Method for dressing polishing pads

Description

The present invention relates to a method for dressing polishing pads (cloths), in particular polishing pads for use in the polishing of semiconductor wafers.

Prior art

For electronics, microelectronics and micro-electromechanics, semiconductor wafers that have to meet extreme requirements for global and local flatness, flatness on one side (nanotopology), roughness and cleanness are required as starting materials. Semiconductor wafers are slices of semiconductor materials such as single-element semiconductors (silicon, germanium), compound semiconductors (for example comprising one element from the third main group of the periodic table, such as aluminum, gallium or indium, and one element from the fifth main group of the periodic table, such as nitrogen, phosphorus or arsenic) or compounds thereof (for example Sil-xGex, $0 < x < 1$).

Semiconductor wafers are produced by means of a large number of successive process steps, which can generally be divided into the following groups:

(a) producing a usually monocrystalline semiconductor rod;
(b) separating the rod into individual wafers;
(c) mechanical processing;
(d) chemical processing;
(e) chemo-mechanical processing;
(f) optionally additional production of layer structures.

Advantageous here in the production of semiconductor wafers for particularly demanding applications are

procedures that comprise at least one processing method in which both sides of the semiconductor wafers are processed in a material-removing manner simultaneously in one processing step by means of two working faces, to be precise in such a way that the processing forces acting on the semiconductor wafer from the front side and the rear side during the removal of material substantially balance out, and no constraining forces are exerted on the semiconductor wafer by a guiding device, in other words the semiconductor wafer is processed in a "freely floating" manner.

Preferred here in the prior art are procedures in which both sides of at least three semiconductor wafers are processed in a material-removing manner simultaneously between two annular working disks, the semiconductor wafers being placed loosely into receiving openings of at least three externally toothed guiding cages (known as carrier plates), which are guided by means of a rolling device and the external toothing under pressure on cycloidal paths through the working gap formed between the working disks, so that they can thereby run completely around the center point of the double-sided processing device. Such methods that process both sides of a plurality of semiconductor wafers over the full surface area simultaneously in a material-removing manner with circulating carrier plates are double-sided lapping ("lapping"), double-sided polishing (DSP) and double-sided grinding with planetary kinematics ("planetary pad grinding", PPG). Of these, DSP and PPG especially are of particular significance. As a difference from lapping, in the case of DSP and PPG the working disks in each case additionally comprise a working layer, the mutually facing sides of which represent the working faces. PPG and DSP are known in the prior art and are briefly described below.

"Planetary pad grinding" (PPG) is a method from the group of mechanical processing steps that brings about

a removal of material by means of grinding. In PPG, each working disk comprises a working layer, which contains bound abrasive material. The working layers take the form of structured grinding cloths, which are attached on the working disks adhesively, magnetically, by interlocking engagement (for example by means of hook-and-loop fastening) or by means of a vacuum. The working layers have sufficient adhesion on the working disk not to be displaced, deformed (formation of a bead) or become detached during the processing. They are, however, easily removable from the working disks by means of a peeling movement, and consequently quickly exchangeable, so that it is possible to change quickly between different types of grinding cloth for different applications without long set-up times. The abrasive material (abrasive) that is used in the grinding cloths is preferably diamond.

Double-sided polishing (DSP) is a method from the group of chemo-mechanical processing steps. DSP processing of silicon wafers is described for example in US 2003/054650 A1 and a device suitable for it is described in DE 100 07 390 A1. In this description, "chemo-mechanical polishing" is to be understood exclusively as meaning a removal of material by means of a mixed action, comprising chemical etching by means of an alkaline solution and mechanical erosion by means of loose grain dispersed in an aqueous medium, which is brought into contact with the semiconductor wafer by a polishing cloth, which does not contain any hard substances that come into contact with the semiconductor wafer, and so a removal of material from the semiconductor wafer is brought about under pressure and by relative movement. In the case of DSP, the working layers take the form of polishing pads, and these are attached on the working disks adhesively, magnetically, by interlocking engagement (for example by means of hook-and-loop fastening) or by means of a vacuum and in the case of DSP are also referred to as

so-called polishing plates. In the case of chemo-mechanical polishing, the alkaline solution preferably has a pH of between 9 and 12, and the grain dispersed therein is preferably a colloid-dispersed silica sol with grain sizes of the sol particles of between 5 nm and several micrometers.

In the case of DSP, residual defects are removed by the preceding mechanical processing steps. The semiconductor wafers are planarized on both sides and the surface of the semiconductor wafers is prepared for further processing steps. In this case, a factor that is decisive for the quality of the processing in the case of DSP or other polishing methods is the dressing of the polishing pads. Dressing is understood as meaning a conditioning of the polishing pads in which the surface of the polishing pads that is contaminated and worn away by the polishing is cleaned and improved. For example, the asperities that are present on the surface, which serve for transporting the polishing agent and are worn away during the polishing, are intended to be restored thereby.

JP 2004-98264 A discloses for example a method for dressing polishing pads in which the polishing pads have been applied to the upper and lower polishing plates of a DSP device. The polishing plates in this case rotate in opposite directions and in each case counter to the direction of rotation that is used during the polishing. Furthermore, although it is mentioned that the method described there can also be used in the case of four-way DSP devices, this is not referred to any more specifically.

DE 697 29 590 T2 also discloses a method for dressing polishing pads. In the case of the method described there, a polishing cloth applied to a turntable is dressed by a dresser being moved on the polishing cloth. In this case, the dresser and the plate are

rotated in the same direction. The rotational speeds of the polishing platen and the dresser are in this case variable and independent of one another.

However, the effect that is achieved by the known methods for dressing polishing pads does not usually last long and also does not produce a satisfactory effect for many polishing pads that are used.

It therefore continues to be desirable to provide a possible way of dressing polishing pads by which the polishing pads have the best possible polishing quality after the dressing and the effect of the dressing lasts as long as possible.

This object is achieved by a method according to the independent patent claim. Advantageous refinements are provided by the subclaims and the description that follows.

Summary of the invention

According to an aspect of the invention, there is provided a method for dressing one polishing cloth or two polishing pads simultaneously, in which a polishing cloth has been applied to a polishing plate, with at least one dresser, which is equipped with at least one dressing element, this at least one dressing element being in contact with the at least one polishing cloth to be dressed, wherein the at least one polishing plate is rotated with a relative rotational speed and the at least one dresser is rotated with a relative rotational speed and at least two different combinations of directions of rotation of the two pairs of polishing plates and pin wheels are executed during the simultaneous dressing of two polishing pads or during the dressing of one polishing cloth of the polishing

plate and of the at least one dresser, and the at least two different combinations include the rotation of the polishing plates in opposite directions of rotation or the rotation of the pin wheels in opposite directions of rotation during the simultaneous dressing of the two polishing pads, and the rotation of the polishing plate and the at least one dresser in opposite directions during the dressing of the one polishing cloth.

Advantages of the invention

The method according to the invention serves for dressing polishing pads, in particular dressing foamed polishing pads for use in the polishing of semiconductor wafers. The method according to the invention may be used both for dressing an individual polishing cloth and for simultaneously dressing two polishing pads.

Semiconductor wafers are slices of semiconductor materials such as single-element semiconductors (silicon, germanium), compound semiconductors (for example comprising one element from the third main group of the periodic table, such as aluminum, gallium or indium, and one element from the fifth main group of the periodic table, such as nitrogen, phosphorus or arsenic) or compounds thereof (for example Sil-xGex, $0 < x < 1$).

When dressing an individual polishing cloth, a device for polishing one side of at least one semiconductor wafer, that is to say a one-sided polishing machine, is preferably used.

The method according to the invention is explained below on the basis of the example of the simultaneous dressing of two polishing pads, without restricting the scope of the invention to this embodiment. For the simultaneous dressing of two polishing pads, a device for simultaneously polishing the front side and the rear side of at least one wafer, that is to say a double-sided polishing machine, is preferably used. Used for this purpose are an upper polishing plate and a lower polishing plate and also at least two, and particularly preferably at least three to five, dressers, which are arranged between the upper polishing plate and the lower polishing plate and are moved by an inner gear wheel and an outer gear wheel.

A dresser is a **carrier in form of a disk or ring** equipped with dressing elements, which can be bounded or screwed or free movable placed in the carrier, on at least the side (front side or rear side or upper side or underside) that is facing the polishing cloth. Depending on the preferred embodiment, disk-shaped or annular dressers may be used. A combination, i.e. some disk-shaped dressers and some annular dressers, is also preferred.

The dressers preferred for the simultaneous dressing of two polishing pads are respectively equipped on their upper side and their underside with at least one dressing element.

In a further embodiment, in a way corresponding to a carrier plate for the polishing of wafers of semiconductor material simultaneously on both sides, these dressers may have clearances into which dressing

elements can be placed in a freely movable or fixed manner, so that the at least one dressing element comes into contact on its front side and its rear side with the upper polishing cloth and the lower polishing cloth respectively.

The edge of the dresser preferred for the simultaneous dressing of two polishing pads has peripheral teeth, which ensure the rotational movement of the at least one dresser by the tooth engagement with the inner gear wheel and the outer gear wheel of the device for the simultaneous dressing of two polishing pads.

The surface of the at least one dressing element is raised with respect to the surface of the dresser, so that the surface of the at least one polishing cloth to be dressed preferably only comes into contact with the surface of the at least one dressing element.

The surface or surfaces coming into contact with the polishing cloth (front side and rear side) of the at least one dressing element is/are preferably covered with diamonds, since diamond has the required hardness for dressing polishing pads.

The front side and the rear side of the dressers are preferably equipped symmetrically, for example circularly, with a number of dressing elements, it being possible for there to be no interspace or in each case a defined interspace between the individual dressing elements. It is likewise preferred that the dressing elements form only part of a circle, i.e. that for example a sector of a circle or a segment of a circle is missing.

If the method according to the invention is used for example for simultaneously dressing two polishing pads, a device for the double-sided polishing of semiconductor wafers for example may be used for

example. The polishing pads are then respectively applied to the mutually facing faces of the upper polishing plate and the lower polishing plate. The polishing plates (and consequently the polishing pads) are then rotated at a relative rotational speed in relation to one another. Similarly, the dressers are rotated at a relative rotational speed by the rotation of the inner gear wheel (pin wheel) and outer gear wheel (pin wheel) with which they are in tooth engagement.

In this way, the polishing pads can be dressed better than for example just by means of rotation of the two polishing plates, since an additional movement of the dressing elements located on the dressers along the polishing pads is achieved by the additional rotation of the dressers with the at least one dressing element respectively located on their upper side and the underside. The individual directions of rotation may in this case be chosen initially in the same direction as during the polishing or else in the opposite direction.

For example, for this purpose both the polishing plates and the pin wheels may be respectively turned in the same direction of rotation, but with a different absolute rotational speed in each case. In particular, however, opposite directions of rotation respectively both for the polishing plates and also for the pin wheels are expedient. What is decisive here is the additional movement of the dressers in each case.

Preferably, the directions of rotation of at least one of the two pairs of polishing plates and pin wheels are reversed at least once during the dressing. A combination of rotations of the two pairs of polishing plates and pin wheels is referred to as kinematics. By contrast with so-called simple kinematics with only one such combination, an additional combination allows not only the removal of disadvantageous directionally

dependent short asperities on the polishing pads, the directional dependence arising during the polishing, but also the creation of additional directionally independent asperities that are advantageous for transporting the polishing agent.

Advantageously, the directions of rotation of only one of the two pairs of polishing plates and pin wheels are reversed at the same time during the dressing. In this way, more combinations can be created than in the case of simultaneous reversal of the directions of rotation of both pairs of polishing plates and pin wheels.

The inventor has discovered that it is particularly advantageous when dressing polishing pads if at least two, particularly at least three, more particularly four, different combinations of directions of rotation of the two pairs of polishing plates and pin wheels or of the polishing cloth and at least one dresser are executed during the dressing (multidirectional dressing).

In the simultaneous dressing of two polishing pads, a total of four different combinations can be created by reversing the directions of rotation in each case of only one of the two pairs of polishing plates and pin wheels. These altogether four possible combinations of directions of rotation relate here to a direction of the asperities present on the polishing pads attributable to the polishing of semiconductor wafers for example.

It has been found that, by executing various combinations, with in particular only the directions of rotation of one of the two pairs of polishing plates and pin wheels being changed respectively from one combination to the next, a particularly long-lasting and significantly stronger effect is obtained than in the case of previously used methods for dressing

polishing pads. The previously used methods would sometimes have to be used five to six times in succession to achieve such effects. It should particularly be mentioned once again here that the method according to the invention causes the creation of new, directionally independent asperities on the polishing pads, which are responsible for transporting polishing agents to the semiconductor wafers to be polished, and in particular also for achieving semiconductor wafers that are as plane-parallel as possible. In tests, multidirectional dressing with all four possible combinations has proven to be particularly successful.

Furthermore, it has been found that the method according to the invention for dressing polishing pads has the effect of significantly improving not only the plane-parallelism of the semiconductor wafers, but also the quality of the surface (so-called haze) of the semiconductor wafers. Similarly, with the method according to the invention, a lasting increase in the removal rate during the polishing can be achieved. However, the method has no appreciable influence on a service life of the polishing pads.

The method according to the invention may preferably be used for dressing foamed polishing pads, in particular of polyurethane, since such polishing pads have to be dressed more frequently than other polishing pads. The method according to the invention, in particular the multidirectional dressing, allows a longer-lasting effect to be achieved with respect to the desired polishing quality than with previously known methods. Accordingly, foamed polishing pads also no longer have to be dressed as often.

In the case of the method according to the invention for dressing polishing pads, during the simultaneous dressing of two polishing pads the mutually facing

faces of the upper polishing plate and the lower polishing plate are preferably set plane-parallel to one another, in particular also by corresponding corrections of the polishing plates during the dressing, for example by exerting corresponding forces on the upper polishing plate. This helps to achieve the most uniform possible dressing of the polishing pads.

Advantageously, a dressing agent, in particular a liquid, is applied to the polishing pads during the dressing. In this way, contaminants in the polishing pads that occur during the polishing of semiconductor wafers in the form of material removed and are deposited in the polishing pads can be washed out. This also enhances the effect of the dressing in the sense of a regeneration of the polishing pads. The use of water as a dressing agent is particularly expedient, since the components, materials and other tools that are used usually react sensitively to chemically reactive agents.

It goes without saying that the features mentioned above and still to be explained below can be used not only in the respectively specified combination, but also in other combinations or on their own without departing from the scope of the present invention.

The invention is schematically represented on the basis of an exemplary embodiment of the simultaneous dressing of two polishing pads in a first drawing and described in detail below with reference to this drawing and also a second drawing. A third drawing shows an exemplary embodiment of the dressing of a polishing cloth.

Description of the figures

Figure 1 schematically shows in cross section a device that can be used for carrying out the method according to the invention in a preferred embodiment.

In Figure 1, dressers (4), which can be moved by means of an inner gear wheel (31) and an outer gear wheel (32), a so-called rolling device, are schematically represented. The dressers (4) are equipped with dressing elements (8). On the lower polishing plate (21) there is a polishing cloth (11). On the upper polishing plate (22) there is a polishing cloth (12). The upper polishing plate (22) is pressed with the polishing cloth (12) in the direction of the polishing or pressing pressure (7) against the dressers (4), and consequently against the dressing elements (8) and also the lower polishing plate (21) with the polishing cloth (11). For the sake of completeness, it should also be mentioned at this point that the mutually facing faces of the polishing plates (21, 22) are annular.

Furthermore, the directions of rotation of the polishing plates and the pin wheels about a common axis of rotation are represented in Figure 1. In this case, (ω22), (ω31), (ω32) and (ω21) denote the directions of rotation of the upper polishing plate (22), the inner pin wheel (31), the outer gear wheel (32) and the lower polishing plate (21), respectively, in the sequence given.

Figure 2 schematically shows in plan view an arrangement of three dressers (4) on the lower polishing plate (21), which is covered with a polishing cloth (11), which can be used for carrying out the method according to the invention in a preferred embodiment. The dressers (4) are moved in a circular manner by means of an inner gear wheel (31) and an outer gear wheel (32), the so-called rolling device. The dressers (4) are represented here as annular, with dressing elements (8) provided on them, without the invention being restricted to this embodiment. Neither the dressing elements directed toward the lower

polishing cloth (11) nor the upper polishing plate (22) are depicted for reasons of overall clarity.

Figure 3 schematically shows in plan view a possible embodiment for the dressing according to the invention of a polishing cloth (11), which covers a polishing plate (21). The at least one dresser (4) can be moved back and forth from the edge of the cloth to the center of the cloth during the dressing by means of an arm (5), and at the same time rotate. The polishing plate (21) covered with the polishing cloth (11) can likewise be rotated. In Figure 3, one possible combination of the directions of rotation of the polishing plate (21) and the at least one dresser (4) is represented by way of example. In this case, ($\omega 21$) and ($\omega 4$) denote the directions of rotation of the polishing plate (21) and of the dresser (4). For reasons of overall clarity, no dressing elements that are directed toward the polishing cloth (11) are depicted in the case of the dresser (4), represented by way of example as circular.

As already stated, the method according to the invention may be carried out both with a device for the one-sided polishing and a with device for the double-sided polishing of semiconductor wafers. If a device for the double-sided polishing of semiconductor wafers is used, the dressers (4) may be used instead of the carrier plates used in the polishing process.

When a device for the double-sided polishing of semiconductor wafers is used, it is preferred to use annular or disk-shaped dressers (4) with a peripheral ring of teeth, which is in tooth engagement with the inner gear wheel (31) and the outer gear wheel (32). The rotational movements of the dresser (4) that are necessary for the multidirectional dressing are ensured by the rotation of the two pin wheels. The side of the dresser (4) facing the upper polishing cloth (12) and the side of the dresser (4) facing the lower polishing

cloth (11) are preferably equipped in each case with at least one dressing element (8).

In a further embodiment of the simultaneous dressing of two polishing pads by the method according to the invention, the at least one dresser (4) has one or more clearances analogous to carrier plates such as are used in the double-sided polishing of semiconductor wafers. The dressing elements (8) necessary for carrying out the method according to the invention are inserted into this at least one clearance. In this embodiment, the dressing elements (8) are preferably freely movable or can rotate freely in the clearance. Likewise preferably, the dressing elements (8) are fixed in the clearance. The at least one dressing element (8) placed into a clearance of a dresser (4) is preferably covered with diamonds on both sides coming into contact with the lower polishing cloth (11) and the upper polishing cloth (12). In addition, the dresser (4) designed like a carrier plate may be additionally equipped with at least one dressing element (8) respectively on the side facing the upper polishing cloth (12) and the side facing the lower polishing cloth (11).

By way of example, in Figure 1 the directions of rotation ($\omega 22$) and ($\omega 32$) of the upper polishing plate (22) and of the outer gear wheel (32) are shown as clockwise, the directions of rotation ($\omega 31$) and ($\omega 21$) of the inner gear wheel (31) and of the lower polishing plate (21) are shown as counterclockwise, which represents one possible combination of four different combinations of directions of rotation. It has been taken into account here that, according to the invention, the polishing plates (21, 22) and the gear wheels (31, 32) respectively rotate with a rotational speed relative to one another, in that they rotate in opposite directions.

The combination shown can then serve for example as a first combination to be set when carrying out a method according to the invention. The further combinations to be successively set are then obtained for example by first the directions of rotation (ω21, ω12) of the polishing plates (21, 22) and later the directions of rotation (ω31, ω32) of the gear wheels (31, 32) being reversed. Finally, the directions of rotation (ω21, ω12) of the polishing plates (21, 22) may subsequently be reversed once again. Altogether, four different combinations of the directions of rotation are obtained in the sense of multidirectional dressing, with only the directions of rotation of one pair of polishing plates (21, 22) or gear wheels (31, 32) being reversed respectively in each step. However, a different sequence of the combinations is also conceivable. These altogether four possible combinations of directions of rotation relate here to a direction of the asperities present on the polishing pads attributable to the polishing (directionally dependent asperities).

The combinations of the multidirectional dressing that are described here may of course likewise be used correspondingly for the dressing of only one polishing cloth. When a device for the one-sided polishing of semiconductor wafers is used, it is preferred to use annular or disk-shaped dressers (4). The at least one dresser (4) is pressed against the polishing cloth to be dressed by a suitable device, for example a movable arm as represented in Figure 3, and can be rotated in various directions (clockwise or counterclockwise).

By way of example, in Figure 3 the direction of rotation (ω21) of the polishing plate (21) is shown as clockwise and the direction of rotation (ω4) of the dresser (4) is shown as counterclockwise, which represents one possible combination of four different combinations of directions of rotation. It has been taken into account here that, according to the

invention, the polishing plate (21) and the at least one dresser (4) respectively rotate with a rotational speed relative to one another.

The exact sequence when changing the directions of rotation during the dressing may in this case be adapted to the previously used kinematics during the polishing. Therefore, different sequences of the combinations that lead to the best result may arise according to the application. Similarly, the time for which the individual combinations remain set may be adapted according to the application.

Patent claims:

1. A method for dressing one polishing cloth or two polishing pads (11, 12) simultaneously, in which a polishing cloth (11, 12) has been applied to a polishing plate (21, 22), with at least one dresser (4), which is equipped with at least one dressing element (8), this at least one dressing element (8) being in contact with the at least one polishing cloth (11, 12) to be dressed, wherein the at least one polishing plate (21, 22) is rotated with a relative rotational speed and the at least one dresser (4) is rotated with a relative rotational speed and at least two different combinations of directions of rotation of the two pairs of polishing plates (21, 22) and pin wheels (31, 32) are executed during the simultaneous dressing of two polishing pads (11, 12) or during the dressing of one polishing cloth (11) of the polishing plate (21) and of the at least one dresser (4), and

the at least two different combinations include the rotation of the polishing plates (21, 22) in opposite directions of rotation (ω21, ω22) or the rotation of the pin wheels (31, 32) in opposite directions of rotation (ω31, ω32) during the simultaneous dressing of the two polishing pads (11, 12), and the rotation of the polishing plate (21) and the at least one dresser (4) in opposite directions during the dressing of the one polishing cloth (11).

2. The method as claimed in claim 1, wherein, when simultaneously dressing two polishing pads (11, 12), the at least one dresser (4) is rotated by a rolling device comprising an inner gear wheel (31) and an outer gear wheel (32).

3. The method as claimed in claim 2, wherein the directions of rotation (ω21, ω22, ω31, ω32) of at least one of the two pairs of polishing plates (21, 22) and pin wheels (31, 32) are reversed at least once during the dressing.

4. The method as claimed in claim 2, wherein the directions of rotation (ω21, ω22, ω31, ω32) of only one of the two pairs of polishing plates (21, 22) and pin wheels (31, 32) are reversed at the same time during the dressing.

5. The method as claimed in claim 1, wherein, when dressing only one polishing cloth (11), at least the direction of rotation (ω21) of the polishing plate (21) or the direction of rotation (ω4) of the dresser (4) is reversed once.

6. The method as claimed in claim 1, wherein, when dressing only one polishing cloth, at least the direction of rotation (ω21) of the polishing plate (21) and the direction of rotation (ω4) of the dresser (4) are reversed once.

7. The method as claimed in one of claims 1 to 6, wherein disks or rings covered with one or more dressing elements (8) are used as dressers (4).

8. The method as claimed in one of claims 1 to 7, wherein the dressing elements (8) have surfaces covered with diamonds.

9. The method as claimed in one of claims 1 to 8, wherein one to five dressers (4) are used simultaneously.

10. The method as claimed in one of claims 1 to 9, wherein at least three dressers (4) are used simultaneously.

11. The method as claimed in one of claims 1 to 10, wherein the polishing pads (11, 12) are foamed polishing pads.

12. The method as claimed in claim 11, wherein polishing pads foamed from polyurethane are used as foamed polishing pads.

13. The method as claimed in either of claims 1 and 2, wherein the mutually facing faces of the upper polishing plate (22) and the lower polishing plate (21) are set plane-parallel to one another.

14. The method as claimed in one of claims 1, 2 or 13, wherein the dressers (4) have clearances and in these clearances there are freely movable and/or fixed dressing elements (8).

15. The method as claimed in one of claims 1 to 14, wherein a dressing agent, in particular a liquid, is applied to the polishing pads (11, 12) during the dressing.