

METHOD FOR THE MATERIAL-REMOVING MACHINING OF VERY THIN
WORK PIECES IN A DOUBLE SIDED GRINDING MACHINE

The invention relates to a method for the material-removing machining of very thin work pieces. Increasingly thin work pieces have to be machined by removing material, in particular by grinding. Such work pieces may, for example, be semiconductor wafers which may have a thickness of less than 100 μm after, and optionally already before, the machining process. Such work pieces are so flexible that machining in standard grinding machines is not possible. Various possibilities for fastening very thin wafers to a carrier are disclosed in C.Landesberger et al.: Carrier Techniques for Thin Wafer Processing, CS Mantech Conference, May 14-17, 2007, Austin, Texas, USA. Thus the wafers may be bonded, for example, to a carrier or held thereon by means of electrostatic forces. Also disclosed is the bonding of the wafers in a thicker carrier frame. By the connection of the wafers to a carrier, it is intended to be able to machine the wafers without having to change between different carriers for the different machining processes. The machining of the work pieces fastened to the carriers takes place by the carriers being held by a vacuum retaining device and a grinding disc being guided along a circular path over the surface of the work pieces and being pressed onto the work pieces. A drawback here is that a point of discontinuity is formed in the middle of the machined workpiece surface.

Proceeding from the aforementioned prior art, the object of the invention is to provide a method of the aforementioned type by which accurate material-removing machining of very thin work pieces is possible in a simple manner.

This object is achieved by the invention by the subjects of Claims 1 and 5. Advantageous embodiments are set forth in the dependent claims, the description and the figures.

The object is achieved by the invention firstly by a method for the material-removing machining, in particular for machining by grinding or polishing, of very thin work pieces which are releasably fastened with one of their surfaces in each case to a corresponding surface of similarly very thin carriers, comprising the steps:

- a double sided processing machine is provided which has an upper working disc with an upper working surface and a lower working disc with a lower working surface,

the working surfaces forming a working gap therebetween, in which at least one rotor disc comprising recesses is arranged,

- the work pieces are arranged together with the carriers in the recesses of the at least one rotor disc,

- at least one of the working discs is driven rotatably, the at least one rotor disc also being set in rotation by means of a roller device, whereby the carriers received in the rotor disc move with the work pieces along cycloid paths between the working surfaces, and one of the working surfaces coming into contact with the respective free surfaces of the carriers and one of the working surfaces coming into contact with the respective free surfaces of the work pieces,

- the free surfaces of the work pieces are machined in a material-removing manner by the working surface associated therewith, whilst by the working surface associated with the free surfaces of the carriers, either no material is removed or a removal rate of the free surfaces of the carriers is substantially less than a removal rate of the free surfaces of the work pieces or the removal rate of the free surfaces of the carriers is the same as the removal rate of the free surfaces of the work pieces.

According to the invention, therefore, a machining of the thin work pieces takes place in a double sided processing machine with planetary kinematics. In this case, in particular, a plurality of rotor discs may be provided which in each case have through-recesses. The carriers with the work pieces fastened thereto are held in the rotor discs and floatingly guided in the working gap between the working surfaces. At least the working surface of the machine associated with the work pieces has a working coating, in particular an abrasive or polishing coating, and this results in the removal of material. In this case, the work pieces may be so thin that they are too flexible after, and optionally even already before, the machining to be machined in the machine without the carriers. According to the invention, already before the machining process and in particular after the machining process, the work pieces may have a smaller thickness than the carriers. By their greater thickness, the carriers provide the required stability for machining in the double sided machine. According to the invention, it has been recognised that in this manner, in particular, an abrasive machining of very thin work pieces may also be carried out in a double sided processing machine with planetary kinematics, when the removal rate of the carriers is at least substantially less than that of the work pieces. By means of the planetary kinematics of the machine, i.e. the configuration of the rotor discs and the

movement thereof in the working gap, a particularly accurate and uniform removal of material is ensured. Points of discontinuity in the middle of the work pieces are reliably avoided.

In order to be able to reuse as far as possible the carriers for a plurality of work pieces to be machined, it is advantageous if as little material as possible is removed from the carriers. To this end, in a particularly appropriate manner, different removal rates of the free surfaces of the work pieces, on the one hand, and the free surfaces of the carriers, on the other hand, may be produced by the upper working surface and the lower working surface having different working coatings. In this manner, the different removal rates are automatically produced, at least in the case where the carriers and work pieces are of similar materials. When the material-removing machining is abrasive machining it is advantageous, in particular, if the working surface associated with the surfaces of the work pieces is provided with an abrasive coating and the working surface associated with the surfaces of the carriers is provided with a polishing coating, and the machining takes place without an abrasive polishing means. A material removal of the carriers may be almost completely avoided in this manner. Provided, however, machining takes place by polishing it is also possible to select the removal rates for the work pieces and carriers to be the same. So little material is removed during polishing that, even with this process, the carriers may be used repeatedly.

The object is also achieved by the invention by a method for the material-removing machining, in particular for machining by grinding or polishing, of very thin work pieces which are releasably fastened in pairs with one of their surfaces to corresponding opposing surfaces of similarly very thin carriers, comprising the steps:

- a double sided processing machine is provided which has an upper working disc with an upper working surface and a lower working disc with a lower working surface, the working surfaces forming a working gap therebetween, in which at least one rotor disc comprising recesses is arranged,

- the work pieces are arranged together with the carriers in the recesses of the at least one rotor disc,

- at least one of the working discs is driven rotatably, the at least one rotor disc being also set in rotation by means of a roller device, whereby the carriers received in the rotor disc move with the work pieces along cycloid paths between the working surfaces, and one of the working surfaces coming into contact with the respective free surfaces of

the work pieces fastened to one side of the carriers and one of the working surfaces coming into contact with the respective free surfaces of the work pieces fastened to the opposing side of the carriers,

- the free surfaces of the work pieces releasably fastened to the opposing sides of the carriers are respectively machined in a material-removing manner by the working surface associated therewith.

Whilst in the first solution according to the invention, in each case only one workpiece is releasably fastened to a carrier, in this solution according to the invention it is provided that two work pieces are releasably fastened to each carrier, in particular one on its upper face and one on its lower face. According to the invention, such a "triple stack" consisting of two work pieces and a carrier may also be machined in a material-removing manner in a particularly advantageous manner by the double sided processing machine comprising planetary kinematics. In this case, the work pieces fastened in pairs to a carrier may be machined by the upper and the lower working surface of the double sided machine, in particular at the same removal rate. In this case, the carriers do not come into contact with the working surfaces.

According to the invention, the work pieces and the carriers may in each case be of cylindrical configuration. The surfaces are in this case the upper and lower faces of the work pieces and/or carriers. They may have substantially parallel surfaces, in particular plane-parallel surfaces. Before the machining process, the work pieces may already have integrated circuits on the upper face thereof. They are then machined from the lower face thereof.

According to the invention, after the machining process, the work pieces may have a thickness of less than 100 μm , preferably less than 50 μm , further preferably less than 20 μm . Such work pieces are not able to be machined without the carriers in a double sided processing machine of the type according to the invention. The carriers may be many times thicker than the work pieces before and/or after machining. The thickness of the carriers may, for example, range between 0.5 mm to 2 mm, preferably 0.7 mm to 1.0 mm before and/or after machining.

According to the invention, when the carriers are machined in a floating manner with the work pieces in the rotor discs, the cylindrical carriers and work pieces terminating flush with one another at their edges results in repeated contact between the rotor discs and the edges of the carriers and work pieces and thus an introduction of force

onto the carriers and work pieces. This may, in particular, lead to damage in the thin work pieces according to the invention. A further embodiment, therefore, provides that the carriers and the work pieces have a substantially cylindrical shape and the carriers have a larger diameter than the work pieces. In this case, the work pieces may be fastened, for example, coaxially to the carriers. In this embodiment, during the machining only the edges of the thicker carriers, in particular, come into contact with the rotor discs which may absorb the corresponding forces without the risk of damage. An undesirable action of force on the thin work pieces is thus reliably avoided.

The work pieces may be fastened to the carriers by a adhesive connection, for example by wax, an adhesive or an adhesive film. The adhesive connection may be releasable thermally, chemically (for example by a solvent) by etching (for example by an etching agent) or by UV radiation. For example, with thermal releasability it has to be ensured that the temperatures present during the material-removing machining are lower than the temperature at which the adhesive connection is released. After the machining, the adhesive connection may thus be released by suitable thermal action and the workpiece removed from the carrier. Similarly, it may also be provided that the work pieces are fastened to the carrier by electrostatic charging.

The work pieces may be semiconductor wafers, in particular silicon wafers. The carriers may also be such semiconductor wafers, in particular silicon wafers. Said silicon wafers are available inexpensively and are very suitable as carriers. The carriers and the work pieces may thus consist of the same material. However, it is also possible that the carriers consist of a glass material, a ceramic material or a plastics material. By selecting a different material for the carriers than for the work pieces, in the first method according to the invention a different removal rate on the carriers may be achieved in a particularly simple manner.

With the exceptionally low material thicknesses of the work pieces according to the invention before and, in particular, after machining, a precise monitoring of the material removal and thus of the workpiece thickness is of particular significance. A further embodiment provides, therefore, that the thickness of the work pieces is measured during the machining thereof in the processing machine by means of an optical measuring method, in particular an interferometric measuring method. For example, infrared interferometry may be used, which is preferred, in particular, in work pieces consisting of silicon which are transparent to infrared radiation. Such measuring methods provide a

particularly high degree of measuring accuracy, as is required when machining very thin work pieces according to the invention. According to the invention, it has been recognised that such measuring methods may be used in a double sided processing machine comprising planetary kinematics. In this case, the thickness of the work pieces is still measured in the processing machine, therefore, in particular an optical measuring device is arranged in or on the processing machine. Thus measuring accuracies of 1 μm and more are possible. Falsifying influences such as temperature drift, tool wear, contaminants and mechanical flexibility of the tool, may thus be substantially eliminated. In contrast to tactile measuring methods, moreover, the work pieces are not in any way affected by the measurement. It is also possible to determine just the thickness of the workpiece separately from the carrier. This applies, in particular, when the carrier and workpiece consist of different materials and/or a suitable optical separating layer is provided between the work pieces and the carrier, for example an adhesive connection. Also, by means of the optical measuring device a thickness profile may be created and thus the uniformity of the machining monitored.

According to a development of this embodiment of the method, accordingly the following steps may further be provided:

- infrared radiation is oriented towards the free surface of the work pieces, a first radiation component being reflected on the free surface and a second radiation component penetrating the workpiece thickness, being reflected on the workpiece surface fastened to the carrier and emerging again on the free workpiece surface,
- the first and the second radiation component interfere, forming an interference pattern,
- the optical workpiece thickness between the free workpiece surface and the workpiece surface fastened to the carrier is determined using the interference pattern,
- by considering the refraction index of the workpiece material, the mechanical workpiece thickness is determined from the optical workpiece thickness.

For monitoring the workpiece thickness, however, in principle other measuring methods are also considered. Thus the thickness of the work pieces may be measured during the machining thereof in the processing machine, for example, by means of at least one eddy-current sensor or by means of at least one ultrasound sensor or by means of other measuring methods which have sufficient measuring accuracy in order to measure thicknesses in the range of less than 1mm.

By its cycloid path movement the work pieces may pass through a region outside the working gap. This is denoted in technical terms as overrun. For example, it is located on the outer face of the working gap. With an annular working gap, however, such overrun may also be located on the inside of the working gap. According to one embodiment, therefore, it may be provided that the thickness is measured (for example optically) in the region outside the working gap. The overrun is easily accessible and, therefore, particularly suitable for thickness measurement in this region.

According to an alternative embodiment, however, it may also be provided that the processing machine has at least one optical or other suitable measuring device arranged in a working disc of the processing machine, by which the thickness is measured. This embodiment is based on the idea of arranging a measuring device in one of the working discs, preferably in the upper working disc due to the possible occurrence of contaminants, and in this manner to permit a thickness measurement during the machining process.

An exemplary embodiment of the invention is explained in more detail hereinafter with reference to the drawings, in which schematically:

- Fig. 1 shows a double sided grinding machine used in the method according to the invention in a perspective view,
- Fig. 2 shows a workpiece connected to a carrier for the machining according to the invention in a sectional view,
- Fig. 3 shows an enlarged plan view of the lower working disc of the device of Fig. 1,
- Fig. 4 shows an enlarged detail of the double sided grinding machine used in the method according to the invention in a sectional view, and
- Fig. 5 shows two work pieces connected to a carrier for the machining according to the invention in a sectional view.

Provided nothing else is revealed, the same reference numerals in the figures denote the same objects. Fig. 1 shows schematically the construction of a double sided processing machine 10 used according to the invention, in the example shown a double sided grinding machine 10 comprising planetary kinematics. The double sided grinding machine 10 has an upper pivoting arm 12 which may be pivoted about a vertical axis via a pivoting device 14 mounted on the lower base 18. An upper working disc 16 is carried on the pivoting arm 12. In the example shown, the upper working disc 16 is able to be driven rotatably via a drive motor, not shown in more detail. On its lower face, not shown in Fig. 1, the upper working disc 16 has a working surface. In the example shown, a polishing coating is arranged on this surface. The lower base 18 has a carrier portion 19 which carries a lower working disc 20 which has on its upper face a working surface corresponding to the working surface of the upper working disc 16. Via the pivoting arm 12 the upper working disc 16 may be oriented coaxially to the lower working disc 20. The lower working disc 20 is, in the example shown, also able to be driven rotatably by a drive motor, not shown, in particular counter to the upper disc 16. Naturally, it is also possible to configure just one of the operating discs 16, 20 to be rotatably drivable. In the example shown, an abrasive coating is arranged on the working surface of the lower working disc 20.

On the lower working disc 20 a plurality of rotor discs 22 are shown which in each case comprise recesses for work pieces to be machined together with the carriers fastened thereto. The rotor discs 22 in each case engage with outer teeth in an inner pin ring 24 and an outer pin ring 26. In this manner, a roller device is formed, the rotor discs 22, for example, also being set in rotation via the inner pin ring 24 with a rotation of the lower working disc 20. The work pieces and the carriers arranged in the recesses of the rotor discs 22 then move on the lower working disc 20 along cycloid paths.

The work pieces to be machined by the double sided grinding machine shown in Figure 1 according to the invention and the carriers are shown in Fig. 2. The work pieces and carriers are in this case of cylindrical configuration. It is understood that the thickness of the work pieces and carriers is shown substantially exaggerated relative to their diameter. In Fig. 2, a cylindrical carrier 28 is shown, in the present case a silicon wafer. The carrier 28 has, in the example shown, a thickness of approximately 1 mm. Whilst the upper face 30 of the carrier 28 is free, the lower face 32 is connected via an adhesive connection 34 to the upper face 36 of a workpiece 38 to be machined, in the present case

also a silicon wafer. The adhesive connection 34 may, for example, be formed by a wax, an adhesive or an adhesive film. The wax, the adhesive and/or the adhesive film may be releasable, for example, thermally, chemically, by etching or by UV radiation. The lower face 40 of the workpiece 38 is, in turn, free. In the example shown in Fig. 2, the carrier 28 and the workpiece 38 on their outer faces terminate flush with one another in the state of the workpiece 38 fastened to the carrier 28. It is, however, also possible for the carrier 28 and workpiece 38 to have different diameters and not terminate flush with one another. The workpiece 38 shown in Fig. 2 has in the example a thickness of less than 100 μm after the machining process. As a result, without the carrier 28 it is so flexible that it could not be machined in the double sided grinding machine 10 shown in Fig. 1. By fastening to the considerably thicker carrier 28, however, a stability is achieved which is sufficient for machining in the machine 10.

For machining, the work pieces 38 together with the carriers 28 are inserted into the recesses of the rotor discs 22 and floatingly mounted in the working gap formed between the working discs 16, 20 which are oriented coaxially to one another by pivoting the pivoting arm 12. In at least one rotating upper or lower working disc 16, 20, for example, the upper working disc 16 is subsequently pressed downward by a pressing force. This results in an abrasive contact between the abrasive coating of the lower working disc 20 and the free lower face 40 of the work pieces 38. At the same time, the polishing coating of the upper working disc 16 comes into contact with the upper free face 30 of the carriers 28. In this case, the machining by grinding only takes place with water as a cooling medium. A polishing means using an abrasive material is not used. As a result, the work pieces 38 may be thinly ground from their lower face 40, without any removal of material on the upper face 30 of the carriers 28. After the machining, the upper working disc 16 is again pivoted away and the machined work pieces 38 may be removed together with the carriers 28 from the rotor discs. Subsequently, for example by thermal action, the adhesive connection 34 may be released and the work pieces 38 are thus separated from the carriers 28. The carriers 28 may be subsequently reused.

In Fig. 3, an enlarged plan view of the lower working disc 20 with its working surface 21 is shown with the abrasive coating. The rotor discs 22 may also be seen with a plurality of recesses 23 for the carriers and work pieces. Also visible is the inner pin ring 24 and the outer pin ring 26 on which the rotor discs 22 roll with their outer teeth 25. During the course of their cycloid path movement the recesses 23 and therewith the

carriers 28 and work pieces 38 received therein partially pass through a region 42 outside the working gap defined by the lower working surface 21 and the upper working surface of the upper working disc 16 during operation. This region 42 is technically denoted as overrun 42. A second region 44 outside the annular working gap defined by the working discs 16, 20 is located in Fig. 3 on the inside of the working gap. Hereinafter, by way of example, an interferometric thickness measurement of the work pieces 38 arranged in the recesses 23, in the region of the external overrun 42, is disclosed. Naturally, such a thickness measurement is also possible in a similar manner in the region of the internal overrun 44. Also, by an arrangement of a suitable measurement device in one of the working surfaces of the upper or lower working disc 16, 20 a measurement could also take place within the working gap. Also, in particular when machining a triple stack, it is possible to provide measuring devices for thickness measurement on the upper and lower face of the stack in order to measure the thickness of both work pieces.

As shown enlarged and in detail in the view of Fig. 4, an optical measuring device 46 is arranged in the region of the external overrun 42. In the example shown, the measuring device 46 is an infrared interferometer. In the sectional view in Fig. 4, a workpiece 38 is shown together with a carrier 28 in a partially visible rotor disc 22. During its machining in the processing machine 10, said workpiece 38 passes from time to time with its carrier 28 through the overrun 42. In the example shown, infrared radiation 48, in the present case an infrared radiation spectrum 48, is oriented from below towards the free lower face 40 of the workpiece 38. The infrared radiation 48 is reflected by a first radiation component on the free workpiece lower face 40, whilst a second radiation component penetrates the workpiece 38 which is highly transparent to infrared radiation, is reflected inwards on the upper face 36 of the workpiece 38 connected to the carrier 28 and immediately or after repeated reflections on the inner surfaces of the workpiece 38 emerges again on the free lower face 40 of the workpiece 38. The first and second radiation components returning from the workpiece 38 into the measuring device 46 subsequently interfere with one another which is recorded by a suitable sensor device (not shown). On this basis, the mechanical workpiece thickness may be determined from the detected optical workpiece thickness and the known refraction index.

Using the measuring device 46, therefore, a precise measurement of the thickness of the workpiece 38 is possible separately from the carrier 28. In this manner, the machining method according to the invention may be carried out even more accurately. It

is also possible, for example, to measure radially the part of the workpiece 38 located in the overrun 42 and to create a corresponding thickness profile in order to increase the machining accuracy further.

In Fig. 5 an arrangement is shown which corresponds substantially to the arrangement of Fig. 2. In contrast to Fig. 2, however, in this case one respective workpiece 38 is releasably fastened to a carrier 28 via the adhesive connection 34 on its opposing upper and lower surfaces. This is a so-called triple stack. This arrangement may also be machined in the device shown, for example, in Fig. 1. Here, in particular, the same removal rate may be provided for the upper and the lower workpiece, as in this case the carrier does not come into contact with the working surfaces.

The method according to the invention permits highly accurate machining of very thin work pieces which, after the machining process, have a thickness in the region of less than 100 μm , preferably less than 50 μm , further preferably less than 20 μm , for example in the region of 10 μm . At the same time, the work pieces 38 may easily be transported with the same tools due to their connection to the carrier 28 during their entire machining process, for example even a subsequent polishing process.

Claims

1. Method for the material-removing machining, in particular for machining by grinding or polishing, of very thin work pieces which are releasably fastened with one of their surfaces in each case to a corresponding surface of similarly very thin carriers, characterised by the steps:

- a double sided processing machine is provided which has an upper working disc with an upper working surface and a lower working disc with a lower working surface, the working surfaces forming a working gap therebetween, in which at least one rotor disc comprising recesses is arranged,

- the work pieces are arranged together with the carriers in the recesses of the at least one rotor disc,

- at least one of the working discs is driven rotatably, the at least one rotor disc also being set in rotation by means of a roller device, whereby the carriers received in the rotor disc move with the work pieces along cycloid paths between the working surfaces, and one of the working surfaces coming into contact with the respective free surfaces of the carriers and one of the working surfaces coming into contact with the respective free surfaces of the work pieces,

- the free surfaces of the work pieces are machined in a material-removing manner by the working surface associated therewith, whilst by the working surface associated with the free surfaces of the carriers, either no material is removed or a removal rate of the free surfaces of the carriers is substantially less than a removal rate of the free surfaces of the work pieces.

2. Method according to Claim 1, characterised in that different removal rates of the free surfaces of the carriers, on the one hand, and the free surfaces of the work pieces, on the other hand, are produced by the upper working surface and the lower working surface having different working coatings.

3. Method according to Claim 1 or Claim 2, characterised in that the material-removing machining is abrasive machining, the working surface associated with the surfaces of the work pieces being provided with an abrasive coating and the working surface associated with the surfaces of the carriers being provided with a polishing coating.

4. Method according to Claim 3, characterised in that the machining with the polishing coating takes place without a polishing means.
5. Method according to one of the preceding claims, characterised in that, already before the machining process, the work pieces have a smaller thickness than the carriers.
6. Method according to one of the preceding claims, characterised in that, after the machining process, the work pieces have a thickness of less than 100 μm , preferably less than 50 μm , further preferably less than 20 μm .
7. Method according to one of the preceding claims, characterised in that the carriers have a thickness ranging between 0.5 mm to 2 mm, preferably ranging between 0.7 mm to 1.0 mm.
8. Method according to one of the preceding claims, characterised in that the carriers and the work pieces have a cylindrical shape and the carriers have a larger diameter than the work pieces.
9. Method according to one of Claims 1 to 8, characterised in that the work pieces are fastened to the carriers by an adhesive connection, in particular by wax, an adhesive or an adhesive film.
10. Method according to Claim 9, characterised in that the adhesive connection is releasable thermally, chemically, by etching or by UV radiation.
11. Method according to one of Claims 1 to 8, characterised in that the work pieces are fastened to the carriers by electrostatic charging.
12. Method according to one of the preceding claims, characterised in that the workpiece is a semiconductor wafer.
13. Method according to one of the preceding claims, characterised in that the carrier is a semiconductor wafer.
14. Method according to one of Claims 1 to 12, characterised in that the carrier consists of a glass material, a ceramic material or a plastics material.
15. Method according to one of the preceding claims, characterised in that the thickness of the work pieces is measured during the machining thereof in the processing machine by means of an optical measuring method, in particular an interferometric measuring method.
16. Method according to one of Claims 1 to 14, characterised in that the thickness of the work pieces is measured during the machining thereof in the processing machine by means of at least one eddy-current sensor or by means of at least one ultrasound sensor.