Disclosed herein is a semiconductor wafer polishing apparatus having a magneto-rheological elastic pad, in which the dielectric layer of the wafer fixed in the wafer holder to contact the abrasive coated on a rotating plate is polished. The semiconductor wafer polishing apparatus comprises a magneto-rheological elastic pad formed by a plurality of segments received to be fixed on the rotating plate; a plurality of electromagnets, having equal or larger diameter than that of wafer to selectively pressurize a part or the entire area of the wafer; which is arranged at the lower portion of the rotating plate in such a way that the central part accords with the central axis of the wafer holder; and a controller for selectively generating the magnetic field at a part or the entire part of the electromagnets.
SEMICONDUCTOR WAFER POLISHING APPARATUS HAVING MAGNETO-RHELOGICAL ELASTIC PAD

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a semiconductor polishing apparatus having a magneto-rheological elastic pad. Particularly, the invention relates to a semiconductor polishing apparatus, in which, a plurality of electromagnets are arranged in a row at the lower portion of the magneto-rheological elastic pad to allow each electromagnet to selectively generate magnetic field so that the central and the surrounding part of a wafer dielectric layer contacting with the abrasive can be processed to the same level without a deflection by adjusting pressure according to multi-area of magneto-rheological elastic pad corresponding to the position of each magnetic field, thereby greatly reducing a defect rate of a semiconductor device.

[0003] 2. Background of the Related Art

[0004] In general, a large-scale integrated semiconductor device has a multi-layer structure formed by alternate piling of a circuit pattern layer and a dielectric layer insulating the circuit pattern layer. When the dielectric layer is piled on the circuit layer, irregularities can be made on the dielectric layer according to an indentation of the circuit layer. Therefore, a planarization process is required in manufacturing the large-scale integrated semiconductor device to reduce the indentation. CMP (Chemical Mechanical Planarization) technique for semiconductor wafers is widely used to flatten wafers in manufacturing the large-scale integrated semiconductor.

[0005] The CMP process includes a fixing process of a semiconductor wafer in a wafer holder. A polishing pad and the wafer rotate together in a condition that the wafer contacts with the polishing pad. Normally, the polishing pad is coated with colloidal silica of a suspension of SiO₂ particles as an abrasive.

[0006] The abrasive has particle sizes in a various range from several nm to several μm. In general, the abrasive is coated in the form of slurry by using a wand which is provided to the wafer holder and the pad.

[0007] In this case, material removal rate from the wafer is a combination of the chemical and the mechanical removal rate. Generally, the mechanical removal rate is proportional to relative speed and pressure of the wafer. The chemical removal rate is a function of slurry particle size and solution pH, which has the maximum removal rate when slurry having about 11.5 pH is used.

[0008] However, when the wafer is polished using a conventional wafer polishing apparatus, the rotating wafer as shown in FIG. 1 has faster rotational speed in the outer part than the central part, therein exists a pressure inequality between the wafer 1 and the abrasive pad as shown in FIG. 2. The undescribed numeral 3 represents the wafer holder.

[0009] In other words, a thickness deflection of the wafer can occur because more materials are polished in the outer part than the central part, as shown in FIG. 3. In this case, polishing in the outer part can damage the circuit layer below the dielectric layer. Therefore, the pressure inequality due to the different relative speed between the outer and the central part is critical factor causing the failure of semiconductor devices.

[0010] In the conventional technology, pressure is controlled by the replacement of pads having different stiffness. In another technology, pressure of an unflat support below a pad platen is controlled, which has problems that the wafer needs to be mounted in a very accurate way and the control cannot be done in real-time.

SUMMARY OF THE INVENTION

[0011] Therefore, the present invention has been made in view of the above problems occurring in the prior art, and it is an object of the present invention to provide a semiconductor wafer polishing apparatus having a magneto-rheological elastic pad, in which, a plurality of electromagnets are arranged in a row at the lower portion of the magneto-rheological elastic pad to selectively generate a magnetic field for each electromagnet and a multi-area pressure of the magneto-rheological elastic pad corresponding to the magnetic field position is adjusted in such a way that the central and the surrounding part of a dielectric layer of the wafer contacting with the abrasive can be processed to the same level without a deflection, thereby decreasing the failure rate of the semiconductor device.

[0012] To accomplish the above objects, according to the present invention, there is provided the semiconductor wafer polishing apparatus having a magneto-rheological elastic pad, in which the dielectric layer of the wafer fixed in the wafer holder to contact the abrasive coated on a rotating plate is polished. The apparatus of the invention includes: a magneto-rheological elastic pad formed by a plurality of segments received to be fixed on the rotating plate; a plurality of electromagnets each having equal or larger diameter than that of wafer to selectively pressurize a part or the entire area of the wafer, each electromagnet being arranged at the lower portion of the rotating plate in such a way that its central part accords with the central axis of the wafer holder; and a controller for selectively generating the magnetic field at a part or the entire part of the electromagnets.

[0013] To form the magneto-rheological elastic pad, first, a magnetic substance is mixed with a solvent and a dispersant. The mixture is stirred with an elastic substance after stirring and dispersing in a powerful mixer. Next, this mixture is stirred in a solution of polyurethane polyol using a ball mill for about 10 hours. This is allowed for hardening for 24 hours at the temperature of 90°C~110°C. After adding one part of isocyanate, thereafter the magnetic field of about 1 Tesla is applied until the hardening is completed.

[0014] In this case, the elastic substance may one of natural rubber, EPDM, polybutadiene, acrylonitrile rubber, synthetic rubber, polyurethane and silicone rubber, or the combinations thereof.

[0015] In addition, the magnetic substance may be one of iron, alloy iron, iron oxide such as Fe₃O₄, Co doped Fe₃O₄, and Fe₃O₄ iron nitride, iron carbide, nickel, cobalt, chrome dioxide, stainless steel and Fe powder.

[0016] Furthermore, the magneto-rheological elastic pad is formed to have a thickness of 0.1 mm~50 mm, preferably 1 mm~10 mm.
In addition, it is preferable that more than three electromagnets of odd numbers are arranged in a row.

Therefore, in the present invention, the magnetic field is selectively applied to a part or the entire part of the magneto-rheological elastic pad formed by a plurality of segments. As stiffness of the magneto-rheological elastic pad increases, pressure between the abrasive particle in the form of slurry and the wafer also increases so that the polishing process can be performed to the same level without a deflection between the central and the surrounding part of the wafer. The equal planarization can significantly reduce not only the failure of the semiconductor device but also the production cost by preventing defective semiconductor wafers from manufacturing.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description of the preferred embodiments of the invention in conjunction with the accompanying drawings, in which:

FIG. 1 shows a speed distribution according to a wafer radius during the wafer polishing process by a conventional semiconductor wafer polishing apparatus;

FIG. 2 is a schematic diagram showing a pressure distribution according to a wafer radius during the wafer polishing process by the conventional semiconductor wafer polishing apparatus;

FIG. 3 is a schematic diagram showing a deflection between the central and the surrounding part during the wafer polishing process by the conventional semiconductor wafer polishing apparatus;

FIG. 4 is a side view of a semiconductor wafer polishing apparatus having a magneto-rheological elastic pad according to one embodiment of the invention;

FIG. 5 is a plane figure of the semiconductor wafer polishing apparatus having the magneto-rheological elastic pad according to one embodiment of the invention;

FIG. 6 is a side view illustrating an operating mode of the semiconductor wafer polishing apparatus having the magneto-rheological elastic pad according to one embodiment of the invention; and

FIG. 7 is a photograph showing an arrangement of magnetic substances after hardening of the magneto-rheological elastic pad.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference will now be made in detail to the preferred embodiment of the present invention with reference to the attached drawings. It is noted that details on the well-known components and their functions will not be described.

FIG. 4 and 5 are a side view and a plane figure of the semiconductor wafer polishing apparatus having the magneto-rheological elastic pad according to one embodiment of the invention, respectively. In addition, FIG. 6 and 7 are a side view illustrating an operating mode of the semiconductor wafer polishing apparatus having the magneto-rheological elastic pad according to one embodiment of the invention, and a photograph showing an arrangement of magnetic substances after hardening of the magneto-rheological elastic pad, respectively.

In the present invention, the semiconductor wafer polishing apparatus includes the magneto-rheological elastic pad 23 received and fixed in a rotating plate 21, in which the top surface thereof is coated with the abrasive 27 in the form of slurry by an abrasive supply line 25.

To form the magneto-rheological elastic pad 23, first, a magnetic substance is mixed with a solvent and a dispersant. The mixture is stirred with an elastic substance after stirring and dispersing in a powerful mixer. Next, this mixture is stirred in a solution of polyurethane polyol using a ball mill for about 10 hours. This is allowed for hardening for 24 hours at the temperature of 90° C.-110° C. after adding one part of isocyanate. Thereafter the magnetic field of about 1 Tesla is applied until the hardening is completed.

Change of elastic strength without the application of magnetic field is less than 5%, but this value with the application of magnetic field increases up to 30%-50% because dipole is formed between particles due to the arrangement of magnetic substances in a row as shown in FIG. 7. In this case, magnetic field by the electromagnet is applied perpendicularly to a surface of urethane.

In addition, the magneto-rheological elastic pad 23 is available when the thickness thereof is in the range of 0.1 mm~50 mm, preferably 1 mm~10 mm.

In this case, one or a combination of more than two of natural rubber, EPDM, polybutadien, acrylonitrile rubber, synthetic rubber, polyurethane and silicone rubber is used as the elastic substance. In addition, one of iron, alloy iron, iron oxide such as Fe₃O₄, Co doped Fe₃O₄ and Fe₃O₄, iron nitride, iron carbide, nickel, cobalt, chrome dioxide, stainless steel and Fe powder forms the magnetic substance.

Furthermore, the alloy iron is made by adding aluminum, silicon, cobalt, nickel, vanadium, molybdenum, chromium, tungsten, manganese and/or copper to iron.

At the lower portion of the rotating plate 21, a plurality of electromagnets are arranged in a row, in which more than three electromagnets of odd numbers are arranged in such a way that the center of electromagnet 33 in the middle accords with the central axis 11a of the wafer holder 11.

Therefore, to use a plurality of the electromagnets 31~35, having equal or larger diameters than the wafer as shown in FIG. 5, is desirable in order to pressurize a part or the entire part of the wafer 13 by means of the magneto-rheological pad 23.

In addition, a controller 40 makes a plurality of the electromagnets 31~35 to selectively generate magnetic field at a part or the entire part. At this stage, magnetic field can be applied to each segment by the controller 40, and field intensity for the magnetic field can be adjusted in real-time.

The polishing process by adding multi-pressure to the wafer 13, operated with the semiconductor wafer polishing apparatus having the magneto-rheological elastic pad according to the present invention, in order to flatten the wafer 13 is as follows.

[0028]
First, during the wafer holder fixing the rotating plate and the wafer rotates, the current flows at the electromagnets while the current does not flow at the electromagnets according to the electric signal of the controller as illustrated in FIG. 6. Therefore, the segments of the magneto-rheological elastic pad corresponding to the electromagnets are activated so that they have larger elasticity magnitude than those of the electromagnets.

Accordingly, segment pressure of the magneto-rheological elastic pad corresponding to the electromagnets is increased so that the polishing speed in the central part of the wafer becomes faster.

Accordingly, magnetic field applied by the electromagnets acts on the corresponding segments of the magneto-rheological elastic pad so that the resulting elastic projection can pressurize the abrasive, thereby the entire surface of the wafer is polished at the same speed.

Furthermore, this local adjustment for the polishing speed can solve problems of the conventional technologies such as speed distributions and pressure differences according to the wafer radius, thereby it significantly reduce the failure of the semiconductor device.

As described above, in the present invention, the magnetic field is selectively applied to a part or the entire part of the magneto-rheological elastic pad formed by a plurality of segments. As stiffness of the magneto-rheological elastic pad increases, pressure between the abrasive particle in the form of slurry and the wafer also increases so that the polishing process can be performed to the same level without a deflection between the central and the surrounding part of the wafer. The equal planarization can significantly reduce not only the failure of the semiconductor device, but also the production cost by preventing defective semiconductor wafers from manufacturing.

While the present invention has been described with reference to the particular illustrative embodiments, it is not to be restricted by the embodiments but only by the appended claims. It is to be appreciated that those skilled in the art can change or modify the embodiments without departing from the scope and spirit of the present invention.

What is claimed is:

1. A semiconductor wafer polishing apparatus having a magneto-rheological elastic pad, in which the dielectric layer of the wafer fixed in the wafer holder to contact the abrasive coated on a rotating plate is polished, the semiconductor wafer polishing apparatus comprising:

   a) a magneto-rheological elastic pad formed by a plurality of segments received to be fixed on the rotating plate;

   b) a plurality of electromagnets each having equal or larger diameter than that of wafer to selectively pressurize a part or the entire area of the wafer, each electromagnet being arranged at the lower portion of the rotating plate in such a way that its central part accords with the central axis of the wafer holder; and

   c) a controller for selectively generating the magnetic field at a part or the entire part of the electromagnets.

2. The apparatus according to claim 1, wherein the magneto-rheological elastic pad is formed by the steps of:

   a) mixing of a magnetic substance with a solvent and a dispersant;

   b) stirring and dispersing the above mixture in a powerful mixer to stir the resultant mixture with an elastic substance;

   c) stirring the stirred mixture again in a solution of polyurethane polyol using a bull mill for about 10 hours;

   d) adding one part of isocyanate to the stirred mixture to harden the resultant mixture for 24 hours at the temperature of 90° C.-110° C.; and

   e) applying magnetic field of about 1 Tesla to the resultant mixture until the hardening is completed.

3. The apparatus according to claim 2, wherein the elastic substance is one selected from the group consisting of natural rubber, EPDM, polybutadiene, acrylonitrile rubber, synthetic rubber, polyurethane, silicone rubber, and combinations thereof.

4. The apparatus according to claim 2, wherein the magnetic substance is one selected from the group consisting of iron, alloy iron, iron oxide, iron nitride, iron carbide, nickel, cobalt, chrome dioxide, stainless steel and Fe powder.

5. The apparatus according to claim 4, wherein the iron oxide is one selected from the group consisting of Fe₂O₃, Co doped Fe₂O₃ and Fe₃O₄.

6. The apparatus according to claim 2, wherein the magneto-rheological elastic pad has a thickness of 0.1 mm-50 mm.

7. The apparatus according to claim 1, wherein more than three electromagnets having odd numbers are arranged in a row.

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