

**Method for cleaning a semiconductor wafer composed of silicon
directly after a process of polishing of the semiconductor
wafer**

- 5 The invention relates to a method for cleaning a semiconductor wafer composed of silicon in respect of polishing agent residues directly after a process of chemical mechanical polishing of the semiconductor wafer.
- 10 Semiconductor wafers composed of silicon are generally subjected to a process of chemical mechanical polishing (CMP) for smoothing one or both sides of the semiconductor wafer. After the polishing process, the semiconductor wafers are contaminated with residues of the polishing agent and have to
- 15 be cleaned. The residues have to be removed as rapidly as possible since they can attack the sensitive surface of the semiconductor wafer, and they have to be removed as completely as possible since particles remaining on the cleaned surface can cause surface defects which can no longer be removed later
- 20 by cleaning. Furthermore, the cleaning must also be completed in the shortest possible time for economic reasons.
- DE 10 2007 032 385 A1 describes a method for cleaning a semiconductor wafer after CMP in a modularly structured
- 25 cleaning installation. The method provides for semiconductor wafers each individually being cleaned in at least two cleaning modules and dried in a drying module. A cleaning sequence which comprises three substeps and is aimed at removing metallic impurities is carried out in the same cleaning module.
- 30 In EP 0 708 480 A1, as an advantageous alternative to cleaning using a cleaning solution containing ammonium hydroxide, hydrogen peroxide and water, it is proposed that a semiconductor wafer, after a polishing process, is firstly
- 35 cleaned using an aqueous solution of hydrofluoric acid, then rinsed using ozone-containing water, and finally cleaned using brushes in the presence of water.

US 5, 944, 906 describes a method by which semiconductor wafers whose surfaces are formed by at least two different materials are cleaned after a polishing process. When this method is employed, the semiconductor wafer is successively treated with
5 a series of aqueous cleaning solutions. The series comprises hydrofluoric acid, a surfactant solution having a pH in the range of 1 to 4, an aqueous ammonium hydroxide solution, a surfactant solution having a pH in the range of 8 to 10, and deionized water.

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It is an object of the present invention to provide a cleaning method by which semiconductor wafers composed of silicon can, individually and with a high throughput effectively after a process of chemical mechanical polishing, be freed of residues
15 of the polishing process on the polished front side and the rear side.

The object is achieved by means of a method for cleaning a semiconductor wafer composed of silicon directly after a
20 process of chemical mechanical polishing of the semiconductor wafer, comprising the following steps in the order indicated:

- a) transferring the semiconductor wafer from a polishing plate to a first cleaning module, wherein both side surfaces of the semiconductor wafer are sprayed at least once with water at
25 a pressure of not more than 1000 Pa in the course of the transfer;
- b) cleaning the semiconductor wafer between rotating rollers with supply of water;
- c) spraying the side surfaces of the semiconductor wafer with
30 an aqueous solution containing hydrogen fluoride and a surfactant, at a pressure of not more than 70 000 Pa;
- d) spraying the side surfaces of the semiconductor wafer with water at a pressure of not more than 20 000 Pa;
- e) dipping the semiconductor wafer into an aqueous alkaline
35 cleaning solution;
- f) cleaning the semiconductor wafer between rotating rollers with supply of water;
- g) spraying the semiconductor wafer with water; and

h) drying the semiconductor wafer.

This method enables the rapid and efficient cleaning of the polished front side and also of the rear side of a semiconductor wafer composed of silicon directly after a process of chemical mechanical polishing of the semiconductor wafer.

The semiconductor wafer is treated in different cleaning modules during the method. A cleaning module is a functional unit in which the semiconductor wafer is cleaned, either by spraying the side surfaces of the semiconductor wafer with a liquid, by dipping the semiconductor wafer into a bath, or by cleaning the semiconductor wafer between rotating rollers with supply of water or with supply of a cleaning solution. It is preferred for the semiconductor wafer to be rotated about its center during the abovementioned treatments in a cleaning module, preferably in a vertical plane.

The method comprises a specific sequence of operations which, in total, achieve the object of the present invention. A semiconductor wafer composed of silicon which has been cleaned in accordance with the method has, with regard to contamination by particles, a degree of purity which is already in the range of what is expected of polished semiconductor wafers composed of silicon which are about to be packaged and sent to the customer. At the same time, the method does not last longer than 360 s, preferably not longer than 300 s, calculated from the transfer from the polishing plate in accordance with step a) until the completion of drying in step h) of the method, times during which the semiconductor wafers are transferred by robots being taken into account.

When the method is employed, the discharge of dried semiconductor wafers per unit time (cycle time) is at least one semiconductor wafer per 75 s, preferably at least one semiconductor wafer per 66 s.

The method comprises the transfer from the polishing plate to a first cleaning module, cleaning steps b) to g) and, finally, the drying of the semiconductor wafer in a drying module. Preferably not more than three cleaning modules are used for
5 carrying out cleaning steps b) to g) of the method, which contributes to a high throughput.

The water used for cleaning the semiconductor wafer is preferably deionized water.
10

At the beginning of the method, the semiconductor wafer that has residues of polishing agent adhering to its polished front side and to its rear side is transported as rapidly as possible from the polishing plate to a first cleaning module. In the
15 course of this transfer, both sides of the semiconductor wafer are sprayed with water at least once, wherein the semiconductor wafer is preferably held in a manner lying horizontally or in a vertically upright manner. It is particularly preferred to transport the semiconductor wafer with the aid of a robot
20 system gripping it at the edge to an acceptance station and to deposit it there, to spray it there with water in accordance with step a) of the method, and then to transport it further to the first cleaning module with the aid of the robot system. The spraying of the side surfaces with water preferably lasts not
25 less than 1 s and not more than 10 s. If the time period is shorter than 1 s, then this detrimentally affects the efficiency of the method, and if it is longer than 10 s, then this is detrimental to the productivity of the method.

30 The pressure at which water is sprayed onto the side surfaces of the semiconductor wafer in the course of step a) of the method is not more than 1000 Pa (10 mbar). If the pressure at this point in the method is higher, there is the risk of surface defects being caused by the higher pressure when the
35 freshly polished and therefore sensitive semiconductor wafer is sprayed with water, which surface defects can no longer be removed by cleaning later.

Steps b) to d) of the method are preferably carried out in the first cleaning module.

Step b) of the method comprises cleaning the semiconductor wafer between rotating rollers with supply of water. The rollers preferably have a sponge-like covering composed of a plastic such as polyvinyl alcohol, with which the semiconductor wafer comes into contact during cleaning. Rotating brushes are also suitable. The semiconductor wafer is preferably held vertically upright and rotated about its center during this treatment. Step b) of the method preferably lasts not less than 10 s and not more than 30 s. If the time period is shorter than 10 s, then this detrimentally affects the efficiency of the method, and if it is longer than 30 s, then this is detrimental to the productivity of the method.

Step c) of the method comprises spraying the side surfaces of the semiconductor wafer with an aqueous solution containing hydrogen fluoride and at least one surfactant. The semiconductor wafer is preferably held vertically upright and rotated about its center during this treatment. Step c) of the method preferably lasts not less than 20 s and not more than 30 s. If the time period is shorter than 20 s, then this detrimentally affects the efficiency of the method, and if it is longer than 30 s, then this is detrimental to the productivity of the method.

The concentration of hydrogen fluoride (HF) is preferably 0.5 to 1.5% by weight, and that of the surfactant is preferably 0.015 to 0.03% by weight. Consideration is preferably given to surfactants which contain one or more acid groups and accordingly form an aqueous solution having a pH of less than 7.

The pressure at which the aqueous solution is sprayed onto the side surfaces of the semiconductor wafer in the course of step c) of the method is not more than 70 000 Pa (0.7 bar) and preferably not less than 40 000 Pa (0.4 bar). If the pressure

at this point in the method is higher, there is the risk of surface defects being caused when the semiconductor wafer is sprayed with the aqueous solution, which surface defects can no longer be removed by cleaning later. If the pressure is too
5 low, the cleaning remains incomplete.

Step d) of the method comprises spraying the side surfaces of the semiconductor wafer with water. The semiconductor wafer is preferably held vertically upright and rotated about its center
10 during this treatment. Step d) of the method preferably lasts not less than 1 s and not more than 10 s. If the time period is longer than 10 s, then this is detrimental to the productivity of the method.

15 The pressure at which water is sprayed onto the side surfaces of the semiconductor wafer in the course of step d) is not more than 20 000 Pa (0.2 bar). If the pressure at this point in the method is higher, there is the risk of surface defects being caused when the semiconductor wafer is sprayed with water,
20 which surface defects can no longer be removed by cleaning later.

Step e) of the method is preferably carried out in a second cleaning module. It comprises dipping the semiconductor wafer
25 into an aqueous alkaline cleaning solution. The semiconductor wafer is preferably held vertically upright and rotated about its center during this treatment. The cleaning solution preferably has a temperature of not less than 50°C and not more than 60°C. It contains an alkaline compound, preferably
30 tetramethylammonium hydroxide (TMAH) and, if appropriate, hydrogen peroxide (H_2O_2). The concentration of the alkaline compound is preferably in the range of 0.1 to 0.4% by weight, and that of hydrogen peroxide is preferably in the range of 0.7 to 1.5% by weight.

35 Step e) of the method preferably lasts not less than 40 s and not more than 60 s. If the time period is shorter than 40 s, then this detrimentally affects the efficiency of the method,

and if it is longer than 60 s, then this is detrimental to the productivity of the method.

Steps f) and g) of the method are preferably carried out in a
5 third cleaning module.

Step f) of the method comprises cleaning the semiconductor wafer between rotating rollers with supply of water. The rollers preferably have a sponge-like covering composed of a plastic such as polyvinyl alcohol, with which the semiconductor wafer comes into contact during cleaning. Rotating brushes are also suitable. The semiconductor wafer is preferably held
10 vertically upright and rotated about its center during this treatment. Step f) of the method preferably lasts not less than 10 s and not more than 30 s. If the time period is shorter than 10 s, then this detrimentally affects the efficiency of the method, and if it is longer than 30 s, then this is detrimental to the productivity of the method.

20 Step g) of the method comprises spraying the side surfaces of the semiconductor wafer with water. The semiconductor wafer is preferably held vertically upright and rotated about its center during this treatment. Step g) preferably lasts not less than 5 s and not more than 10 s. If the time period is shorter than 5 s, then this detrimentally affects the efficiency of the method, and if it is longer than 10 s, then this is detrimental to the productivity of the method.

Step h) of the method comprises drying the semiconductor wafer
30 in a drying module. A drying module in which drying is effected in the presence of isopropanol vapor is particularly preferred. The drying lasts preferably not less than 45 s and preferably not more than 65 s.

35 The method according to the invention is suitable for cleaning semiconductor wafers composed of silicon, in particular those having diameters in the range of 200 to 450 mm.

Example 1:

Semiconductor wafers composed of silicon were subjected to chemical mechanical polishing and cleaned after the polishing process in the manner according to the invention. The efficiency of the method was manifested in the number of particles measured on the semiconductor wafers prior to packaging and sending to the customer. In the case of half of the semiconductor wafers examined, not more than 5 particles having a maximum linear extent of more than 37 nm were found. In a comparative fashion, semiconductor wafers were also cleaned according to a standard method. In the case of these semiconductors wafers, the corresponding number of particles was in the range of 15 to 20.

Example 2:

In order to show the importance of the surfactant during step c), a first and a second group of semiconductor wafers were subjected to chemical mechanical polishing and cleaned. Each group comprised 40 semiconductor wafers composed of silicon. The cleaning of the second group directly after the polishing process was effected according to the invention. The cleaning of the first group differed therefrom merely in that the surfactant was dispensed with during step c). The cleaned semiconductor wafers were subjected to a final cleaning corresponding to the prior art and examined for the presence of particles having a size of 40 nm or greater. Figs. 1 and 2 show maps of the particles found on the front side, wherein each map indicates the total of the particles found on the polished front sides of the semiconductor wafers of the respective group of semiconductor wafers. The comparison of fig. 1 and fig. 2 shows that the number of particles found on the front side of semiconductor wafers cleaned according to the invention (second group, fig. 2) was significantly lower than the number found in the case of the semiconductor wafers not cleaned according to the invention (first group, fig. 1).

Example 3:

In order to show the importance of the pressure during step c),
a third and a fourth group of semiconductor wafers were
5 subjected to chemical mechanical polishing and cleaned. Each
group comprised 10 semiconductor wafers composed of silicon.
The cleaning of the fourth group directly after the polishing
process was effected according to the invention. The cleaning
of the third group differed therefrom merely in that the
10 aqueous solution during step c) was sprayed onto the side
surfaces of the semiconductor wafers at a pressure of 100 000
Pa. A corresponding pressure of 60 000 Pa was set for cleaning
the semiconductor wafers of the fourth group. The cleaned
semiconductor wafers were subjected to a final cleaning
15 corresponding to the prior art and examined for the presence of
particles having a size of 40 nm or greater. Figs. 3 and 4 show
maps of the particles found on the front side, wherein each map
indicates the total of the particles found on the front sides
of the semiconductor wafers of the respective group of
20 semiconductor wafers. The comparison of fig. 3 and fig. 4 shows
that the number of particles found on the front side of
semiconductor wafers cleaned according to the invention (fourth
group, fig. 4) was significantly lower than the number found in
the case of the semiconductor wafers not cleaned according to
25 the invention (third group, fig. 3).

Patent claims

1. A method for cleaning a semiconductor wafer composed of silicon directly after a process of chemical mechanical polishing of the semiconductor wafer, comprising the following steps in the order indicated:
 - a) transferring the semiconductor wafer from a polishing plate to a first cleaning module, wherein both side surfaces of the semiconductor wafer are sprayed at least once with water at a pressure of not more than 1000 Pa in the course of the transfer;
 - b) cleaning the semiconductor wafer between rotating rollers with supply of water;
 - c) spraying the side surfaces of the semiconductor wafer with an aqueous solution containing hydrogen fluoride and a surfactant, at a pressure of not more than 70 000 Pa;
 - d) spraying the side surfaces of the semiconductor wafer with water at a pressure of not more than 20 000 Pa;
 - e) dipping the semiconductor wafer into an aqueous alkaline cleaning solution;
 - f) cleaning the semiconductor wafer between rotating rollers with supply of water;
 - g) spraying the semiconductor wafer with water; and
 - h) drying the semiconductor wafer.
2. The method as claimed in claim 1, wherein steps b) to d) are carried out in the first cleaning module, step e) is carried out in a second cleaning module, and steps f) and g) are carried out in a third cleaning module.
3. The method as claimed in claim 1 or claim 2, wherein the semiconductor wafer is held vertically upright and rotated about its center during steps b) to g).
4. The method as claimed in any of claims 1 to 3, wherein steps b) to g) are carried out within a time period which for step b) has a length of not less than 10 s and not more than 30 s, for step c) has a length of not less than 20 s and not more

than 30 s, for step d) has a length of not less than 1 s and not more than 10 s, for step e) has a length of not less than 40 s and not more than 60 s, for step f) has a length of not less than 10 s and not more than 30 s, and for step g) has a
5 length of not less than 5 s and not more than 10 s.

5. The method as claimed in any of claims 1 to 4, wherein not more than 360 s elapse from transferring the semiconductor wafer from the polishing plate in accordance with step a) until
10 the completion of drying the semiconductor wafer in accordance with step h).

6. The method as claimed in any of claims 1 to 5, wherein the dried semiconductor wafer is discharged after a cycle time of
15 not more than 75 s.

7. The method as claimed in any of claims 1 to 6, wherein the cleaned semiconductor wafer has a diameter in the range of 200 mm to 450 mm.