Method for Polishing a Semiconductor Wafer

The invention relates to a method for polishing a semiconductor wafer.

Various polishing methods are already known in the prior art.

So-called double-side polishing (DSP) is described in US3691694 for example.

In accordance with one embodiment of DSP as described in EP208315B1, semiconductor wafers in "carrier plates" composed of metal or plastic, which have suitably dimensioned cut-outs, are moved between two rotating polishing plates covered with a polishing pad in the presence of a polishing sol on a path predetermined by the machine and process parameters, and are thereby polished.

DSP is conventionally carried out using a polishing pad composed of homogeneous, porous polymer foam, as described in DE10004578C1, for example, where it is also disclosed that the polishing pad adhering to the upper polishing plate is permeated by a network of channels and the polishing pad adhering to the lower polishing plate has a smooth surface without such a texture. This measure is intended firstly to ensure homogeneous distribution of the polishing agent used during the polishing, and secondly to prevent the semiconductor wafer from sticking to the upper polishing pad when the upper polishing plate is lifted after polishing has been completed.

In addition to DSP, in the prior art so-called CMP polishing is necessary in order to eliminate defects and to reduce the surface roughness. In the case of CMP, a softer polishing pad is used than in the case of DSP. Moreover, only one side of the semiconductor wafer is polished by means of CMP, namely the

side on which components are subsequently intended to be fabricated. The prior art also makes reference to finish polishing. CMP methods are disclosed for example in US 2002-0077039 and in US 2008-0305722.

The German Patent Application DE 102 007 035 266 A1 describes a method for polishing a substrate composed of silicon material, comprising two polishing steps of the FAP type, which differ in that a polishing agent slurry containing non-bonded abrasive substance as a solid is introduced between the substrate and the polishing pad in one polishing step, while in the second polishing step the polishing agent slurry is replaced by a polishing agent solution that is free of solids. FAP denotes fixed abrasive polishing, which describes a polishing method that uses polishing pads containing fixedly bonded abrasives.

The prior art therefore discloses polishing methods using polishing pads which contain no abrasives, wherein abrasives in the form of a polishing sol are supplied in this case, and also polishing methods using polishing pads containing abrasives, wherein a polishing sol does not have to be supplied.

All the methods known in the prior art are disadvantageous with regard to the geometry and/or nanotopology of the polished wafers. DSP and CMP lead to a decrease in thickness at the edge (Edge Roll-Off). FAP is disadvantageous with regard to the surface roughness.

The object of the invention was to provide an alternative to the method known in the prior art.

The object of the invention is achieved by means of a method for polishing a semiconductor wafer, comprising polishing a surface of the semiconductor wafer using a polishing pad and in a first step with supply of a polishing agent slurry containing

abrasives, subsequently ending the supply of the polishing agent slurry and in a second step with supply of a polishing agent solution having a pH value of greater than or equal to 12, which is free of solids, wherein the polishing pad used has a surface structure comprising elevations on the side that comes into contact with that surface of the semiconductor wafer which is to be polished, and wherein the polishing pad is free of substances with abrasive action.

Preferably, the polishing agent slurry used in the first step contains abrasives selected from one or more of the group consisting of oxides of the elements aluminium, cerium and silicon.

The size distribution of the abrasive substance particles is preferably monomodal in nature.

The average particle size is 5 to 300 nm, particularly preferably 5 to 50 nm.

The proportion of the abrasive substance in the polishing agent slurry is preferably 0.25 to 20% by weight, particularly preferably 0.25 to 1% by weight.

The use of colloidal silica as polishing agent slurry is particularly preferred.

By way of example, the aqueous polishing agents Levasil® 200 from Bayer AG and Glanzox 3900® from Fujimi can be used.

The polishing agent slurry can contain additives such as sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3), sodium hydroxide (NaOH), potassium hydroxide (KOH), ammonium hydroxide (NH_4OH), tetramethylammonium hydroxide (TMAH).

However, the polishing agent slurry can contain one or more further additives, for example surface-active additives such as wetting agents and surfactants, stabilizers acting as protective colloids, preservatives, biocides, alcohols and complexing agents.

The polishing agent solution used in the second step is preferably water or aqueous solutions of the compounds sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3), sodium hydroxide (NaOH), potassium hydroxide (KOH), ammonium hydroxide (NH_4OH), tetramethylammonium hydroxide (TMAH) or any desired mixtures thereof.

The proportion of the stated compounds in the polishing agent solution is preferably 0.01 to 10% by weight.

The pH value of the polishing agent solution is greater than or equal to 12.

The polishing pad used preferably has a porous matrix.

The polishing pad is preferably composed of a thermoplastic or heat-resistant polymer. A multiplicity of materials may be envisaged for the material, for example polyurethanes, polycarbonate, polyamide, polyacrylate, polyester, etc.

The polishing pad preferably comprises solid, microporous polyurethane.

It is also preferred to use polishing pads composed of foamed plates or felt or fibre substrates, which are impregnated with polymers.

Coated/impregnated polishing pads can also be configured such that they have a different pore distribution and different pore sizes in the substrate compared with those in the coating.

In order to control the porosity of the polishing pad, fillers can be introduced into the polishing pad.

Commercially available polishing pads which can be used after a corresponding surface topography has been produced are e.g. the SPM 3100 from Rodel Inc. or the pads of the DCP series and the pads having the trade names IC1000™, Polytex™ or SUBA™ from Rohm & Haas.

The use of hard or very hard polishing pads is preferred, however.

The hardness according to Shore A should be at least 80°.

By way of example, the SUBA™ 1200 from Rohm & Haas having a hardness of 84° according to Shore A is suitable for this purpose.

A polishing pad of the type SUBA™ 800T2 from Nitta Haas Inc. is likewise suitable, and an alternative thereto should have the hardness according to ASKER C (SRIS 0101) of greater than 90.

The use of a polishing pad having a hardness of 80-100° according to Shore A is particularly preferred.

Pads of the type MH-S24A from Nitta Haas Inc. are specified for example with a hardness of up to 86 JIS-A (JIS K 6253A), where a hardness according to JIS-A corresponds to a hardness according to Shore A.

The hardness of the polishing pad is especially preferably 92-100° according to Shore A (very hard polishing pad).

The polishing pad preferably has pyramidal or tile-shaped structures. These microstructures can therefore have, for example, the form of columns having a cylindrical or polygonal cross section or the form of pyramids or truncated pyramids.

The polishing pad preferably has round or oval elevations.

The polishing pad preferably has angular, e.g. hexagonal elevations.

The height of the structures or elevations is preferably greater than or equal to 10 µm up to a few mm.

The extent of the elevations is preferably at least 50 µm to at most 400 µm, particularly preferably 50-200 µm.

The use of polishing pads having circular elevations having a diameter of 50-200 µm is especially preferred.

The elevations are preferably arranged in regular fashion on the polishing pad. The distances between two adjacent elevations is preferably a few µm to approximately 500 µm.

The polishing pad preferably has grooves or channels. The depth of the grooves or channels is preferably 10-200 µm. The distance between two adjacent channels or grooves is preferably a few µm to approximately 500 µm.

A surface of the polishing pad is preferably treated by means of chemical etching in order to produce such structures, elevations, channels or grooves.

A surface of the polishing pad is preferably treated by means of mechanical grinding or milling in order to produce such structures, elevations, channels or grooves.

A surface of the polishing pad is preferably treated by means of sintering or furrowing in order to produce such structures, elevations, channels or grooves.

Preferably, in the second step of polishing with supply of the polishing agent solution, the polishing pressure with which the polishing pad is pressed onto the surface of the semiconductor wafer is reduced versus the polishing pressure used in the first step.

The invention provides abrasiveless polishing with supply of a polishing agent solution having a high pH value of greater than or equal to 12. A polishing agent slurry is supplied in the first step of the polishing. This first step serves to start the polishing process.
As soon as the polishing process has started, the supply of the polishing agent slurry is ended.

Instead, an alkaline polishing agent solution is then supplied. Preferably, the polishing time in the second step of the polishing with supply of a polishing agent solution is at least 50%, preferably at least 70%, and especially preferably at least 85%, of the total polishing time. Preferably, only the front side of the semiconductor wafer is polished, wherein the total material removal is preferably not more than 1.0 µm.

The second step of the polishing with supply of a polishing agent solution is preferably effected at reduced polishing pressure. In this case, the polishing pressure is preferably approximately 70 to approximately 200 hPA, whereas at the beginning of the method, when a polishing agent slurry is

supplied, the polishing pressure is up to 560 hPa, preferably 250-400 hPa.

Conventional polishing machines such as e.g. the polishing machine of the Reflection type from Applied Materials, Inc. are suitable for carrying out the method.

This polishing machine has hitherto been used in CMP polishing, in particular. It is a multi-plate polishing machine. This polishing machine comprises a 5-zone membrane carrier, which permits the pressure profile of the carrier to be set differently in 5 zones.

In conventional chemical-mechanical polishing methods, polishing agent slurries (silica sol) having a fixed pH value are supplied both in the case of DSP and in the case of CMP in order to obtain the polishing removal. In the case of FAP, abrasives are incorporated in the polishing pad itself.

In the context of the present invention, the addition of abrasives is necessary only for starting the polishing process. Immediately after the commencement of the polishing removal until the end of polishing, the polishing is effected without addition of abrasive substances and without polishing pads containing abrasives. The polishing agent slurry initially added serves exclusively as a catalyst that starts the removal polishing process, and is then deactivated.

The geometry- and topography-determining polishing itself takes place without the use of abrasives, whether in the form of externally supplied silica sol particles or in the form of abrasive particles incorporated in the polishing pad.

Conventional CMP process parameters are otherwise employed in the method. The speeds of plate and polishing head are preferably approximately 30-150 rpm. The volumetric flow rate of the polishing agent is preferably 100 to 1000 ml/min. It is also preferred for the polishing head with the wafer guided therein to be moved over the polishing pad in an oscillatory fashion during polishing.

The local polishing pressure on the surface of the semiconductor wafer increases in particular where the local topography of the semiconductor wafer comes into contact with the local elevations of the polishing pad surface. Together with the alkaline polishing agent solution, an abrasiveless topography-dependent removal polishing process is effected on the semiconductor wafer.

This is advantageous in comparison with conventional CMP polishing, especially as the freely movable alkaline-loaded silica sol particles in combination with a soft finishing polishing pad effect further removal even at depressions on the surface of the semiconductor wafer. This can be eliminated by the method according to the invention, which leads to an improvement in the topography of the surface of the semiconductor wafer.

It is especially preferred to apply the method according to the invention to the polishing of the rear side of the semiconductor wafer as an intermediate step between a double-side polishing of the semiconductor wafer and the concluding final polishing of the front side of the semiconductor wafer, that is to say as a process sequence of double-side polishing - abrasiveless polishing of the rear side - polishing of the front side. It is furthermore preferred for the concluding polishing of the front side also to be configured as

abrasiveless polishing according to the method according to the invention.

It has been found that the polishing method claimed here is advantageous with regard to geometry and nanotopology. The inventors attribute the advantageous properties of this predominantly abrasiveless polishing to the fact that the latter eliminates disturbing properties of the polishing slurries used hitherto in the case of DSP and CMP. A three-body interaction of wafer, polishing pad and polishing slurry occurs in the case of DSP and CMP. This leads to a non-selective material removal on the wafer. The material removal is independent of the topography of the wafer in the case of DSP and CMP.

In the case of the polishing according to the invention of silicon wafers on a polishing machine of the Reflection type from Applied Materials, it has been found that silicon wafers having a slightly concave initial form lead to good polishing results, in particular with regard to the geometry values that can be obtained locally. In order to achieve this, it was necessary to define the average removal rate during polishing in a range of approximately 0.05 - 0.15 µm/min, which is ensured by polishing agent solutions having a pH value of greater than 12.

By comparison with FAP, a significant improvement in the surface roughness of the wafer can be observed as a result of the method according to the invention. Experiments have shown that significantly fewer scratches and defects on the surface are visible by comparison with FAP.

What is advantageous about the invention is the fact that even very hard polishing pads can be used.

With the use of silica sol as in the case of CMP, by contrast, the pad hardness that can be used is upwardly limited since, in the case of CMP, as uniform a removal as possible is realized as the interaction of a compliant polishing pad surface and the sol particles loaded with hydroxide ions (OH-) in order to press them as it were softly onto the wafer surface and thus softly to shear away the material with simultaneous chemical attack and to transport it away.

In the case of the substantially abrasiveless polishing claimed here, by contrast, the hydroxide ions (OH-) are contacted with the wafer surface in a targeted manner by means of the profiled surface structure of a preferably very hard polishing pad, which leads to a locally delimited increased removal rate at the locations having the highest local pressures, for example if a local elevation of the polishing pad surface impinges on an elevation of the wafer surface.

This results in an ideal removal behaviour which leads to an optimum planarization of the wafer surface whilst at the same time avoiding defects of the wafer surface.

The semiconductor wafer polished by the method according to the invention is preferably a wafer composed of silicon, silicon-germanium, silicon dioxide, silicon nitride, gallium arsenide and further so-called III-V semiconductors.

The use of silicon in monocrystalline form, for example crystallized by means of a Czochralski or float zone process, is preferred.

Patent Claims:

1. Method for polishing a semiconductor wafer, comprising polishing a surface of the semiconductor wafer using a polishing pad and in a first step with supply of a polishing agent slurry containing abrasives, subsequently ending the supply of the polishing agent slurry and in a second step with supply of a polishing agent solution having a pH value of greater than or equal to 12, which is free of solids, wherein the polishing pad used has a surface structure comprising elevations on the side that comes into contact with that surface of the semiconductor wafer which is to be polished, and wherein the polishing pad is free of substances with abrasive action.

2. Method according to Claim 1, wherein the polishing agent slurry used in the first step contains abrasives selected from one or more of the group consisting of oxides of the elements aluminium, cerium and silicon.

3. Method according to Claim 1, wherein the polishing agent slurry used in the first step is colloidal silica.

4. Method according to any of Claims 1 to 3, wherein the polishing pad used has a porous matrix.

5. Method according to any of Claims 1 to 4, wherein the polishing pad used is composed of a thermoplastic or heat-resistant polymer.

6. Method according to any of Claims 1 to 5, wherein the polishing pad used comprises pyramidal or tile-shaped structures, round or oval or hexagonal elevations or grooves.

7. Method according to any of Claims 1 to 6, wherein a surface of the polishing pad is structured by means of chemical etching, grinding ("buffing"), sintering or furrowing.

8. Method according to any of Claims 1 to 7, wherein in the second step of polishing with supply of the polishing agent solution, the polishing pressure with which the polishing pad is pressed onto the surface of the semiconductor wafer is reduced versus the polishing pressure used in the first step.