A replaceable cover secured to the surface of a membrane positioned on a wafer carrier.
REPLACEABLE COVER FOR MEMBRANE CARRIER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of wafer carriers, and in particular, to removable covers added to wafer carrier membranes used during the processing of silicon wafers.

2. Description of the Prior Art

Integrated circuits, including computer chips, are manufactured by building up layers of circuits on the front side of silicon wafers. An extremely high degree of wafer flatness and layer flatness is required during the manufacturing process. Chemical-mechanical planarization (CMP) is a process used during device manufacturing to flatten wafers and the layers built-up on wafers to the necessary degree of flatness.

Chemical-mechanical planarization is a process involving polishing of a wafer with a polishing pad combined with the chemical and physical action of a slurry pumped onto the pad. The wafer is held by a wafer carrier, with the backside of the wafer facing the wafer carrier and the front side of the wafer facing a polishing pad. The polishing pad is held on a platen, which is usually disposed beneath the wafer carrier. Both the wafer carrier and the platen are rotated so that the polishing pad polishes the front side of the wafer. A slurry of selected chemicals and abrasives is pumped onto the pad to affect the desired type and amount of polishing. CMP being thus achieved by a combination of chemical softener and physical downward force that removes material from the wafer or wafer layer. The downward force is split in the wafer carrier to a retaining ring force and a wafer force.

Using the CMP process, a thin layer of material is removed from the front side of the wafer or wafer layer. The layer may be a layer of oxide grown or deposited on the wafer or a layer of metal deposited on the wafer. The removal of the thin layer of material is accomplished so as to reduce surface variations on the wafer. Thus, the wafer and layers built-up on the wafer are very flat and uniform after the process is complete. Typically, more layers are added and the chemical mechanical planarization process repeated to build complete integrated circuit chips on the wafer surface.

A variety of wafer carrier configurations are used during CMP. One such wafer carrier configuration is the hard backed configuration. The hard backed configuration utilizes a rigid surface such as a piston or backing plate against the backside of the silicon wafer during CMP forcing the front surface of the silicon wafer to the surface of the polishing pad. Using this type of carrier may not conform the front wafer surface of the wafer to the surface of the polishing pad resulting in planarization non-uniformities. Such hard backed wafer carrier designs generally utilize a relatively high polishing pressure. These relatively high pressures effectively deform the wafer to match the surface conformation of the polishing pad. When water surface distortion occurs, the high spots are polished at the same time as the low spots giving some degree of uniformity but also resulting in poor planarization. Too much material from some areas of the wafer will be removed and too little material from other areas will also be removed. In addition to wafer distortion, the relatively high pressure also results in excessive material removal along the edges of the silicon wafer. When the amount of material removed is excessive, the entire wafer or portions of the wafer become unusable.

In other wafer carrier configurations, the wafer is pressed against the polishing pad using a membrane or other soft material. Use of membrane carriers tend not to cause distortion of the wafer. Lower polishing pressures may be employed, and conformity of the wafer front surface is achieved without distortion so that both some measure of global polishing uniformity and good planarization may be achieved. Better planarization uniformity is achieved at least in part because the polishing rate on similar features from die to die on the wafer is the same.

While many soft backed wafer carrier configurations are used in CMP, their use has not been entirely satisfactory. In some carrier designs, there have been attempts to use a layer of pressurized air over the entire surface of the wafer to press the wafer during planarization. Unfortunately, while such approaches may provide a soft back for the wafer carrier, it does not permit independent adjustment of the pressure at the edge of the wafer and at more central regions of the wafer to solve the wafer edge non-uniformity problems.

In order to correct or compensate for edge polishing effects, attempts have been made to adjust the shape of the retaining ring and to modify a retaining ring pressure so that the amount of material removed from the wafer near the retaining ring was modified. Typically more material is removed from the edge of the wafer resulting in over polishing. In order to correct this over polishing, the retaining ring pressure is adjusted to be somewhat lower than the wafer backside pressure so that the polishing pad in that area was somewhat compressed by the retaining ring and less material was removed from the wafer within a few millimeters of the retaining ring. These attempts, however, have not been entirely satisfactory as the planarization pressure at the outer peripheral edge of the wafer was only indirectly adjustable based on the retaining ring pressure. It was not possible to extend the effective distance of a retaining ring compensation effect an arbitrary distance into the wafer edge. Neither was it possible to independently adjust the retaining ring pressure, edge pressure, or independently adjust backside wafer pressure with respect to retaining ring pressure to achieve a desired result.

Ther has remained a need for a membrane backed wafer carrier having independent control of both the membrane pressure and retaining ring pressure providing excellent planarization, control or edge planarization effects, and adjustment of the wafer material removal profile to compensate for non-uniform deposition of the structural layers on the wafer semiconductor substrate.

U.S. Pat. No. 7,238,083 to Fuhriman et al describes a wafer carrier adapted to reduce the edge effect thus enabling a wafer to be uniformly polished across its entire surface. The wafer carrier has a pressure-regulated soft membrane behind the wafer, a retaining ring having a retaining ring actuator, and a pressurized edge control bladder or resilient ring used during CMP. Pressures behind the soft membrane, within the retaining ring actuator, and within the edge control bladder are regulated independently from one another. This enables the wafer carrier to account for non-uniformities on the wafer surface, changes in the retaining ring, and edge effects.

Although the system described in the '083 patent provides excellent results, a problem still exists. In particular, membranes are replaced periodically (typically after 1500...
wafers) due to contamination by slurry, slurries or abrasives. Specifically, the abrasive particles become lodged in the elastomer and causes scratching or cleaning issues. Since membranes are expensive, the wafer process as a result can be costly.

[0014] What is desired is to provide a membrane that can be used to process more wafers than currently possible without substantially increasing the cost of wafer processing.

SUMMARY OF THE INVENTION

[0015] The present invention provides a thin, peel off skin member at the membrane surface that contacts the wafer thereby protecting the membrane surface for an extended period time. If the member itself becomes contaminated, it is removed and replaced with a similar member. Since the member is less expensive than the membrane, the operating cost of the wafer process is substantially reduced. Although the invention is primarily directed to processing a silicon wafer, other wafer materials can be used to fabricate items other than chips, such as magnetic disk heads and LEDs.

DESCRIPTION OF THE DRAWINGS

[0016] For a better understanding of the present invention as well as other objects and further features thereof, reference is made to the following description which is to be read in conjunction with the accompanying drawing therein:

[0017] FIG. 1 shows a cross-sectional view of a prior art wafer carrier having a pressure-regulated soft membrane, retaining ring actuator;

[0018] FIG. 2 is a cross-sectional view of a wafer carrier modified in accordance with the teachings of the present invention;

[0019] FIG. 3 shows a detail of the cross-sectional view shown in FIG. 2;

[0020] FIG. 4 is a view of a tool used to join the membrane to the protective cover;

[0021] FIG. 5 is a top view of the tool shown in FIG. 4;

[0022] FIG. 6 is a cross-sectional view along line BB of FIG. 5; and

[0023] FIG. 7 is a detail of a portion of the view shown in FIG. 6.

DESCRIPTION OF THE INVENTION

[0024] In order to put the present invention in perspective, the description of the wafer carrier described in the '083 patent will be set forth herein since the basic structure of that wafer carrier is the same as that utilized to implement the present invention. The teachings of the '083 patent necessary for the understanding of the present invention is incorporated herein by reference. The same reference numerals shown in the figures identify the same components.

[0025] FIG. 1 shows a cross section of a wafer carrier 2. The wafer carrier 2 includes, a top plate 23 coupled to a spindle (not shown), a housing 24 coupled to top plate 23, a gimbal plate 27 coupled to housing 24, a retaining ring 25 coupled to the gimbal plate 27, a retaining ring actuator 26 disposed in the retaining ring 25, a piston plate 28 having one degree of freedom in the vertical direction coupled to the gimbal plate 27, and a pressure regulated soft membrane 29. The membrane may be made of a synthetic rubber or other pliable material. The piston plate 28 is disposed within the inner diameters of the membrane 29 and gimbal plate 27. When pressurized fluid is applied, the pressurized fluid flows through the passage to the recessed regions in the lower face 30 of the piston plate 28 forcing the soft membrane 29 downwardly away from the lower face 30 of the piston plate 28. At the same time, the pressurized fluid pushes the piston plate 28 upward (note that piston plate 28 is only utilized for wafer pick up and not critical to the operation of the carrier for polishing).

[0026] The soft membrane 29 extends horizontally over a peripheral portion of the backside of a wafer 3 and extends vertically between the side of the piston plate 28 and the retaining ring 25 and gimbal plate 27. An extension of the membrane 29 projects into an annular space 31 provided in the gimbal plate 27. Thus, the pressure-regulated soft membrane 29 moves with the wafer and the piston plate but, during polishing, moves independently of the movement of the gimbal plate 27 and the retaining ring 25. Pressure in the soft membrane is adjusted by a computer to apply downward force to the backside 32 of the wafer and to ensure that the rate at which material is removed from the front side 33 of the wafer is uniform across the entire front side of the wafer.

[0027] The retaining ring actuator in the wafer carrier 2 is independently controlled and affects the amount of force being applied behind the retaining ring 25. A retaining ring actuator 26 is provided within the retaining ring 25 (note that the retaining ring can be fixed, or static). When the actuator is pressurized, it extends against the retaining ring and increases the amount of force being applied to the polishing pad by the retaining ring relative to the rest of the wafer carrier. The retaining ring 25 is attached to the gimbal plate 27 in such a manner that allows the pressure inside the retaining ring actuator 26 to be increased or decreased. Change of pressure within the retaining ring actuator will influence the amount of force acting on the polishing pad by the retaining ring. The computer regulates the pressure in the retaining ring actuator 26 independently of the pressure in the inflatable membrane 29 and pressure in the edge control bladder 37. Pressure inside the retaining ring actuator 26 is used to force the retaining ring 25 downwardly as material is removed from the bottom surface of the retaining ring 25.

[0028] Polishing removes material from the bottom surface of the retaining ring, particularly over the course of multiple polishing runs. When the carrier 2 is in use, the soft membrane pressure, retaining ring actuator pressure, and edge control bladder pressure can all be regulated independently. This enables an operator to account for non-uniformities on the wafer surface, changes in the height of the retaining ring, and edge effect while using a CMP tool. Thus, the front side 33 of the wafer will remain substantially co-planar with the bottom surface of the retaining ring even as material is removed from the bottom surface of the retaining ring. The retaining ring actuator 26 and the fluid inside it allow the retaining ring 25 to move independently of the wafer 3 and the inflatable membrane 29.

[0029] Referring now to FIGS. 2 and 3, the present invention provides a cover 50 for protecting the surface of the membrane for the reasons noted hereinabove. Covers can be made out of most any elastomer including: Buta-N, Butadiene, Butyl, Chlorinated Polyethylene, EPDM, HNBR, Hypalon, Kalrez, Neoprene, Nitrile, Polyurethane, Silicone, Viton, etc. The cover material is chosen as to protect the base membrane material from the chemistry at hand. For example, if the first step in the CMP process is basic, the protective material then can be geared toward withstanding basic chemistry used.
in the process. If the process changes to acidic, then the cover can be so chosen to protect against low PH chemistries.

[0030] Cover 50 is manufactured with a suitable pressure sensitive adhesive on one side. The adhesive is formulated to adhere the chosen protective cover material to the membrane face surface and could be acrylic or silicone based. The material can be purchased in sheet form with the adhesive pre-applied. The shape can be pre-cut with a steel rule die or with a laser cutting tool or water jet cutting tool.

[0031] Although the cover is preferably of a uniform thickness and stiffness (thickness in the range between 1/8" and 1/4", the preferred thicknesses are 1/16" and 1/32"), the cover could have a non-uniform thickness or non-uniform stiffness. This would provide a variable down force on the wafer locally (even with a uniform air pressure behind/above the membrane) in order to remove polish local zones in a multi-zone processing system.

[0032] Cover 50 is applied to the surface of membrane 29 by having the end user remove the carrier from the polishing machine and positioning it on a surface with the membrane cover pointing up. The retaining ring is then removed to facilitate access to the membrane. The old cover is peeled off and a new one applied. If this is not easily accomplished, the membrane will be removed from the carrier. A tool that is basically just a plate with a hole the same diameter as the cover and membrane is placed in front of the operator. The cover is then placed in the hole, adhesive side up and the membrane placed in the tool on the top cover. Since the bore of the tool is the same size as the parts to be assembled, the parts necessarily will come out of the tool concentric as is desired.

[0033] A vacuum port with a tube connected to a vacuum source can be employed to evacuate the bore and minimize the potential for air bubbles to form between the membrane face surface and the cover (the tool is shown in FIGS. 3-7).

[0034] The purpose of the membrane cover 50 is to protect the membrane from damage and aging since the cost of the membrane is typically 20 times the cost of the cover. The membrane 29 is subject to abrasion and tearing when a wafer breaks. If a wafer breaks and pieces of wafer ledge in the cover, it can be peeled off and replaced. The membrane is also subject to chemical attack at noted hereinabove. The membrane is also subject to the accumulation of the abrasive particles suspended in polishing slurries which the cover can absorb. Thus, the cover can be replaced at roughly 1/2 the cost of replacing the membrane thus reducing the overall cost of the process to the end user.

[0035] Referring now to FIGS. 4-7, a tool 52 utilized to prepare a membrane having a protective cover formed thereon is illustrated.

[0036] In particular, protective cover 50 is placed adhesive side up in the bore of tool 52.

[0037] The tool bore is sized unilaterally larger in diameter than the diameter of cover 50 by a predetermined amount. The cover 50 and the membrane 29, nominally the same diameter (and corresponding to the wafer diameter), causes the two components to be concentric within the aforementioned range. The diameter of protective cover 50 (and thus the diameter of the wafer) is in the range between 100 mm and 450 mm.

[0038] Membrane 29 is placed in the bore of tool 52 at an angle such that the point furthest from the vacuum port touches first. Membrane 29 is then tilted down toward the vacuum port 54 allowing the membrane 29 to come into contact with the adhesive surface of cover 50 while the volume between the parts is evacuated.

[0039] A disk, or mandrel, 70 may be placed in the membrane bore to apply pressure to the backside of membrane 29 to facilitate adhesion of the protective cover 50 thereto.

[0040] Tool 52 is preferably made from polyolefin material since these materials repel adhesion; therefore, any glues on the parts being assembled have less chance of sticking to the tool surface thus making it easier to clean. Alternatively, tool 52 could be fabricated of a metal for better size control, hence potentially better concentricity.

[0041] Membrane 29 is placed at an angle for two reasons. The first is to allow for a gradual, controlled application of cover 50, helping the operator to maintain the concentricity of parts. If the membrane is put in parallel to the cover, it needs to be correctly lined up, or likely the operation would have to be repeated. The second reason is to start opposite the vacuum port and push any air that could be trapped toward the vacuum port. Otherwise, there is a risk of blocking the port and still trapping air.

[0042] Since the membrane is flexible, it may be hard to control in its free state. The outer ring is relatively stiff as compared to the membrane, but can be distorted. Membrane 29 can droop or be forced in the other direction due to trapped air. The addition of disk, or mandrel 70, will keep the outer ring round and help to push the air out toward the vacuum port. It could be most any plastic material, either a polyolefin, polyurethane, Nylon, Delrin or PET. Metal is also possible, however, plastic would be preferred to keep the weight down for the operator. The disk 70 is smaller than the inside diameter of the membrane ring, by just a few thousandths of an inch and would slip easily into the internal diameter of the membrane and be removed just as easily.

[0043] While the invention has been described with reference to its preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the spirit and scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its essential teachings.

What is claimed is:
1. An object carrier used in a polishing device comprising: a housing;
   a retaining ring characterized by an inner diameter coupled to the housing, said retaining ring sized and dimensioned to receive the object;
   a membrane having a first surface and extending across a bottom surface of a support member within the object housing, said membrane disposed within the inner diameter of said retaining ring; and
   a first cover secured to said first surface of said membrane to protect the membrane from damage.
2. The carrier of claim 1 wherein said first cover is removed from said membrane and replaced with a second cover.
3. The carrier of claim 1 wherein said object comprises a wafer.
4. The carrier of claim 1 wherein said protective cover comprises first and second surfaces, said first surface having an adhesive layer formed thereon.
5. The carrier of claim 4 wherein said protective cover is made from an elastomer.
6. The carrier of claim 1 wherein said protective cover is circular in shape.
7. The carrier of claim 6 wherein the diameter of said protective cover is in the range between 100 mm and 450 mm.

8. The carrier of claim 6 wherein the thickness of said protective cover is in the range between ½₄ inches and ½ inches.

9. A method for polishing the surface of an object comprising:
   - providing an object carrier, the carrier comprising a housing, a retaining ring characterized by an inner diameter and coupled to the housing;
   - inserting a membrane having first and second surfaces, said first surface of said membrane extending across a bottom surface of a support member in the object carrier, within the inner diameter of the retaining ring; and
   - providing a first member having first and second surfaces, said first surface covering said second surface of said membrane thereby protecting said membrane from damage.

10. The method of claim 9 wherein said first surface of said protective cover has an adhesive layer formed thereon.

11. The method of claim 9 further including the step of inflating said membrane in the object carrier to apply downward force to said object.

12. The method of claim 9 further including the step of removing said first protective cover from said membrane and replacing it with a second protective cover.

13. The method of claim 9 wherein said object comprises a wafer to be polished.