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IN-SITE ROLLER DRESSER

(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 chemically and/or physically abrasive slurry. The present invention provides a pad profile conditioning apparatus to condition the polishing pad while the polishing pad is being used to polish semiconductor substrates.

(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 a 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.

The profile of the polishing pad plays an important role in determining good overall polishing results. The polishing pad can, for instance, be profiled thick at the

inner diameter of the polishing pad as compared to the outer diameter of the polishing pad and visa versa. The profile of the polishing pad is typically achieved by trial and error and by adjusting the position of a diamond dresser (see following paragraph). This method of profiling the polishing pad is destructive, time consuming and causes the loss of the polishing pad. Since this measure of the polishing pad profile can only be performed at the end of the useful life of the polishing pad, the wrong profile can only be detected after the polishing pad has served its useful life.

The function of the diamond dresser is to maintain and/or restore the polishing characteristics of the polishing pad to the maximum extent possible during the polishing operation and in doing so to extend the useful life or the operating characteristics of the polishing pad. The diamond dresser performs this function by influencing the polishing action of the polishing pad during its operation. This influencing can take the form of exerting pressure on the polishing pad and in so doing influencing the polishing characteristics of the polishing pad.

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 that rotates in a direction indicated by arrow 24 at a rate in the order of 1 to 100 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 wafer (not shown). The wafer 18 can also be attached to the wafer carrier 26 by the application of a substrate attachment film (not shown) to the lower surface of the wafer carrier 26. 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 18 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.

Accordingly, the subject surface (that is the lower surface) of the substrate 18 is polished by the combination of a chemical polishing action of alkali contained in the polishing agent or slurry 21 and a mechanical polishing action by silica contained in the polishing slurry 21.

US 5,775,983 (Shendon et al.) shows a conical roller for conditioning a pad.

US 5,779,526 (Gill) show a polishing pad conditioning roller.

US 5,681,212 (Hayakawa) shows a disk dresser.

US 5,421,768 (Fijiwara et al.) shows a brush to clean a polishing pad.

US 5,688,360 (Jairath) shows cylindrical and conical polishing pads.

SUMMARY OF THE INVENTION

It is therefore the primary objective of the present invention to provide a polishing device that can realize a high semiconductor wafer throughput and that exhibits uniformity and planarity or evenness of surface in the plane of the surface of the substrate that is to be polished.

The in-site roller dresser that is the subject of the present invention allows for the profile of the pad to be monitored while the roller is dressed or refurbished. This eliminates the need for destructive testing of the polishing pad. The in-site roller dresser at the same time eliminates the need for machine downtime for polishing pad profile determination since the polishing pad profile is dynamically tested and monitored during polishing operations. In conventional arrangements, the

dresser is a disk, in the arrangement of the present invention the dresser is a roller type that can rotate around its axis in either direction. A sensor is provided with the diamond dresser that monitors the surface or profile of the polishing pad. Based on the data obtained by the sensor the diamond dresser can be adjusted which directly controls the polishing pad refurbishing action provided by the dresser.

In the first embodiment of the present invention the in-site roller dresser is manually controlled and adjusted for desired polishing pad profile and in accordance with a visually observed profile of the polishing pad as observed via an electronic display.

In the second embodiment of the present invention the in-site roller dresser is automatically controlled and adjusted for desired polishing pad profile. This adjustment is in accordance with a desired and predetermined polishing pad profile that is contained within the controlling mechanism of the polishing pad dresser.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a Prior Art polishing pad apparatus.

Fig. 2 shows an overview of the mounting of the present invention diamond dresser with respect to the polishing pad and the polishing table.

Fig. 3 shows the mounting of the sensor of the present invention with respect to the polishing pad and the polishing table.

Fig. 4 shows the profile of a polishing pad as can be obtained within the scope of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now more specifically to Fig. 2, there is shown a rotating diamond dresser 20 that is mounted in a suspended manner and in such a manner that the diamond dresser 20 is above the polishing pad 22 and can be brought into physical contact with polishing pad 22. Polishing pad 22 is mounted on top of the polishing table 21. The mounting or suspension of dresser 20 is such that

either of the two extremities of the dresser 20 can move in the Z direction, that is the direction perpendicular to the plane of the polishing pad 22. This movement or rotation is indicated by rotations 16 and 18. The two forces 12 and 14 that are exerted in the Z direction cause this movement.

It must be noted at this time that the operation of the diamond dresser 20 is an operation that may or may not take place concurrent with the polishing action of the polishing pad. The action of the diamond dresser is invoked at the time that it is considered necessary to refurbish or 'dress' the polishing pad. That is the profile of the polishing pad must, after the pad has been used for a period of time, be restored to a new or corrected profile that is required for further and continued polishing operation.

Fig. 3 shows the mounting of the sensor 28 with respect to the polishing pad 22 and the polishing table 21. The sensor 28 can be of a variety of types, for instance a capacitive sensor. The sensor position can be varied in a direction 26, that is parallel to the polishing pad 22. This motion 26 enables the sensor 28 to

measure or track the profile of the polishing pad 22 across the entire surface of the polishing pad 22. These measurements provide a direct feedback of the condition of the profile or surface condition of the polishing pad 22. By increasing force 12 (Fig. 2) with respect to force 14 (Fig. 2), the diamond dresser 20 will exert more pressure on the polishing pad in the center of the polishing pad 22. Inversely, by increasing the pressure of force 14 (Fig. 2) with respect to force 12 (Fig. 2), the diamond dresser 20 will exert more pressure on the polishing pad 22 in the periphery or outer edges of the polishing pad 22. It is thus clear that the diamond dresser 20 has direct control over the shaping of the profile or top surface of the polishing pad 22 in a closed loop control system.

The parameters required to determine the position of the sensor 28 above the polishing pad 22 are the angle of rotation of the polishing pad 22 combined with the position of the movement 26 of the detector 28 along its axis of motion. Since the measurements obtained by the sensor 28 are a direct indication of the profile or top surface of the polishing pad 22 and since this information can be compared directly with a desired

profile or top surface of the polishing pad, it is apparent that the information which directs forces 12 and 14 in Fig. 2 is available which in turn allows for either manual or automatic control or adjustment of the profile or top surface of the polishing pad 22.

Fig. 4 shows how the profile can be displayed and monitored by using an electronic display or monitor. This does allow for human intervention and adjustment. This human intervention however is not in conflict with a completely automatic control system of the profile of the polishing pad where measured (by the sensor) data is compared with stored or required profile data. The adjustment parameters, if any, can automatically adjust the two polishing pad profile control parameters 12 and 14 of Fig. 2.

From the foregoing it will be clear that, although a specific embodiment of the present invention has been described herein for purposes 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.

What is claimed is:

1. An apparatus for chemical mechanical polishing of semiconductor wafers, comprising:

a platform for mounting semiconductor wafers;

a means for rotating said platform for mounting semiconductor wafers;

a platform for mounting semiconductor wafer polishing pad;

a means for rotating said platform for mounting said semiconductor wafer polishing pad;

a means for measuring or observing the profile of said semiconductor wafer polishing pad;

a cylindrical diamond dresser for refurbishing said semiconductor wafer polishing pad;

a means for rotating said cylindrical diamond dresser;

a means for evenly distributing slurry across the surface of said polishing pad; and

a means for controlling the pressure exerted by said diamond dresser on said semiconductor polishing pad.

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



3. The apparatus of claim 1 wherein said means for rotating said platform for mounting semiconductor wafers consists of a rotary actuator or motor.

4. The apparatus of claim 1 wherein said platform for mounting semiconductor wafer polishing pad consists of a polishing table.

5. The apparatus of claim 1 wherein the means for rotating said platform for mounting said semiconductor wafer polishing pad consists of a rotary actuator or motor.

6. The apparatus of claim 1 wherein said cylindrical diamond dresser consists of a cylindrical roller that is mounted in a suspended manner above and in close physical proximity to said semiconductor wafer polishing pad where the direction of the axis of said diamond dresser when in the null or inactivated position is parallel to the plane of said polishing pad and where the dressing characteristics of said diamond roller are uniform along the surface of said cylindrical roller in the direction of the axis of said diamond dresser.



7. The apparatus of claim 6 where said dressing characteristics of said diamond dresser are not uniform along the surface of said cylindrical roller and demonstrate a linear gradient of dressing efficiency with the highest dressing action occurring at the center of said diamond dresser from where the dressing action linearly decreases toward the periphery or edge of said diamond dresser

8. The apparatus of claim 6 where the polishing characteristics of said diamond dresser are not uniform along the surface of said cylindrical roller and demonstrate a linear gradient of dressing efficiency with the highest dressing action occurring at the periphery or edge of said polishing pad from where the dressing action linearly decreases toward the center of said polishing pad.



9. The apparatus of claim 6 where the dressing characteristics of said diamond dresser are not uniform along the surface of said cylindrical roller and demonstrate an exponential gradient of dressing efficiency with the highest dressing action occurring

at the center of said polishing pad from where the dressing action exponentially decreases toward the periphery or edge of said polishing pad.

10. The apparatus of claim 6 where the dressing characteristics of the diamond dresser are not uniform along the surface of said cylindrical roller and demonstrate an exponential gradient of dressing efficiency with the highest dressing action occurring at periphery or edge of said polishing pad from where the dressing action exponentially decreases toward the center of said polishing pad.

11. The apparatus of claim 6 where said dressing characteristics of said diamond dresser are not uniform along the surface of said cylindrical roller and are profiled or graded to exhibit a dressing efficiency with the highest dressing action occurring at the center of said polishing pad from where the dressing action decrease in accordance with the polishing profile of said diamond dresser toward the periphery or edge of said polishing pad.



12. The apparatus of claim 6 where the dressing characteristics of said diamond dresser are not uniform along the surface of said cylindrical roller and are profiled or graded to exhibit a dressing efficiency with the lowest dressing action occurring at the center of said polishing pad from where the dressing action increases in accordance with the dressing profile of said diamond dresser toward the periphery or edge of said polishing pad.

13. The apparatus of claim 1 where said means for controlling the pressure exerted by said diamond dresser on said polishing pad consists of manual control of the forces exerted on the two extremities of said diamond dresser.



14. The apparatus of claim 1 where said means for controlling the pressure exerted by said diamond dresser on said polishing pad consists of an automatic closed loop control system of the forces exerted on said two extremities of said diamond dresser.

15. The apparatus of claim 1 where said means for controlling said pressure exerted by said diamond

dresser on said polishing pad consists of manual control of the forces exerted at said two extremities of said diamond dresser which can, under certain conditions of operation, be preempted by an automatic, closed loop control system of said forces exerted on said two extremities of said diamond dresser.

16. The apparatus of claim 1 where said means for controlling the pressure exerted by said diamond dresser on said polishing pad consists of a closed loop control system for the control of said forces exerted at said two extremities of said diamond dresser which can, under certain conditions of operation, be preempted by manual control of said forces exerted on said two extremities of said diamond dresser.



17. The apparatus of claim 1 wherein the means for measuring or observing the profile of said semiconductor wafer polishing pad consists of a sensor mounted in a plane that is parallel to the plane of said polishing pad and that can be positioned such that it can observe or measure all points contained within the surface of said polishing pad that engage

in or are meant for said semiconductor wafer polishing activity.

18. The apparatus of claim 1 wherein said sensor consists of an electrical mechanical device that can provide measurements of polishing pad profile combined with data of sensor position within the profile such that a presentation of a complete and accurate profile of said polishing pad can be obtained.

19. The apparatus of claim 1 wherein the means for rotating said cylindrical diamond dresser consists of a rotary activator or motor.

20. The apparatus of claim 1 wherein said means for evenly distributing slurry across the surface of said polishing pad is the method of using the slurry drip process.



21. A method for planarizing a semiconductor wafer comprising:
providing a set of one or more semiconductor wafers;
providing a set of one or more abrasive polishing pads
having a suspension medium, a plurality of abrasive

particles fixedly suspended in the suspension medium,
and a planarizing surface with a plurality of exposed
abrasive particles;

translating at least one of said abrasive polishing
pads and said semiconductor wafers with respect to
each other to impart relative motion therebetween;
pressing said semiconductor wafers against said
abrasive particles to remove material from said
wafers; and

engaging a rotating cylindrical shaped non-abrasive
refurbishing element with said planarizing surface,
wherein said non-abrasive refurbishing element removes
waste material from said planarizing surface without
substantially altering said exposed abrasive particles
at said planarizing surface.

22. The method of claim 21 further comprising the step of
varying the pressure applied by said rotating cylindrical
shaped none-abrasive refurbishing element to said polishing
pads thus controlling the rate of polishing pad
refurbishing.



23. The method of claim 21 further comprising the step
of profiling or varying the dressing characteristics

of said rotating cylindrical shaped none-abrasive refurbishing element in the direction of the axis of said cylinder thus further controlling the rate of polishing pad refurbishing.

24. The method of claim 21 further comprising the step of dressing the surface of said rotating cylindrical shaped none-abrasive refurbishing element with diamond particles to further enhance the refurbishing characteristics of said refurbishing element.

25. A method for planarizing a semiconductor wafer comprising:
providing a set of one or more semiconductor wafers;
providing a set of one or more abrasive polishing pads having a suspension medium, a plurality of abrasive particles fixedly suspended in the suspension medium, and a planarizing surface with a plurality of exposed abrasive particles;
translating at least one of said abrasive polishing pads and said semiconductor wafers with respect to each other to impart relative motion therebetween;



pressing said semiconductor wafers against said abrasive particles to remove material from said wafers;

engaging a rotating cylindrical shaped non-abrasive refurbishing element with said planarizing surface, wherein said non abrasive-refurbishing element removes waste material from said planarizing surface without substantially altering said exposed abrasive particles at said planarizing surface;

actuating a polishing pad sensor, for moving said polishing pad sensor in at least one axis in response to a motion control signal;

positioning said polishing pad sensor;

sensing polishing pad profile wherein the polishing pad sensing means has a polishing pad profile output;

comparing said sensed polishing pad profile with a stored or desired polishing pad profile; and

actuating a diamond dresser for controlling refurbishing action of said polishing pads.

