. The rotation of the slurry tube outlet is in a direction that is opposite to the direction of rotation of the polishing pad. This allows for quick and efficient broadcasting of the slurry across the entire surface of the polishing pad.

## BRIEF DESCRIPTION OF THE DRAWING

Fig. 2 shows an overview of the implementation of the present invention with the relative positioning of the polishing table, the polishing pad, the wafer carrier and the slurry distribution tube.

Fig. 3a and Fig. 3b show the design of the outlet of the rotating slurry distribution tubing.

Fig. 4 shows a cross section of an alternate implementation of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the first embodiment of the present invention the means of distributing slurry evenly across the surface of a polishing pad consists of a slurry feed tubing arrangement whereby the last or lowest section of this arrangement rotates and in so doing distributes the slurry over the face of the polishing pad. Fig. 3a and Fig. 3b address the first embodiment of the present invention.

In the second embodiment of the present invention the means of distributing slurry evenly across the surface of a polishing pad consists of a rotating shaft contained within the slurry supply reservoir. Fig. 4a and Fig. 4b address the second embodiment of the present invention.

#### First embodiment of the present invention

Referring now specifically to Fig. 2, there is shown an overview of the implementation of the present invention with relative positioning of the polishing table 22, the polishing pad 24, the wafer carrier 26 and the slurry supply tube 35. The slurry supply tube 35 consists of two sections, the upper section 28 which is fixed or stationary in

position and the lower section 36 which rotates around its axis 31 which is also the axis of the stationary slurry tube 28. The wafer-polishing table rotates in direction 34; the lower section 36 of the slurry supply tube 35 rotates in direction 32, the wafer carrier rotates in direction 33. The wafer carrier holds wafer 37 in place. Note that directions 34 and 32 are in opposite directions. The slurry is fed into the slurry supply tube 35 at point 30; the slurry gravity feeds down through the stationary upper section 28 and the rotating lower section 36 and exits the lower section 36 at point 36. The slurry spray 39 is, due to the counter directive rotations of the lower section 36 and the wafer polishing table 22, that is 32 and 34, efficiently broadcast and distributed across the surface of the wafer polishing pad 24.

The polishing pad arrangement is not limited to one (physical) polishing pad but can be extended to contain one or more abrasive polishing pads that are attached to a suspension medium, thereby creating a plurality of abrasive particles that are fixedly suspended in a suspension medium. In addition, slurry 39 that is supplied to the surface of the polishing pad arrangement 24 can be supplied under either gravity feed or under pressure, thereby further controlling polishing speed that is applied to the surface of the wafer 37 by the polishing arrangement 24. To as yet further enhance the method of slurry distribution that is

applied using the methods and apparatus of the invention, the slurry can be exited from the slurry supply head 35 in either concentrate form (as one essentially solid stream) or via a multiplicity of openings that are for this purpose provided in the lower portion 36 of the slurry supply tube 35. The lower section 36 is thereby the rotating slurry distribution nozzle, which rotates in direction 32, Fig. 2. In addition, a method can be provided whereby the semiconductor wafer that is being planarized can be pressed against the abrasive particles that are being used to provide the planarizing by forcing the wafer carrier 26 towards the polishing table 22. This pressure that can be applied between the wafer carrier 26 and the polishing table 26 affects and further controls the action of planarizing the semiconductor wafer 37.

Fig. 3 provides further detail of the construction of the slurry supply tube 35. Fig. 3a shows the cross section of the stationary upper section 28 of the slurry supply tube 35. Fig. 3b shows a cross section of the rotating lower section 36 of the slurry supply tube 35. The slurry 30 enters upper section 28 at the top of section 28 and gravity flows down through the tube 28. The concave section 42 provided at outside surface of the lower portion of tube 28 matches the convex section 52 provided at the inside surface of the upper portion of the rotating section 36 of the slurry supply tube 35. These

matching sections 42 and 52 are operationally combined by affixing the concavity of 42 within the convexity of 52, this affixing is done in such a manner that the two sections, that is the stationary and the rotating sections, exhibit little or no motion with respect to each other in the vertical or Z direction while the two sections maintain freedom of rotation with respect to each other around the axis of rotation 31. The gravity fed slurry 30 is, on its downward path, routed through a channel 54 of spiral shape within the inside of the rotating section 36 thus causing and maintaining the rotation of this section 36. By providing a seal 56 within section 36 across the lower extremity of 36 and in a plane perpendicular to the axis 31 of lower section 36, the slurry is prevented from exiting section 36 in the direction of its axis 31. The exit spout 53 forces the slurry 30 to exit section 36 under an angle with its axis 31 thus causing section 36 to rotate around its axis 31.

It is clear from the previous description and from the cross section that is shown in Figs. 3a and 3b that the gravity downward flow of the slurry through channel 54, which has a spiral shape within the inside of the rotating section 36, thus causing and maintaining the rotation of this section 36, provides one means for providing slurry to the surface that is being polished. This gravity flow can be further controlled and selectively augmented by adding varying and adjustable

pressure, which is applied to the slurry while the slurry exits the rotating slurry nozzle. by further enclosing the upper section of tube 28 (not shown in Figs. 3a and 3b) the added and controlled pressure that is exerted on the slurry is contained within tube 28 from where this pressure extends into the rotating section 36 of Fig. 3b. This increased pressure is released through the opening 53 that is provided in the lower surface of tube 36. The same pressure under which the slurry is provided can be used to control the flow rate of the slurry. It is entirely within the means of such a pressure to also control and regulate the amount (flow rate) of the slurry that is provided. In short: the slurry can be released from opening 53 under either gravity feed (no added pressure, the slurry proceeds through channel 54 without additional pressure being applied to the slurry on its downward path through channel 54) or the slurry can be forced out of opening 53 under increased pressure by supplying the slurry to the tube 28 under pressure. The same considerations of slurry supply apply to the slurry that exits as indicated by 68, Fig. 4a, an opening or exit provided in the bottom part 72 of shaft 76.

#### Second embodiment of the present invention

Fig, 4a shows an and alternate method of implementing the rotational aspect of the slurry distribution arrangement. The slurry 60 enters the slurry reservoir 62 and is forced to flow through a channel 66, which is shaped in the form of a spiral. The downward or Z-axis directional motion of the slurry 60 is

in this manner translated into a rotational motion 70, which is transferred to a rotational motion of a shaft 76. The shaft 76 is held in a fixed or stationary position with respect to the slurry reservoir 62 by means of two membranes 64 within the reservoir 62. The shaft 76 does however have freedom of rotation 70 within these membranes 64. An opening or exit point provided within the bottom part 72 of shaft 76 allows the slurry to escape as indicated by 68. This opening is provided under an angle with respect to the X-Y-Z direction forcing the slurry to be broadcast or distributed across the surface of the polishing pad and to impact this surface under an angle. This angle which can be selected and designed to suit any particular application of the present invention.

Fig. 4b shows a top plan view of the implementaion of the second embodiment of the present invention. Indicator 80 further highlights that the slurry reservoir 62 and the membranes 64 within this reservoir are stationary while the head 74 of shaft 76 has freedom of rotation 70.

From the foregoing it will be clear that, although a specific embodiment of the present invention has been described herein for purpose of illustration, various modifications to the present invention may be made without deviating from the spirit and scope of the present invention. Accordingly, the present invention is not limited except as by the appended claims.

## Claims

1. Planarizing apparatus for chemical mechanical planarization of a semiconductor wafer, comprising:

a rotating platform for mounting semiconductor wafers;

a rotating platform for mounting semiconductor polishing pads;

a means for evenly distributing slurry across a polishing pad comprising a stationary slurry feed tube to which a rotating slurry distribution nozzle is attached further comprising at least one opening through which said slurry exits said rotating slurry distribution nozzle wherein the direction of the axis of said opening does not coincide with the X-Y-Z direction of said rotating slurry distribution nozzle; and

a means for controlling rate of slurry flow.

2. The apparatus of claim 1 wherein said platform for mounting said semiconductor wafers consists of a wafer carrier having a flat surface.

3. The apparatus of claim 1 where said platform for mounting semiconductor polishing pads consists of a rigid table or platen having a flat top surface.

4. The apparatus of claim 1 wherein the slurry exits the rotating slurry distribution nozzle under pressure applied to the slurry while the slurry exits said rotating slurry distribution nozzle.

5. The apparatus of claim 1 wherein said at least one opening through which the slurry exits said rotating slurry distribution nozzle consists of a multiplicity of openings wherein the direction of the axis of said openings does not coincide with the X-Y-Z direction is of said slurry nozzle.

6. The apparatus of claim 5 wherein said slurry exits said rotating slurry distribution nozzle under pressure applied to said slurry while said slurry exits said rotating slurry distribution nozzle.

7. The apparatus of claim 1 wherein said means of distribution of said slurry uses pressure applied to said slurry while said slurry exits said rotating slurry distribution nozzle.

8. The apparatus of claim 1 wherein said means for distributing said slurry comprises a multiplicity of openings in said rotating slurry distribution nozzle.

9. The apparatus of claim 8 wherein said distribution of said slurry takes place by means of pressure applied to said slurry during said distribution of said slurry.