

FIXED ABRASIVE LINEAR POLISHING BELT AND SYSTEM USING THE SAME

This application is related to co-pending U.S. App. Ser. No. 09/386,741, entitled "Unsupported Chemical Mechanical Polishing Belt," filed August 31, 1999, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates generally to equipment for processing semiconductor wafers. More particularly, the present invention relates to a fixed abrasive polishing belt and an associated linear polisher for chemical mechanical polishing of semiconductor wafers.

BACKGROUND

Chemical mechanical polishing (CMP) is used for planarizing semiconductor wafers during processing of the wafers. Many steps in the manufacture of semiconductor devices produce a highly irregular surface on the front side of the wafer which contains the semiconductor devices. In order to improve the manufacturability of the devices on the wafer, many processing steps require planarizing the wafer surface. For example, to improve the uniformity of deposition of a metal interconnect layer, the wafer is planarized prior to deposition to reduce the peaks and valleys on the surface over which the metal is deposited.

In conventional planarization technology, a semiconductor wafer is supported face down against a moving polishing pad. Two types of polishing or planarizing apparatus are commonly used. In rotary planarizing technology, a wafer is secured on a chuck and is brought into contact with a polishing surface. The polishing surface may include a fixed abrasive for contacting and polishing the wafers. Use of fixed abrasive polishing pads typically requires a subpad in order to achieve the desired planarization property and to control the polishing pressure distribution across the wafer surface. An example of a fixed abrasive pad useful in a rotary planarization system is disclosed in U.S. Pat. No. 5,692,950,

issued to Rutherford, et al. In that patent, the fixed abrasive material is adhered to the rigid layer (e.g., polycarbonate), which then is adhered to a soft resilient layer, such as a foam.

In a second type of planarization technology, called linear planarizing technology, an endless belt travels over two or more rollers. The wafer is placed against the moving polishing surface of the belt. An example of such a system is the TeresTM CMP System manufactured by Lam Research Corporation, Fremont, California, which is disclosed in U.S. Pat. Nos. 5,692,947, 5,762,536, and 5,871,390, and in commonly assigned co-pending U.S. App. Serial No. 09/386,741, entitled "Unsupported Chemical Mechanical Polishing Belt," filed August 31, 1999.

While the conventional linear belt technology has been very successful, room for improvement remains. For example, fixed abrasive polishing pads, such as those used in rotary planarization systems, have heretofore been difficult to use on linear planarization systems. The difficulty arises because the rigid material used to support the fixed abrasive materials does not readily bend over the rollers of the linear systems.

Accordingly, there is a need in the art for an improved polishing belt for linear CMP systems that allows for the use of fixed abrasive materials.

SUMMARY

By way of introduction only, an improved polishing belt for a chemical mechanical planarization (CMP) system is formed from a fixed abrasive material attached to a top surface of an endless loop support layer. The endless layer can be any suitable polymeric material having sufficient strength, durability and flexibility.

The foregoing discussion of the preferred embodiments has been provided only by way of introduction. Nothing in this section should be taken as a limitation on the following claims, which define the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the linear chemical mechanical polishing system according to a preferred embodiment of the invention;

FIG. 2 is a side view of the system of FIG. 1;

FIG. 3 is a side view of a first embodiment of a belt for use in the system of FIG. 1;

FIG. 4 is a side view of a second embodiment of a belt for use in the system of FIG. 1; and

FIG. 5 is an exploded perspective view of a belt for use in the system of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and initially to FIGURES 1 and 2, a chemical mechanical polishing or planarization (CMP) system is shown generally at 100. The system is modeled on the TeresTM CMP System manufactured by Lam Research Corporation, Fremont, California, and described in U.S. Pat. Nos. 5,692,947, 5,762,536, and 5,871,390, all of which are incorporated by reference herein in their entireties. The system 100 includes an endless belt 102 tensioned between a first roller 104 and a second roller 106. The system 100 also includes a platen 108, a polishing head 110, and a wafer carrier 118 within the polishing head 110. The system 100 in the illustrated embodiment is adapted for planarization of semiconductor wafers such as the semiconductor wafer 116. However, the operative principles embodied in the system 100 may be applied to chemical mechanical polishing of other workpieces as well.

The rollers 104, 106 are mounted on spindles 105, 107, respectively. The rollers 104, 106 include roller pads 144, 146 and are spaced to retain the belt 102 and move the belt 102 to permit linear planarization of the wafer 116. The rollers 104, 106 are turned by activation of spindle 105 or spindle 107 by, for example, an electric motor (not shown) in the direction indicated by the arrow 122. The rollers 104, 106 thus form a transport means for moving the belt in a continuous loop past the workpiece, wafer 116. Other transport means include combinations of wheels,

pulleys and tensioning devices which maintain proper tension on the belt 102, along with their associated drive elements such as electric motors and mechanical linkages. Operational parameters such as the speed and tension of the belt 102 are controlled through the rollers 104, 106 by a controller (not shown). The controller may include a processor or other computing device which operates in response to data and instructions stored in an associated memory. Operation and control of the system 100 is more fully described in U.S. Patent Nos. 5,692,947, 5,762,536, and 5,871,390 referred to above.

The wafer 116 is mounted on the polishing head 110. The wafer 116 may be mounted and retained in place by vacuum force or by any other suitable mechanical technique. The polishing head 110 is mounted on an arm and is movable to an extent under control of the controller. The polishing head 110 applies a polishing pressure to the wafer 116 against the belt 102. The polishing pressure is indicated in FIG. 1 by the arrow 126.

To further control the polishing pressure, the platen 108 is located opposite the polishing head 110 below the wafer 116. The belt 102 passes between the front surface 117 of the wafer 116 and the platen 108. The platen 108 applies pressure to the belt 102, for example by direct contact with the belt 102 or by supplying pressurized air or water to the underside of the belt. In some applications, the platen 108 is arranged to apply pressure in controllable zones or areas of the platen 108 under control of the controller (not shown). For example, the zones may be arranged radially on the surface of the platen 108. This controlled application of pressure through the platen 108 allows the belt 102 to polish uniformly across the surface 117 of the wafer 116.

A dispenser 112 dispenses a liquid agent or slurry 113 onto the belt 102. The liquid or slurry 113 is an important component of the chemical mechanical polishing process. The exact components of the slurry are chosen based on the material to be polished or planarized. For example, the slurry components for planarizing a silicon dioxide layer on the surface 117 of the wafer 116 will differ from the slurry components for planarizing a metal layer on the surface 117. Similarly, the slurry components appropriate for a tungsten metal layer will be

different from the components for a copper layer. For uniform planarization or polishing, it is important that the liquid or slurry be distributed evenly across the surface 117 of the wafer 116. The liquid or slurry 113 does not include any loose abrasive components.

The system optionally includes a conditioner 115 that treats the surface of the belt 102 to keep the belt's roughness or abrasiveness relatively constant. As the belt 102 planarizes or polishes the wafer 116, there is some deposit of the material removed from the wafer 116 on the surface of the belt 102. If too much material from the surface 117 of the wafer 116 is deposited on the belt 102, the removal rate of the belt 102 will drop quickly and the uniformity of abrasion across the wafer will be degraded. The conditioner 115 cleans and roughens the surface of the belt 102. A preferred conditioner is disclosed in co-pending U.S. App. Ser. No. 09/188,779, entitled "Method and Apparatus for Conditioning a Polishing Pad Used in Chemical Mechanical Planarization," filed November 9, 1998, the entire disclosure of which is incorporated herein by reference.

The belt 102 is preferably an endless loop fixed abrasive polishing belt with no supplementary reinforcing or supporting components such as stainless steel, reinforcing fibers or fabric. FIG. 3 is a schematic side-view of a portion of a first embodiment of the belt 102. The belt 102 includes a fixed abrasive material 201 substantially coextensive with a top surface of a support layer 205, which is in the form of an endless loop (as shown in FIGURES 1 & 2). The fixed abrasive material provides the surface for polishing the front surface 117 of wafer 116, and the support layer 205 provides the mechanical strength for mounting, tensioning and tracking the belt on the rollers 104, 106. The support layer 205 is preferably manufactured of a single, substantially uniform layer of polymeric material, by a process such as hot cast molding. The polymeric material is of a substantially uniform thickness and structure. Thus, the belt 102 is manufactured without reinforcing or supporting layers or supporting components, such as aramid fibers, fabric or backing materials such as stainless steel.

The fixed abrasive material may be any suitable abrasive known in the art. Typically, the abrasive material will be an aggregate of abrasive particles. The

abrasive materials include, but are not limited to, particles of oxide compounds, such as oxides of cerium, silicone, aluminum, tantalum, and manganese; carbide compounds, such as black silicon carbide, green silicon carbide, boron carbide, tungsten carbide, titanium carbide, diamond; nitrides compounds such as silicon nitride, cubic boron nitride, hexagonal boron nitride; and mixtures thereof. Especially preferred abrasive materials are those disclosed in U.S. Pat. Nos. 5,692,950 and 5,958,794, both of which are incorporated herein by reference in their entireties.

In general, the abrasive material preferably has a thickness of about 10-100 micrometers, and more particularly, about 30-70 micrometers. The size of the abrasive particles making up the abrasive material depends in part upon the particular composition of the abrasive material and any liquid used during the process. Abrasive particles having an average particle size no greater than about 5 micrometers are preferred. Even more preferred are abrasive articles in which the average abrasive particle size is no greater than 1 micrometer. In a most preferred embodiment, the particle size is about 30-70 nanometers.

To avoid harming the surface of the semiconductor wafer (particularly where the wafer surface is a metal oxide-containing surface such as a silicon dioxide-containing surface), the abrasive particles may have a Mohs hardness value no greater than about 8. The abrasive particles may be used in combination with filler particles. Examples of preferred filler particles include carbonates (e.g., calcium carbonate), silicates (e.g., magnesium silicate, aluminum silicate, calcium silicate, and combinations thereof), and combinations thereof. Plastic filler particles may also be used. The abrasive particles preferably are resistant to the liquid medium such that their physical properties do not substantially degrade upon exposure to the liquid medium.

Also preferred are abrasive materials that include a plurality of abrasive composites arranged in the form of a pre-determined pattern. At least some of the composites may be precisely shaped abrasive composites. All of the composites preferably have substantially the same height. The composite height preferably is

no greater than about 100 microns. Moreover, the abrasive article preferably includes at least about 1,200 composites per square centimeter of surface area.

Preferably, substantially all of the abrasive composites have substantially the same shape. Examples of representative shapes include cubic, cylindrical, prismatic, rectangular, pyramidal, truncated pyramidal, conical, truncated conical, cross, post-like with a flat top surface, and hemispherical shapes, as well as combinations thereof. The abrasive composites are preferably spaced apart from each other. For example, they may be provided in the form of elongated ridges spaced apart from each other (such that a channel forms between a pair of composites).

The support layer 203 can be any suitable polymeric material with sufficient strength, flexibility, and durability, and includes a wide range of rubbers and plastics. Particularly preferred rubbers and plastics include, but are not limited to, polyurethanes, polyureas, polyesters, polyethers, epoxies, polyamides, polycarbonates, polyetheylenes, polypropylenes, fluoropolymers, vinyl polymers, acrylic and methacrylic polymers, silicones, latexes, nitrile rubbers, isoprene rubbers, butadiene rubbers, and various copolymers of styrene, butadiene, and acrylonitrile. The polymeric material can be thermoset or thermoplastic, and solid cellular. A solid layer is preferably uniformly solid throughout its length and cross section. In cellular layers, the cells can be open or closed and can be formed by any suitable means, including but not limited to blowing, expansion, frothing, and inclusion of hollow microelements. In one application, the polymeric material is a microcellular polyurethane having cells or voids on the order of 0.1 to 1000 micrometers in size. The belt should be sufficiently elastic to maintain tension during use, i.e., not to relax and loosen during use. The belt may be expected to operate at temperatures ranging from -60 to +150 °C.

Especially preferred polymeric support layer include a SCAPA[®] belt, manufactured by SCAPA Precision Belts of Salem, New Jersey, and the IC-1000 pad manufactured by Rodel, Inc., of Newark, Delaware.

The fixed abrasive material 201 is attached to the support layer 205 by any suitable attachment material 203. The preferred attachment material 203 is a pressure sensitive adhesive (e.g., in the form of a film or tape). Representative examples of pressure sensitive adhesives suitable for this purpose include those based on latex crepe, rosin, acrylic polymers and copolymers (e.g., polybutylacrylate and other polyacrylate esters), vinyl ethers (e.g., polyvinyl n-butyl ether), alkyd adhesives, rubber adhesives (e.g., natural rubber, synthetic rubber, chlorinated rubber), and mixtures thereof. One preferred pressure sensitive adhesive is an isooctylacrylate:acrylic acid copolymer. The pressure sensitive adhesive is preferably laminated or coated onto the back side of the abrasive article using conventional techniques.

As noted and described above, in its simplest embodiment, the support layer 203 is formed of a single layer of polymeric material, such as a polyurethane. In alternative embodiments, the belt 102 can have multiple layers. For example, a second layer or even a third layer can be combined with the polymeric support layer. The additional layers can be made of any suitable polymeric material including rubbers or plastics. By putting a softer sublayer beneath the harder support layer increases the overall rigidity of the belt 102 but still allows enough softness so that the polishing layer can flex to conform to the surface of the wafer 116, and to be able to bend around rollers 104, 106. Thus, by adding additional layers, the polishing performance of the belt 102 can be tailored to the workpiece or to the CMP system.

FIG. 4 illustrates an alternative embodiment of the belt having multiple sublayers. The belt 402 includes a fixed abrasive material 401 attached by an attachment material 403 to a support layer 405. Suitable fixed abrasive materials, attachment materials, and polymeric materials are the same as those already described. A bottom side of the support layer 405 is attached to polymeric sublayer 407. The polymeric sublayer 407 generally is any polymeric material that is softer and more porous than the polymeric support layer 403. Suitable materials for the polymeric sublayer 407 generally include polymeric foams. An especially preferred sublayer is the Thomas West Pad 817 manufactured by

Thomas West, Inc., of Sunnyvale, California. The bottom side of the polymeric layer is in turn attached to a stainless steel layer 409. Because the second sublayer is a soft, highly porous polymeric material, it allows the belt to maintain the flexibility needed to ride around the rollers without being damaged, while at the same time providing the durability associated with a steel belt.

The belts can have any suitable dimensions necessary for effective operation. Different polishing tools may require different belt lengths. Different workpiece sizes may require different belt widths. Also, different types of polishing may require different overall thicknesses and different relative thicknesses of multiple layers. Either the top or bottom surfaces of the belt can be convex or concave or otherwise shaped to match the profile of the workpiece being polished or to match the rollers or supporting structures below the belt.

Exemplary dimensions for the belt 102 include a thickness of 0.020 – 0.200 inch and a nominal inner length of 90 – 110 inches. In the illustrated embodiment, the belts are sized for use with the TeresTM CMP system available from Lam Research Corporation, Fremont, California.

The edges of the belts may be smooth, textured, or patterned. The edges may contain holes or other physical features that serve a functional purpose, such as aiding in alignment and tracking of the belt in use or such as aiding in triggering or counting. The edges of the belts and any related features may be formed during molding or may be created in a secondary manufacturing operation such as cutting, drilling, lathing or punching.

The belts can have holes that penetrate all layers. FIG. 5 is a perspective view of a portion of the belt 102. In FIG. 5, a viewing hole 502 has been cut in the belt 102 to expose a portion of the workpiece, wafer 116 (see FIG. 1) during polishing. Further, a trigger hole 504 has been formed in the belt 102 and is associated with the viewing hole 502. The holes are useful for allowing slurry transport or for optically monitoring the condition of the workpiece during polishing.

Thus, the chemical mechanical polishing system 100 of FIG. 1 includes a monitoring system 135 (see FIG. 2). The monitoring system 135 persistently or

periodically shines light on the belt 102. As the viewing hole 502 passes the monitoring system 135, the trigger hole 504 engages a sensor (not shown) to indicate to the monitoring system 135 that the viewing hole is present. In response the monitoring system 135 shines light or other energy on the belt 102 in the vicinity of the viewing hole 502 and also measures the light or other energy reflected back from the viewing hole. By measuring the energy and its variation, the measuring system can provide an indication of the polishing progress of the CMP system 100. The trigger hole 504 may be placed with any suitable relation to the viewing hole 502. Further, a plurality of viewing holes such as the viewing hole 502 may be formed in the belt. Additional holes increases the acquisition frequency or number of data samples collected per revolution of the belt 102.

The belt 102 can have various depressions or protuberances. The belt 102 or certain areas of the belt 102 may be transparent to electromagnetic radiation or may be affixed with membranes or sheets or plugs that serve as transparent windows or optical pathways for use in monitoring the condition of the workpiece during polishing. Thus in an optional embodiment illustrated in FIG. 5, an optically clear panel 506 is positioned over the viewing hole 502. The belt may contain any of various types of sensors that may be used to monitor conditions of the belt, slurry, and workpiece during polishing.

The belts of the present invention can be made by any suitable manufacturing method. Examples of methods include but are not limited to extrusion, injection molding, hot casting, pressing, rotational molding, and centrifugal molding. A belt with multiple layers can be made by directly forming one layer to the next, as noted above.

While a particular embodiment of the present invention has been shown and described, modifications may be made. It is therefore intended in the appended claims to cover all such changes and modifications which follow in the true spirit and scope of the invention.

WE CLAIM:

1. A belt for polishing a workpiece in a linear chemical mechanical polishing system, the belt comprising:
a support layer forming an endless loop; and
at least one fixed abrasive material attached with at least one side of said support layer.
2. The belt of claim 1, wherein said support layer comprises a polymeric material.
3. The belt of claim 2, wherein said at least one fixed abrasive material is substantially coextensive with said at least one side of said polymeric support layer.
4. The belt of claim 1, wherein said at least one abrasive material is attached with said support layer by an attachment material.
5. The belt of claim 4, wherein said attachment material comprises a pressure sensitive adhesive.
6. The belt of claim 2, wherein the belt excludes reinforcing elements and supporting components for supporting said support layer.
7. The belt of claim 2, further comprising a polymeric sublayer attached with said support layer on a side of said support layer opposite said at least one abrasive material.
8. The belt of claim 7, wherein said polymeric sublayer has a higher porosity than said support layer.
9. The belt of claim 7, further comprising a metallic reinforcing element attached with said polymeric sublayer on a side of said polymeric sublayer opposite said support layer.

10. The belt of claim 1, wherein said at least one abrasive material comprises at least one oxide compound.

11. The belt of claim 1, wherein said at least one abrasive material comprises at least one carbide compound.

12. The belt of claim 2, wherein said polymeric material comprises a polyurethane.

13. The belt of claim 2, wherein said support layer is fabricated of a single, substantially uniform layer of polymeric material.

14. The belt of claim 1 wherein the belt comprises at least one viewing hole formed in the belt to expose a portion of the workpiece during polishing.

15. The belt of claim 14 further comprising trigger holes formed in the belt and associated with said at least one viewing hole.

16. The belt of claim 15 wherein said at least one viewing hole is located along a centerline of the belt.

17. A belt for polishing a workpiece in a chemical mechanical polishing system, the belt comprising:

a polymeric support layer forming an endless loop and manufactured exclusively of a single, substantially uniform layer of polymeric material; and

at least one fixed abrasive material on one side of said endless loop.

18. The belt of claim 17, wherein the belt excludes reinforcing elements and supporting components for supporting said polymeric support layer.

19. A chemical mechanical polishing system for polishing a workpiece, the system comprising:

a continuous loop belt formed of a support layer of polymeric material having at least one abrasive material attached with at least one surface thereof; and

transport means for moving the continuous loop belt past the workpiece.

20. The system of claim 19 wherein the transport means comprises a plurality of rollers over which the continuous loop belt is extended, the rollers being selectively rotatable to move the continuous loop belt linearly past the workpiece.