

Method for Grinding Semiconductor Wafers

The present invention relates to a method for grinding semiconductor wafers.

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Semiconductor wafers are produced according to the prior art by a plurality of process groups:

- a) producing a monocrystalline semiconductor rod (crystal
10 growth)
- b) slicing the rod into individual wafers ("wafering",
"sawing")
- c) mechanical processing
- d) chemical processing
- 15 e) chemical-mechanical processing
- f) optionally coating

A multiplicity of further steps, such as cleaning, sorting, measuring and packaging steps, are carried out besides this.

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The group of mechanical processing steps comprises rounding the wafer edge and planarizing the wafer surface by means of mechanically abrasive steps which remove material.

- 25 The edge rounding is carried out by grinding or polishing, for example with round or band-shaped tools.

The planarizing of the wafer surface is carried out "in batch", i.e. for a plurality of wafers simultaneously, by so-called
30 lapping with free abrasive using a lapping suspension ("slurry") or as a single-wafer process by grinding with bound abrasive.

In the case of single-sided grinding, one side of the semiconductor wafer is fixed by means of a vacuum in a wafer

carrier ("chuck"), and the other side is processed by a grinding disc coated with grinding abrasive. If both sides of the wafer are intended to be ground, the processing of the two sides of the semiconductor wafer is generally carried out sequentially.

Batch double-sided grinding methods are also employed, with lapping kinematics in which there is bound abrasive or abrasive applied onto coatings (cloth) onto large working discs facing one another, between which the semiconductor wafers are ground on both sides as in the case of lapping while being partially free to move in guide cages.

In order to achieve a particularly good geometry of the processed wafers, a simultaneous double-sided grinding method ("double disc grinding", DDG) is often used.

EP 1 049 145 A1 discloses a processing sequence which involves a DDG pregrinding step ("roughing"), followed by one or more (sequential) single-sided fine grinding steps ("flattening").

Conversely, US 6,066,565 describes the use of the DDG method in a two-stage process with double-sided pregrinding and a double-sided fine grinding. This requires two machines and clamping the workpiece a plurality of times.

DE 101 42 400 A1 discloses a method which is carried out with a simultaneous double-sided grinding machine and is characterized in that it comprises only a single processing operation with the workpiece being clamped only once. This means that the generally required pre-processing and fine processing ("roughing" and "flattening") take place in a single integrated processing step. Also described is a simultaneous double-sided grinding method, using a workpiece retainer which holds and

moves the semiconductor wafer virtually without constrained guiding ("free-floating process", FFP).

In the case of simultaneous double-sided grinding, which is also described for example in EP 868 974 A2, the semiconductor wafer is processed simultaneously on both sides while floating freely between two grinding discs mounted on opposite collinear spindles, and is guided substantially free from constraining forces axially between a water cushion (hydrostatic principle) or air cushion (aerostatic principle) acting on the front and back sides, and is radially prevented from floating thereon loosely by a thin circumferential guide ring or by individual radial spokes. The semiconductor wafer rotates about its symmetry axis during the grinding. This rotation is driven by friction tools engaging on the front and back sides, via a "notch finger" which engages in an orienting reference "notch", or by friction belts which partially enclosed the semiconductor wafer circumferentially.

DE 10 2004 005 702 A1 discloses a method for producing a semiconductor wafer, comprising double-sided grinding of the semiconductor wafer in which the semiconductor wafer is ground initially coarsely and subsequently finely on both sides by a grinding tool, which is characterized in that the semiconductor wafer remains clamped in a grinding machine between the coarse grinding and the fine grinding and the grinding tool is brought to engage with a load essentially remaining constant when changing from coarse grinding to fine grinding. DE 10 2004 005 702 A1 furthermore describes a device for the double-sided grinding of flat workpieces, comprising two double spindles each with an inner sub-spindle and an outer sub-spindle, an instrument for loading and unloading the workpiece and a workpiece retainer which is arranged between the double

spindles and by which the workpiece is held free-floating during a grinding step, the sub-spindles being arranged coaxially and carrying grinding tools for grinding opposite sides of the workpiece and at least one sub-spindle of each double spindle respectively being displaceable axially independently of the other sub-spindle of the double spindle.

During the grinding processes - this applies to both single-sided and double-sided grinding methods, it is necessary to cool the grinding tool and/or the processed semiconductor wafer. Water or deionized water is conventionally used as a coolant. Commercial grinding machines, for example the models DFG8540 and DFG8560 ("Grinder 800 Series") from Disco Corp., which are suitable for grinding wafers with diameters of 100-200 mm and 200-300 mm respectively, are equipped on the working side with a vacuum unit which ensures a constant coolant flow rate of 1 or 3 l/min (= litres per minute) during the grinding, depending on the coolant temperature (constantly 1 l/min for a temperature of less than 22°C, constantly 3 l/min for a temperature of more than 22°C).

Double-sided grinding machines are available for example from Koyo Machine Industries Co., Ltd. The model DXSG320 is suitable for the DDG grinding of 300 mm wafers. Both vertical and horizontal spindles are employed in combination with special diamond grinding tools. These grinding tools are designed so that they cut only with the edge and combine a rapid forward feed rate with little heat production. The main difference is the wafer holding. The wafer to be processed is fixed by hydrostatic pressure pads on both sides in a transport ring. The wafer is driven merely by a small nose which engages in the notch or in the flat. Stress-free holding of the wafer can be ensured in this way.

JP58143948 describes a method for cooling in single-sided grinding machines and the way in which the coolant is applied onto the wafer surface to be processed.

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JP2250771 teaches to determine the coolant flow rate and, depending on a measured grinding temperature, to increase it rapidly in order on the one hand to keep the grinding temperature within a predetermined temperature range and on the other hand also to keep the amount of coolant used at a minimum required level.

In double-sided grinding machines, the process coolant conventionally emerges from the centre of the grinding tool and is transported to the grinding teeth by means of the centrifugal force. The coolant throughput can be regulated by keeping the coolant flow rate at a setpoint value. This regulating may be carried out electronically by means of a suitable measuring device and actuators or by mechanical means (pressure reducer).

US2001/025660 AA proposes to monitor machine working/engagement times and machine idle/setup times ("active" and "idle" modes) of the grinding machine automatically on the grinding machine, and to regulate the coolant flow rate accordingly. At the start of the setup time the coolant flow is reduced or entirely stopped, and it is subsequently increased periodically during the setup time, i.e. the introduction of a new workpiece. This achieves more economical use of coolant compared with the solutions likewise known in the prior art, namely to keep the coolant flow rate constant even during the machine idle time. A certain coolant flow rate at least towards the end of the setup time seems to be advantageous, since the grinding machines

comprise for example sensors which react extremely sensitively to temperature differences.

US 5113622 AA proposes temperature detectors on the coolant in-
5 and outflows. The difference between the temperatures at the inflow and the outflow is thereby determined. This temperature difference is intended to indicate the amount of heat generated during the grinding, by taking into account the coolant flow rate and the dissipation of heat. In order to keep the
10 temperature of the GaAs wafer to be processed below a particular target temperature, and to avoid fracture or warp due to residual thermal stresses, corresponding regulation of the coolant flow rate is proposed as a function of the continuously determined amounts of heat.

15 The methods known in the prior art therefore involve either keeping the temperature of the workpiece constant or below a target value and increasing the coolant flow rate accordingly, or setting a constant coolant flow rate with one or two target
20 values.

Problems, which the prior art was not able to resolve at the application date, consist in workpieces ground with one and the same grinding tool having different surface damages, which
25 implies non-constant grinding conditions, and also the lifetime of grinding tools (in this context, the person skilled in the art also refers to grinding tool service life) being rather unsatisfactory even when a constant coolant flow rate and therefore supposedly sufficient cooling of the workpiece and
30 the grinding tool are meant to be ensured.

It was an object of the present invention to achieve more constant grinding conditions and an improved type of cooling in grinding machines

The object of the present invention is achieved by a method for grinding semiconductor wafers, the semiconductor wafers being processed so as to remove material on one or both sides by
5 means of at least one grinding tool, respectively with supply of a coolant into a contact region between a semiconductor wafer and the at least one grinding tool, characterized in that the coolant flow rate is respectively selected as a function of a grinding tooth height of the at least one grinding tool and
10 this coolant flow rate is reduced as the grinding tooth height decreases.

Both single-sided and a double-sided grinding machines according to the prior art are suitable for the method
15 according to the invention.

The invention thus preferably relates to a method for the single-sided grinding of semiconductor wafers.

20 Methods for the simultaneous double-sided grinding of semiconductor wafers (DDG) are more particularly preferred.

Preferably, when using an unworn grinding tool fresh from the factory, a current grinding tooth height of this grinding tool
25 is respectively determined during the grinding processes and the coolant flow rate is reduced as a function of the grinding tooth height determined in this way, although the coolant flow rate should not fall below a particular minimum value even with a low grinding tooth height.

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In contrast to the prior art, the coolant flow rate is thus not constant or even increased, rather it is reduced.

The Inventors have discovered that only in this way is it

possible to achieve constant cooling of the contact region between a workpiece and a grinding tool. The coolant then stops in front of the grinding teeth, flows around them and is turbulated as a function of the height of the grinding teeth in the contact region between the workpiece and the grinding tool.

The amount of coolant which reaches this contact region is crucial for the grinding outcome ("sub-surface damage") and the service life of the grinding tool.

Ceramically bound diamond grinding teeth are subject to wear, so that the height of the grinding teeth decreases with an increasing length of use. The Inventors have discovered that in the prior art, constant cooling of the contact region between a workpiece and a grinding tool is not in fact possible throughout the period of use, when provision is simply made to keep the coolant flow rate constant.

The Inventors have discovered that it is advantageous to set a higher coolant throughput for tools fresh from the factory than for worn tools.

When the grinding tooth height of the workpiece reaches a minimum value, the throughput should be selected to be so low as to prevent an aquaplaning effect, which would interrupt the grinding process. This preferably applies for double-sided grinding machines, whereas the aquaplaning effect is less critical for single-sided machines.

In order to avoid the aquaplaning effect with a continuously constant coolant flow rate in the prior art, grinding tools with a critical minimum grinding tooth height have been replaced.

Software of the electronic cooling-water flow regulator ensures that a current setpoint value of the coolant flow rate for the one grinding tool, or for both grinding tools separately, is determined via a parameterizable profile, comprising a plurality of sample points and dependent on the grinding tooth height, of the coolant flow rate (cf. Example and **Table 1**) after measuring a current grinding tooth height.

The throughput is regulated, preferably by means of an actuator or by means of a pressure reducer, to this setpoint value which changes with the grinding tooth height. The corresponding actuator and pressure reducer devices are already known in the prior art for ensuring a constant coolant flow rate by regulation.

The current grinding tooth height of the one grinding tool, or both grinding tools, is preferably ascertained after each workpiece has been processed.

The particular advantages of the method according to the invention are that constant surface damage is achieved throughout the grinding tool service life owing to constant cooling of the contact region between the workpiece and the grinding tool.

It furthermore prevents aquaplaning from being able to occur with a low grinding tooth height, or the grinding tool needing to be replaced prematurely when a particular grinding tooth height is reached. In the prior art, the device for measuring the grinding tooth height was provided for the purpose of monitoring the grinding tooth height in order to carry out the necessary tool replacement immediately when the minimum grinding tooth height is reached.

Furthermore, a better cooling effect with a large grinding tooth height allows a longer grinding tool service life overall.

5 Example

The following example relates to a double-sided grinding machine of the DXSG320 type from Koyo Machine Industries.

10 Here, the two vertically arranged grinding tools are cooled separately from one another, i.e. different coolant throughputs are selected for the left and right grinding tools in the event that the grinding tooth height of the left grinding tool is less than that of the right grinding tool.

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The water flow rate sets a 100% reference value for the left and right grinding tools. In this example, it is 1.5 litres/minute for a cooling-water temperature of 21°C, which represents a conventional value according to the prior art. In
20 the prior art, attempts are usually made to keep this water flow rate constant. The prior art has already proposed actuators or pressure reducers on the said grinding machines.

For each grinding tool, a plurality of sample points of the
25 water flow rate are set as % of the water flow rate reference value (= 100%) as a function of a current grinding tooth height, i.e. for example a water flow rate which is 60% of the reference value (= 0.9 lmin⁻¹) for a grinding tooth height of 0.5 mm.

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The grinding tooth height, which is ascertained separately by the machine for each grinding tool after each grinding step, is specified in mm, cf. **Table 1**. The grinding machine in question is already equipped on the working side with devices for

measuring the grinding tooth heights of the grinding tools.

	Water flow rate $1.5 \text{ lmin}^{-1} = 100\%$ (left and right grinding tools)					
Grinding tooth height (mm)	0.0	0.3	0.5	1.0	2.0	6.0
Water flow rate (%)	40	40	60	100	108	140

Table 1

5 By means of machine software, curves are interpolated between the parameterized sample points (five sample points in this example) so that an exact setpoint value for the cooling-water flow rate can be assigned to each ascertained grinding tooth height. This setpoint value for the cooling-water flow rate is
10 given to the in-machine regulator as a target quantity. During the grinding process, the machine then separately regulates the two grinding tools to the respective current setpoint value. The regulating per se is carried out substantially automatically by means of actuators and pressure reducers.

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The grinding tools used initially have a grinding tooth height of 6.00 mm in the unused state. The water flow rate at the start is selected to be 140% of the standard value (100%) of 1.5 litres/minute. The minimum coolant flow rate to prevent
20 aquaplaning effects is 40% of the standard value.

Patent Claims

1. Method for grinding semiconductor wafers, the semiconductor wafers being processed so as to remove material on one or both sides by means of at least one grinding tool, respectively with supply of a coolant into a contact region between a semiconductor wafer and the at least one grinding tool, characterized in that the coolant flow rate is respectively selected as a function of a grinding tooth height of the at least one grinding tool and this coolant flow rate is reduced as the grinding tooth height decreases.
2. Method for grinding semiconductor wafers according to Claim 1, wherein a single-sided grinding machine is used and the semiconductor wafer is ground on one side by means of a grinding tool.
3. Method for grinding semiconductor wafers according to Claim 1, wherein a double-sided grinding machine is used and the semiconductor wafer is ground simultaneously on both sides by means of two grinding tools.
4. The method as claimed in one of Claims 1 to 3, wherein a high coolant flow rate is initially selected when using at least one unworn grinding tool, a current grinding tooth height of the at least one grinding tool is respectively determined during the grinding processes, and the coolant flow rate is respectively reduced as a function of the grinding tooth height determined in this way.
5. Method according to Claim 3 or 4, wherein the coolant flow rate does not fall below a minimum value.
6. Method according to one of Claims 3 to 5, wherein a

grinding tool with ceramically bound diamond grinding teeth is used.

7. Method according to one of Claims 3 to 6, wherein a

5 setpoint value of the coolant flow rate is determined electronically as a function of the grinding tooth height by means of software, and is adjusted by means of an actuator or pressure reducer.

10 8. Method according to Claim 7, wherein the setpoint value of the coolant flow is determined by means of the software from a parameterizable profile, comprising a plurality of sample points and dependent on the grinding tooth height, of the coolant flow rate for a previously determined grinding tooth
15 height.

9. Method according to one of Claims 3 to 8, wherein current grinding tooth heights on both grinding tools are ascertained after the end of each processing step, setpoint values of the
20 coolant flow are determined for those grinding tooth heights and that setpoint value of the coolant flow is adjusted separately for the two grinding tools.