

APERTURED CONDITIONING BRUSH FOR CHEMICAL MECHANICAL PLANARIZATION SYSTEMS

Cross-Reference to Related Applications

5 This application claims the benefit of US Provisional Application No. 60/728,126, filed October 19, 2005 and herein incorporated by reference.

Technical Field

10 The present invention relates to a conditioning brush for use in cleaning the polishing pad of a chemical mechanical planarization (CMP) apparatus and, more particularly, to a conditioning brush formed as disk to include an arrangement of both bristles and apertures to facilitate the cleaning operation.

Background of the Invention

15 In the field of chemical mechanical planarization (CMP), a process known as “pad conditioning” or “pad dressing” is used to restore the surface of the polishing pad and remove surface glazing by dislodging particulates and spent polishing slurry from the pad. Pad conditioning may be performed “ex-situ” (i.e., conditioning the polishing pad between wafer polishing cycles) or “in-situ” (i.e., concurrent with, or during, a wafer
20 polishing cycle). In a typical prior art “in-situ” pad conditioning process, a fixed abrasive conditioning disk is moved across the pad surface to remove a small amount of pad material and debris, thus creating new asperities in the pad surface to allow for the free flow of the polishing slurry. The removed pad material and debris then combine with the slurry dispensed during the polishing process and are passively carried away
25 from the pad.

 Particulate generation is an on-going problem with known processes of conditioning CMP polishing pads, where particles from any one of the CMP apparatus, slurry, wafer, pad or conditioner remain on the pad’s surface after conditioning. Any individual particle remaining on the pad may later scratch a wafer surface during
30 polishing, creating a potential defect or contributing to polishing non-uniformity. For example, a particle disposed on the polishing pad may create a high spot that locally concentrates the forces between the polishing pad and the wafer. If large numbers of particles are present on the polishing pad, local disparities in polishing rates may result in polishing non-uniformities.

In certain types of CMP, for example tungsten CMP or post-planarization buffing, a relatively porous polishing pad is utilized, where this type of pad is characterized by a microstructure exhibiting vertically oriented, open pores. Various referred to as a “soft” polishing pad, fibrous polishing pad, and the like, such pads may consist of a poromeric coating over a felt substrate, the poromeric coating comprising vertically oriented large pores sitting on top of a smaller, microporous felt layer. The polishing slurry and debris that settles within the lower regions of the pores within these pads can become nearly stagnant and develop recirculating eddy flows that trap even more material and limit the polishing/buffing capabilities of the pad. Over time, the trapped/recirculated materials can resurface and damage the wafer, dilute the process materials, or both. The conventional diamond abrasive conditioning disk is not effective in removing this deeply-trapped material, and has the additional drawback of quickly wearing away the porous pad material. As an alternative, a conditioning “brush” may be used to scour the porous pad surface in a manner that is likely to dislodge deeply embedded particles and move them into the waste stream. Prior art CMP systems utilizing a conditioning brush, however, require a large amount of slurry and rinse waters in an attempt to displace these particulates.

US Patent 6, 386,963 issued to S. Kenji et al. on May 14, 2002 discloses a conditioning element that is formed to support a combination of an abrasive surface and brush bristles. In the Kenji et al. structure, abrasive conditioning material is formed on a ring-shaped plate that is attached to the bottom surface of the conditioner head, leaving the center region of the element open. A plurality of brush bristles is formed on a small disk that is then attached to the center region of the abrasive ring. One problem with this particular arrangement, however, is that the limited positioning of the bristles in the central region of the conditioning element allows some particulate matter to be unaffected by the bristles and thus remain embedded within the pad. Further, the differential in height between the abrasive material and the bristles will likely result in inconsistent conditioning behavior and wear rates for the pad material.

Another prior art arrangement is disclosed in US Patent 7,033,253, issued to F.L. Dunn on April 25, 2006. In the Dunn arrangement, brush bristles are disposed in any desired pattern on the bottom surface of a conditioning element, with the remaining portion of the surface covered by an abrasive material. The relative hardness of the bristles and the abrasive material may be controlled to best condition a particular pad material.

While both the Dunn and Kenji et al. arrangements provide an improvement in implementing a conditioning brush within a conventional CMP conditioning element, problems remain in that the material dislodged by the bristles (and the abrasive material) may be re-introduced to the pad surface before the conditioning process has an opportunity to flush the debris away.

Thus, a need remains in the art for a conditioning arrangement that provides the brushing motion preferred for large pore, fibrous or soft polishing pads/felts, while efficiently removing the debris from the polishing pad surface.

Summary of the Invention

The need remaining in the prior art is addressed by the present invention, which relates to a conditioning brush for use in cleaning the polishing pad of a chemical mechanical planarization (CMP) apparatus and, more particularly, to a conditioning brush formed as a disk to include an arrangement of both bristles and apertures to facilitate the cleaning operation.

In accordance with the present invention, an apertured conditioning disk is formed to support a plurality of brush bristles in any desired configuration. The apertures in the conditioning disk are used to allow for the efficient evacuation of the effluent created during the conditioning process, including both the debris dislodged by the bristles and slurry material remaining in the pores. The apertures may also be used to introduce conditioning fluids to assist in the conditioning process. The utilization of the apertures to evacuate the effluent (via an attached vacuum source) overcomes problems associated with the prior art by immediately removing the dislodged and/or accumulated material from the pad surface before it has an opportunity to be re-incorporated into the polishing pad.

In one embodiment of the present invention, the conditioning disk is formed of a stiff material capable of supporting the bristles in position such that the bristles have a slight stand-off from the bottom surface of the disk, allowing for the conditioner head to maintain a vacuum seal while the bristles engage the pores of the pad material. In an alternative embodiment, the conditioning disk may be formed of an abrasive material to permit simultaneous abrading and brushing of the polishing pad surface. In yet another embodiment, the bristles themselves may be formed of an abrasive-filled composite material.

Other and further embodiments and aspects of the present invention will become apparent during the course of the following discussion and by reference to the accompanying drawings.

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Brief Description of the Drawings

Referring now to the drawings,

FIG. 1 illustrates an exemplary CMP system including a conditioning brush formed in accordance with the present invention;

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FIG. 2 is a top view of system of FIG. 1;

FIG. 3 is a top view of an exemplary conditioner head/conditioning brush formed in accordance with the present invention, include a plurality of bristles and a separate plurality of apertures within the brush;

FIG. 4 is a cut-away side view of the conditioning brush of FIG. 3;

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FIG. 5 is a simplified view of the arrangement of FIG. 4, illustrating in particular the intrusion of the bristles within the pores of the polishing pad;

FIG. 6 is a top view of an alternative embodiment of the present invention, with the bristles disposed in V patterns and the apertures disposed therebetween, the view of FIG. 6 illustrating the placement of only a few bristles;

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FIG. 7 is a top view of the same embodiment as FIG. 6, in this case with a complete set of bristles in place; and

FIG. 8 is a top view of yet another embodiment of a conditioning brush formed in accordance with the present invention, in this case, the bristles and apertures disposed as a plurality of arms configured in a spiral pattern from the center.

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Detailed Description

FIG. 1 contains a perspective view of an exemplary CMP system 10 formed in accordance with the present invention for brushing the surface of a polishing pad used to polish/planarize surface S of a semiconductor wafer 12. In operation, surface S of wafer 12 is positioned against a polishing pad 14 through an arrangement not shown (and not relevant to the subject matter of the present invention). Wafer 12 is rotated on polishing pad 14, as shown by the arrow in FIG. 1. Polishing pad 14 itself is secured to a rotating, orbital or linear platen 16. A stream of polishing slurry, generally containing an oxidizer, abrasive and/or ultrapure water (UPW) is poured on polishing pad surface 18

from a conventional polishing slurry delivery apparatus (not shown). The polishing slurry, in cooperation with the rotating motion of wafer 12 and pad 14, acts to remove a portion of the wafer's surface unevenness.

As mentioned above, it is necessary to "condition" or "redress" surface 18 of polishing pad 14 to remove the glaze/build-up of polishing slurry from the pad's surface, as well as to remove accumulated debris and other materials associated with the polishing process itself. In the arrangement as shown in FIG. 1, an end effector arm 20 is used to perform the conditioning process, where arm 20 moves in an arc A about a fixed shaft 21 and simultaneously provides a rotational motion R and a downward force F on an attached conditioner head 22. FIG. 2 shows, in a top view, the relative motions of arm 20, conditioner head 22 and polishing pad 14, illustrating in particular arc movement A of arm 20 across the surface of polishing pad 14. In an alternative embodiment, the end effector can be configured to cover a full radius of polishing pad 14, such that it conditions surface 18 without the need of the arc-based sweeping motion. The apertured conditioning brush of the present invention, as discussed in detail below, may be used with either embodiment. The apertured conditioning brush of the present invention is equally applicable for use in systems that include polishing felts instead of polishing pads, where the felts have the same deep nap configuration as the soft polishing pads discussed above. That is, the polishing pads and polishing felts best suited for conditioning with the apertured brush of the present invention are characterized by a microstructure exhibiting vertically oriented, open pores (e.g., poromeric coating), capable of trapping debris and fluids in recirculating eddies, as discussed above.

Referring back to FIG. 1, conditioner head 22 is shown as further comprising an apertured conditioning brush 30, formed in accordance with the present invention to perform the functions of: (1) brushing surface 18 of polishing pad 14 to loosen debris lodged deep within pad 14; (2) evacuating the conditioning fluid, dislodged debris and/or spent polishing fluid (hereinafter referred to as "effluent") from the vicinity of polishing pad 14; and, possibly, (3) introducing conditioning fluids onto surface 18 of pad 14. Conventional abrasive conditioning disks are not always successful in removing debris deeply embedded within the pores of some of the more fibrous polishing pads and polishing felts. A plurality of bristles, as described below, are included in contacting surface 31 of conditioning brush 30 and will enter the deep pores of the fibrous polishing pad to dislodge accumulated debris. Apertures formed within conditioning brush 30

provide a channel for the removal of effluent through a vacuum path, where in FIG. 1 conditioner head 22 is illustrated as including a vacuum outlet port 37 coupled to a vacuum source 50. Conditioning fluids may be used in combination with the surface brush to efficiently remove accumulated debris, where the conditioning fluids may be disposed onto the surface of polishing pad 18 through an inlet port 39 in conditioner head 22.

FIG. 3 contains a top view of an exemplary apertured conditioning brush 30 as fixed within conditioner head 22, where illustrated surface 31 will contact the surface of a polishing pad during conditioning. There exist various arrangements for attaching conditioning brush 30 to conditioner head 22, where a particularly suitable arrangement that maintains apertured alignment between brush 30 and the remaining components of conditioning disk 22, using a magnetic-based hex key arrangement, is disclosed in co-pending application Serial No. 10/819,754, filed April 7, 2004, and assigned to the assignee of this application. Referring to FIG. 3, a plurality of apertures 34 are shown, where apertures 34 are surrounded by a plurality of bristles 40 that function to provide the soft pad brushing in accordance with the present invention. FIG. 4 is a cut-away side view of the arrangement of FIG. 3. Bristles 40 function to dislodge particulate matter from the fibrous pores below surface 18 of pad 14 (see FIG. 5) and push the effluent through apertures 34 toward vacuum outlets 35 around the outer periphery of conditioner head 22, as shown in FIG. 4. The rotation of conditioner head 22 will assist in moving the effluent outward through vacuum outlets 35 into an evacuation channel 36. The effluent is then pulled, by vacuum force, through vacuum exit port 37 on conditioner head 22, providing an efficient cleaning of polishing pad surface 18. In the particular embodiment as illustrated in FIG. 4, conditioning brush 30 further comprises a channel system 32 coupled to apertures 34 to allow for the introduction of conditioning fluids, if desired, via inlet port 39 of conditioner head 22.

FIG. 5 illustrates, in a simplified view, the relationship between pad 14, conditioner head 22 and bristles 40. As mentioned above, bristles 40 are formed to stand off a predetermined distance below conditioner head 22, allowing for bristles 40 to enter the deep, soft-walled pores of polishing pad 14 during conditioning, while maintaining the integrity of the vacuum connection or seal between pad 14 and conditioner head 22. As shown, bristles 40 extend deep enough into vertically-oriented open pores P of pad 14 so that the accumulated debris may be dislodged as conditioning brush 30 sweeps across the pad surface. The length of bristles 40 is controlled, however, so that sidewalls 22W

of conditioner head 22 maintain contact with surface 18 of polishing pad 14. It is to be understood that the particular dimensions of the bristles will be a function of parameters such as, but not limited to, the depth of the pores of the fibrous polishing material, the pad material itself, the downforce applied by the conditioner head to the polishing pad, and the applied vacuum force. The contact between surface 18 and conditioner head sidewalls 22W is required so that the vacuum force/leakage is controllable and the debris will continue to be evacuated from pad surface 18, through conditioning brush 30 and exit from vacuum outlet port 37 of conditioner head 22. Bristles 40 comprise an inert material, such as nylon, that will not react with any of the chemicals that may be present at the pad surface, such as polishing slurry, conditioning liquids, wafer debris material and the like. In a specific embodiment, bristles 40 may be formed of an abrasive-filled composite material that will provide an even greater amount of cleaning energy to surface 18 of conditioning pad 14.

FIG. 6 is a top view of an alternative conditioning brush 60, where in this particular embodiment, bristles 40 are disposed in V-like patterns 62 across surface 61 of brush 60. For the sake of clarity, only a portion of bristles 40 are shown in position in FIG. 6. FIG. 7 is a top view of conditioning brush 60 with a complete set of bristles 40 in place. Referring back to FIG. 6, a set of apertures 34, is shown as disposed between each V pattern 62 of bristles. Apertures 34 function in the manner discussed above to dispense conditioning liquids and evacuate effluent from surface 18 of polishing pad 14.

FIG. 8 contains a top view of yet another embodiment of an apertured conditioning brush formed in accordance with the present invention. In this arrangement, a conditioning brush 70 comprises bristles 40 arranged in a set of spiral arms 72 emanating from a central area 74 of brush 70. Apertures 34 are similarly arranged in a spiral arm configuration, with a separate set of apertures 34 disposed between adjacent sets of bristles 40. As with the arrangement described above in association with FIG. 4, bristles 40 and apertures 34 of brush 70 are designed so as to channel the debris toward the outer periphery for efficient removal through evacuation.

It is to be understood that the apertured conditioning brush of the present invention can be used in association with any type of polishing pad, or polishing felt, but is preferably intended for use with the fibrous polishing and/or buffing pads as discussed above that consist of deep, soft-walled, vertically-oriented pores conducive to the creation of recirculating eddy currents deep within the pad that trap the debris and spent slurry. The apertured conditioning brush of the present invention may also be utilized

with conventional (i.e., relatively “hard”) polishing pads, where abrasive bristles provide sufficient surface abrasion, with lower pad wear rates, than traditional abrasive conditioning disks. Moreover, the arrangement of the bristles and apertures across the surface of the conditioning brush may be modified, as need be, to suit the needs of the particular CMP system. Indeed, the subject matter of the present invention is intended to be limited only by the scope of the claims appended hereto.

What is claimed is:

1. An apparatus for conditioning a polishing pad utilized in a chemical mechanical planarization (CMP) system, the apparatus comprising
a conditioner head housing including an inlet port for introducing conditioning
5 fluids onto the polishing pad and an outlet port for evacuating conditioning effluent from a conditioned area of said polishing pad; and

a conditioning disk disposed within the housing so as to contact a top major surface of the polishing pad surface during conditioning, the conditioning disk comprising

10 a brush for sweeping the top major surface of the polishing pad and dislodging debris therefrom, and

a plurality of apertures for dispensing conditioning fluids to, and evacuating conditioning effluent from, the polishing pad.

2. An apparatus as defined in claim 1 wherein the brush comprises a plurality of
15 bristles.

3. An apparatus as defined in claim 1 wherein the conditioning disk comprises an abrasive material.

4. An apparatus as defined in claim 2 wherein the plurality of bristles comprises an inert material.

20 5. An apparatus as defined in claim 4 wherein the inert material comprises nylon.

6. An apparatus as defined in claim 2 wherein the plurality of bristles comprises a composite abrasive-filled material.

7. An apparatus as defined in claim 2 wherein the plurality of bristles is disposed in a series of nested V-patterns across the conditioning disk, with the apertures disposed
25 therebetween.

8. An apparatus as defined in claim 2 wherein the plurality of bristles is disposed in a series of concentric circles across the conditioning disk.

9. An apparatus as defined in claim 2 wherein the plurality of bristles is disposed in a plurality of spiral arms emanating from a central region of the conditioning disk.

30 10. An apparatus as defined in claim 2 wherein the plurality of bristles stand off a predetermined distance below the conditioner head housing so as to allow for the bristles to enter the polishing pad material without interrupting the evacuation of effluent therefrom.

11. An apparatus as defined in claim 1 wherein the conditioning disk further comprises a hex key alignment structure for providing aligned attachment between the conditioning disk and the conditioner head housing, providing alignment between the plurality of apertures of said conditioning disk and the inlet and outlet ports of said conditioner head housing.

12. A conditioning disk for use in dressing a polishing pad within a chemical mechanical planarization (CMP) apparatus, the conditioning disk comprising a plurality of apertures for dispensing conditioning fluids to, and evacuating conditioning effluent from, the polishing pad surface; and

a brush for sweeping across the fibrous polishing pad and dislodging debris therefrom.

13. A conditioning disk as defined in claim 12 wherein the brush comprises a plurality of bristles.

14. A conditioning disk as defined in claim 12 wherein the disk comprises an abrasive material suitable for dressing the polishing pad.

15. A conditioning disk as defined in claim 13 wherein the plurality of bristles comprises an inert material.

16. A conditioning disk as defined in claim 15 where the inert material comprises nylon.

17. A conditioning disk as defined in claim 13 wherein the plurality of bristles comprises a composite abrasive-filled material.

18. A conditioning disk as defined in claim 13 wherein the plurality of bristles is disposed in a series of nested V-patterns across the conditioning disk, with the plurality of apertures disposed therebetween.

19. A conditioning disk as defined in claim 13 wherein the plurality of bristles is disposed in a series of concentric circles across the conditioning disk.

20. A conditioning disk as defined in claim 13 wherein the plurality of bristles is disposed in a plurality of spiral arms emanating from a central region of the conditioning disk.

21. A method of conditioning a polishing pad utilized in a chemical mechanical planarization system, the method comprising the steps of:

presenting an apertured conditioning brush against a top major surface of the polishing pad, the apertured conditioning brush comprising a plurality of bristles and a plurality of apertures;

providing a downforce on the apertured conditioning brush sufficient to push the plurality of bristles into the pores of the polishing pad;

moving said apertured conditioning brush across the surface of said polishing pad such that the plurality of bristles dislodge accumulated debris from the pores; and

5 applying a vacuum force sufficient to evacuate the dislodged accumulated debris through the plurality of apertures and away from the chemical mechanical planarization system.

22. The method as defined in claim 21 wherein the method further comprises the step of

10 dispensing processing fluids onto the surface of the polishing pad as the apertured conditioning brush is moved across the surface of the polishing pad.

23. The method as defined in claim 21 wherein the applied downforce and the vacuum force are controlled so as to allow for the plurality of bristles to engage the pores of the polishing pad without interrupting the vacuum-controlled evacuation of the

15 dislodged debris therefrom.