

Method for measuring the thickness of flat workpieces

The invention relates to a method for measuring the thickness of flat workpieces processed in a double-side processing machine. Flat workpieces such as wafers, in particular silicon wafers, are processed in a material-removing manner in double-side processing machines, for example double-side polishing machines. During this removal polishing of the workpieces, it is of vital importance to inspect the workpiece thickness in order to attain the quality requirements. The target window for achieving the best possible workpiece geometry is approx. 100 nm. If the target measure is passed, for example because the processing operation takes too long, the edge geometry is generally not sufficient for the requirements of wafer consumers. In particular, high demands are placed on the flatness of the workpieces. Typically, the requirement for the wafer geometry parameter SFQRmax, i.e. the maximum value of the local flatness ("site flatness") on a silicon wafer, is 15 nm or even as low as 10 nm. During other processing operations such as, for example, haze-free polishing or even grinding, a precise knowledge of the respective workpiece thickness is also required.

The process of measuring the distance of the working disks and, therefore indirectly the workpiece thickness, by means of eddy current sensors is known. However, the accuracy requirements explained above cannot always be achieved. In addition, this type of measurement is dependent on the thickness and the wear of a working coating on the working disk such as a polishing cloth. It is therefore standard procedure to predict the workpiece thickness based on a plurality of external parameters such as the properties of the polishing agent (temperature, pH value, age, dilution, concentration of solids, solid particle sizes) and the polishing cloth (nature of the conditioning, type of diamond dressing, flatness, shape, wear, glazing) as well as process and handling times. By inspecting these external parameters, an attempt is made to comply with process conditions which are as constant as possible (a

repeatable removal rate). The thickness is then inspected via the process time and a known preliminary measurement. The accuracy requirements mentioned above cannot, however, be regularly achieved with this method either. In particular, the external parameters change during processing, for example, due to wear. This results in deviations from the predicted workpiece thickness. Therefore, an external thickness measurement of the workpieces is generally performed following processing in the double-side processing machine. This is complex, both from a metrological and process technology point of view. In particular, the wafers must be cleaned in a cleaning plant prior to measurement. Depending on the production capacity of the double-side processing machine, a substantial measurement capacity must be provided. In addition, a non-permissible thickness deviation can only be determined in this way following processing. The process parameters of the processing machine are corrected at correspondingly staggered intervals, resulting in scrap.

A process of measuring the thickness of flat workpieces, such as wafers, by means of interferometry is generally known from WO 2010/037452 A1. In this way, the workpiece thickness can be established extremely precisely. For example, optical measuring methods for determining the thickness of flat workpieces are also known from US 2006/0037699 A1, EP 1 970 163 B1, DE 11 2009 001 875 T5 or US 6 437 868 B1. The thickness measurement apparatus is fixed on the processing machine and measures the thickness of the workpieces processed in the machine, for example through a measurement opening in a, for example, rotating part of the machine. It is of course only possible to take measurements if the optical axis of the measuring apparatus is aligned precisely with the measurement opening. This is complex in design and process engineering terms, and only relatively few measuring points are available. This, in turn, adversely affects the reliability and accuracy of the measurement.

Starting from the explained prior art, the object of the invention is therefore to provide a method of the type indicated above, with which it is possible to determine the thickness of workpieces processed in a double-side processing machine reliably and extremely precisely, using a simple process engineering method.

The invention achieves the object through the subject-matter of Claim 1. Advantageous configurations can be found in the dependent claims, the description, and the figures.

The invention achieves the object through a method for measuring the thickness of flat workpieces processed in a double-side processing machine, comprising the steps:

- the workpieces are processed in a working gap formed between an upper working disk and a lower working disk of the double-side processing machine while the working disks rotate relative to one another in a material-removing manner,
- during the processing of the workpieces the workpiece thickness is optically measured by means of at least one optical thickness measurement apparatus arranged on the upper working disk and/or the lower working disk, wherein the at least one thickness measurement apparatus measures the thickness of the workpieces located in the working gap through at least one through-hole in the upper working disk and/or the lower working disk,
- the measurement results of the at least one thickness measurement apparatus are supplied to a control apparatus of the double-side processing machine,
- on reaching a previously specified target thickness of the workpieces the control apparatus terminates the processing operation of the workpieces.

The double-side processing machine can, for example, be a double-side polishing machine. However, it can also be another double-side processing machine such as,

for example, a double-side grinding machine. Multiple workpieces can be processed simultaneously in the working gap of the double-side processing machine, removing material on both sides. To this end, the working disks are regularly provided with a working coating, for example a polishing coating. Rotor disks, which each have openings for receiving one or more workpieces such as semiconductor wafers, in which the workpieces are held in a floating manner, are known. The rotor disks have teeth on their outer circumference, which teeth mesh with corresponding teeth on the outer side and on the inner side of the working gap. As a result, the rotor disk rotates in the working gap and the workpieces are guided along cycloid tracks through the working gap. A particularly uniform processing can be achieved in this way. During the processing one of the working disks or both working disks can then be rotatingly driven in opposite directions. Such double-side processing machines are themselves known.

According to the invention, the workpiece thickness is optically measured by means of at least one optical thickness measurement apparatus fixed to the upper working disk and/or the lower working disk during the processing of the workpieces in the working gap. To this end, the upper and/or lower working disk equipped with the thickness measurement apparatus has a through-hole, through which the thickness measurement apparatus which also rotates with the respective working disk detects the workpiece thickness. The through-hole therefore extends from the optical thickness measurement apparatus right into the working gap, in which the workpieces are located. The working disk can also have a two-piece construction with a first part which delimits the working gap and a second part which holds the first part in the manner of a carrier disk. The thickness measurement apparatus can then accordingly also be attached to the second part which is configured as a carrier.

As explained, the thickness measurement apparatus according to the invention operates optically and accordingly achieves a high precision. To this end, it has an

optical radiation source, for example a laser. The radiation from an optical radiation source can be coupled into a light guide, such as a fiber optic, which directs the optical radiation, if necessary, via a focusing optic comprising, for example, lenses through the through-hole onto the workpieces to be measured. The through-hole or through-bore through which the thickness measurement apparatus measures can, in particular, be configured decentrally in the upper and/or lower working disk. It is understood that if a working coating is provided on the working disk, said working coating must accordingly also have the through-hole so that the workpieces located in the working gap can be measured.

The measurement results of the at least one thickness measurement apparatus detected during the processing are also supplied to a control apparatus during the processing of the workpieces. Said control apparatus can compare the measured values, for example, with a target thickness previously specified for the workpieces. As soon as the target thickness is reached the control apparatus can terminate the current processing operation. This can be the end of the processing operation of the workpieces in the processing machine as a whole. However, it is also possible that following the end of the current processing operation, a different subsequent processing operation commences which is, in turn, controlled by the control apparatus. The measurement results can of course also be processed prior to forwarding to the control apparatus. The measurement results can, for example, be initially supplied to an interposed computer or similar, which further processes the thickness values of the thickness measurement apparatus and ascertains those thickness values which have been filtered, smoothed or processed in a different way, which are finally sent to the control apparatus. The computer or similar can, in this respect, also be part of the control apparatus.

The advantage of the fixed connection according to the invention of the thickness measurement apparatus having the working disk is that, even in the case of a single

through-hole in the working disk, a light path which is not interrupted by the rotating working disk is directed into the process area having the workpieces, i.e. the working gap, at any time. Therefore, as opposed to measuring apparatuses which are arranged in a non-rotating manner on a frame or housing of the machine, such as those proposed in the prior art, it is also possible to take thickness measurements continuously. In any case, the scope and the number of the measured values obtained are not restricted in design terms, as is the case in the prior art.

In addition, the advantage of the invention is that the through-hole can be sealed from the side of the thickness measurement apparatus so that dirt and moisture cannot get into the light path or the focusing optic of the thickness measurement apparatus. At the same time, the direct optical thickness measurement according to the invention makes it possible to detect the thickness precisely in situ during processing, wherein an elaborate preliminary measurement and an external subsequent measurement are dispensed with. Rather, the control apparatus can automatically terminate the processing operation after reaching the predefined target thickness or a predefined minimum removal. Due to the reliable and precise in-situ determination of the workpiece thickness according to the invention, measuring capacities on elaborate external measuring instruments are freed up. The production logistics are simplified, as it is no longer essential to know the process history. Precisely continuous operation in order to stabilize the rate of removal is no longer absolutely necessary, reducing the volume of scrap.

As already mentioned, the method according to the invention can be used in a particularly advantageous way during the processing of wafers, for example (monocrystalline) silicon wafers, and indeed both in the case of lightly doped p-type and in the case of highly doped p-type wafers. This also applies to boron, phosphorus, arsenic or other, including mixed, dopings. Of course, the method according to the invention can also be advantageously applied to other workpieces,

for example monocrystalline, polycrystalline or glass-like workpieces made of silicon, silicon carbide, aluminum oxide, silicate or other materials.

The workpieces are flat, preferably planar workpieces, which can be circular or even square. Wafers within a diameter range between approx. 100 mm and 450 mm, with diameters staggered in accordance with the SEMI standard of 100 mm, 125 mm, 150 mm, 200 mm, 300 mm and 450 mm, including in particular silicon wafers having the diameter 300 mm, are particularly preferred. Typical thickness ranges are in the range of 300 μm to 950 μm , in the case of silicon wafers having a diameter of 300 mm in particular between 770 μm to 800 μm . The target thickness of the workpieces striven for following the complete wafer processing process chain is typically between 770 μm and 780 μm and the workpiece thickness during double-side polishing is usually between 0 μm and up to 20 μm above that due to the required allowance. The absorption of the optical radiation in the workpiece varies, as does the optical density of the material, depending on, for example, the doping of the silicon workpieces. Both, but in particular the latter, influence the measurement result. If the corresponding workpiece property is known in advance, the control apparatus can adjust the measurement method accordingly or modify the measurement result in a suitable manner, in order to take account of these workpiece properties. To this end, it is possible to divide workpieces into different classes and to allow an operator of the double-side processing machine to select the class in the control apparatus. Alternatively, the workpiece properties, for example the doping concentration, could be stored as a numerical value in the control apparatus which then adjusts the measurement result in a suitable manner. Another alternative would be measuring those workpiece properties or properties correlating with them, for example conductivity in the case of the doping concentration of wafers, in the double-side processing machine so that the control apparatus can, in turn, modify the measurement result in a suitable manner. In particular, the optical density of the material varies depending on the temperature of the workpieces. This, in turn,

influences the measurement result. If the workpiece temperature is known during the measurement, this can, in turn, be taken account of in an appropriate manner in the control apparatus. The storing of the temperature expected for the respective processing operation in the control apparatus, the classification of different temperature ranges and/or the selection of a temperature range by the operator would be conceivable. It is also possible to use temperature measurement values of temperature measuring apparatuses which go to the control apparatus. In this case, for example, temperatures of the cooling media which are regularly supplied to the working disks are possible. These can be measured, for example, by means of suitable measuring apparatuses in the inlet or outlet of the double-side processing machine or also in the coolant reservoir. Temperatures, which are measured by means of suitable measuring apparatuses in, on or near the working gap, can also be taken as a basis.

It is understood that the optical workpiece thickness can in particular be determined according to the invention. If the refractive index is known or ascertained, the (mechanical) workpiece thickness can then be determined from this.

According to the invention, the measured workpiece thickness can, on reaching or falling below a certain workpiece thickness, above all be used to terminate the current processing operation or to transfer to a subsequent processing operation. A processing program specified according to the control apparatus can, to this end, include multiple processing operations which can be successively terminated in each case on reaching or falling below a previously specified target thickness of the workpieces, or transferred to the next processing operation. Such processing operations can follow each other immediately or with interruptions. Of course, the measured workpiece thickness can also be used to determine the current workpiece removal rate and adjust process parameters during the workpiece processing in a

suitable manner, for example by means of an algorithm, in order to bring the removal rate to a predefined level.

The plurality of data, which the at least one thickness measurement apparatus transmits to the control apparatus, are preferably evaluated with statistical or general mathematical methods, data filtering, averaging, extrapolation or trend determination or other data evaluation, in particular with the aid of algorithms, such that the evaluation produces good time-resolved representatives of the workpiece thickness. Such algorithms include an alteration of the measurement results preferably on the basis of a calibration and corrections as described above.

According to a particularly preferred configuration, the at least one thickness measurement apparatus can measure the thickness of the workpieces by means of an interferometric thickness measurement method. Using interferometric measurement methods, the workpiece thickness can be determined in a particularly precise manner. The prerequisite for the optical radiation of the at least one thickness measurement apparatus is partially transparent and partially reflecting workpieces which therefore allow a relevant portion of the optical radiation to pass through the workpiece and back. An interferometric thickness measurement method is, for example, known from the aforementioned WO 2010/037452 A1. This method can generally be used within the context of the present invention. In this case, optical radiation is directed at the top side of the workpiece, wherein a first radiation portion is reflected on the top side and a second radiation portion penetrates the workpiece thickness, is reflected on the bottom side of the workpiece and emerges again on the top side of the workpiece. The first and the second radiation portions then interfere under formation of an interference pattern. Using this interference pattern, the optical workpiece thickness between the top side of the workpiece and the bottom side of the workpiece can be determined in the manner described in WO 2010/037452 A1. If the refractive index is known or established, for example as

described in WO 2010/037452 A1, the mechanical workpiece thickness can, in addition, be determined. It is also possible to direct an infrared radiation spectrum at the top side of the workpiece, wherein the radiation created by interference of the radiation portions can be analyzed by means of a spectrometer.

An optical radiation source of the at least one thickness measurement apparatus can in particular emit infrared radiation. This is particularly favorable during the thickness measurement of, in particular, highly doped silicon workpieces, that means silicon workpieces specifically provided with foreign atoms such as boron or phosphorus. The optical radiation source preferably emits infrared radiation in the wavelength range between 1050 nm and 1600 nm, because silicon is particularly transparent in this wavelength range. This wavelength range is more preferably between 1150 nm and 1350 nm.

At least one focusing optic of the at least one thickness measurement apparatus can be arranged in the at least one through-hole. A reduction of the distance between the focusing optic, which can for example comprise suitable lenses or similar, and the workpieces to be measured increases the light output and therefore the attainable signal quality. In particular, workpieces having a high degree of light absorption can only be determined in the case of sufficient light output with sufficient precision. The thickness of the working disk can already be problematic in this context. It is therefore advantageously envisaged in the case of this configuration that the focusing optic is introduced into the working disk and is therefore a short distance from the workpiece.

According to a further configuration, the focusing optic can have a focus depth of at least 1 mm, preferably at least 2 mm. One difficulty of the thickness measurement method is the changing distance between the focusing optic and the workpiece. In particular, the thickness of the working coating which is usually located

therebetween, such as a polishing cloth, of the working disk, varies depending on the type of working coating and the wear. However, the workpiece thickness which is determined by measuring technology is to be determined with a deviation if at all possible of less than $\pm 0.1 \mu\text{m}$, in particular approx. $\pm 0.05 \mu\text{m}$ independently of these circumstances. Therefore, in the case of this configuration, a focusing optic is envisaged which has a large focus depth. In order to increase the attainable accuracy, the focusing optic can furthermore be mechanically adjustable such that the focus depth fully encloses the process area, that means the area in which the workpiece is located during the different processing conditions, or places said process area into the center of the focus depth. The mechanical adjustment can, in this case, be implemented such that it can be carried out, for example, during interruptions between processing operations. In principle, an actuated mechanism which is used during the processing operation or in accordance with an adjustment instruction, which includes additional parameters such as, for example, a polishing cloth thickness, is also feasible.

The at least one through-hole can be flushed with compressed air in the area of its entry to the working gap. It is also possible to generate an excess pressure with respect to the working gap in the at least one through-hole. Both serve to protect the thickness measurement apparatus, in particular a focusing optic, from contamination from the working gap. This protection can also be combined with a shutter which only releases the light path for the duration of a measuring operation.

However, it is particularly preferred if at least one protective window which is at least partially transparent to optical radiation from an optical radiation source of the at least one thickness measurement apparatus is arranged in the at least one through-hole between the thickness measurement apparatus and the working gap. The protective window can, in particular, be substantially completely transparent to the radiation from an optical radiation source. The thickness of such a protective

window is preferably within a range between 0.5 mm and 20 mm, particularly preferably between 2 and 10 mm. In particular, in the case of silicon workpieces, materials that are transparent in the range of infrared radiation are suitable for the protective window. Preferred materials for the protective window are aluminum oxide or calcium fluoride. A high chemical resistance of the protective windows in particular to alkaline media, which are typically used as polishing agents in double-side polishing machines, is also advantageous. Generally, advantageous properties are a low temperature expansion or a temperature expansion similar to the working disk material, a high scratch resistance and a low tendency to fractures.

According to another configuration, the at least one protective window can be set further back with respect to the surface delimiting the working gap of the working disk provided with the at least one through-hole by not more than 10 mm, preferably not more than 3 mm, more preferably not more than 1 mm, most preferably not more than 0.3 mm. The fact that the surface of the protective window on the workpiece side is located close to the working disk surface means that the space between the working gap and the protective window is quickly filled homogeneously with a working medium, for example a polishing agent, during operation. In addition, the working medium flows evenly, less turbulently and forming few bubbles past the protective window. Otherwise, this could lead to unstable measurement results. The fact that the protective window is only set back slightly can also be useful for helping to avoid interfering measuring signals, e.g. due to a working medium film, e.g. a polishing agent film, between the workpiece and the protective window. The thickness thereof would then be limited accordingly and a measurement signal can be distinguished and filtered out from the signal for the workpiece thickness.

In another embodiment, the at least one protective window can be set back with respect to the surface delimiting the working gap of the working disk provided with the at least one through-hole by at least 2 mm and at most 10 mm. Other than in the case of the configuration explained above, the protective window could also be advantageously set

back to a greater extent, at least 2 mm in the configuration described above, so that the working medium film would be particularly thick. The thickness thereof would then be limited at the bottom and any measurement signal which might occur could then be distinguished and filtered out from the signal for the workpiece thickness.

It should also be pointed out with respect to the aforementioned configurations that the protective window does not have to have a flat surface, in particular in the direction of the working gap. The numerical values indicated above then relate to that part of the protective window which protrudes furthest being set back. In this respect, it may suffice if a majority of the light is guided through the area of the protective window, which area corresponds in terms of its geometry to the embodiments described above.

The at least one protective window can be cleaned from the side of the working gap by a cleaning apparatus using a cleaning fluid. In addition to or instead of flushing the working gap with a free-flushing process medium, for example deionized water or an alkaline solution, during or shortly before the end of the processing operation, the protective window can also be freely flushed following a processing operation, between two processing operations or before a processing operation with a cleaning apparatus. This can be done manually under low pressure. However, a method in which the protective window is regularly freely flushed from the workpiece side with a pressurized cleaning fluid, e.g. with deionized water or an alkaline solution, is preferred. This can be done automatically by the control apparatus. This can preferably be the same apparatus which is used to freely flush or refresh the working coatings of the working disks. The space between the working gap and the protective window can also be deliberately supplied during the processing operation with a liquid, preferably with water, an alkaline solution or the working medium itself, in order to address the problem described above that the working medium flows past the protective window in a turbulent manner and forming bubbles.

According to another configuration, it can be envisaged that the workpiece thickness is optically measured during the processing of the workpieces by means of multiple through-holes which are configured in the upper working disk and/or the lower working disk. It is in principle possible to carry out the thickness measurement through the different through-holes (for each working disk) with a joint thickness measurement apparatus, wherein the radiation from an optical radiation source of the thickness measurement apparatus can then be divided up in a suitable manner, for example by means of beam splitters. However, it is of course also feasible that multiple thickness measurement apparatuses are arranged, to this end, on the upper working disk or on the lower working disk. The workpiece thickness can be measured through the different through-holes simultaneously during processing. However, it is also possible to measure the workpiece thickness through the different through-holes at different times during processing. i.e. staggered from each other.

As explained above, multiple workpieces can be simultaneously processed in the double-side processing machine. In the process, measuring errors can be sorted so that measured values, which were ascertained while a workpiece was actually in the light path of the optical thickness measurement apparatus, are only or preferably taken into account. It is then additionally possible to clearly associate the measurement results of the at least one thickness measurement apparatus in each case to one workpiece. This requires knowledge of the position and, at best, also the twisting of the rotor disks and the working disks in high temporal precision. However, this information is available depending on the machine configuration. In addition, the number of measured values can also be restricted in other ways, for example by pulsed thickness measurements, wherein the radiation pulse can be provided by means of a shutter in the light path, an electrical circuit or sorting on the basis of an algorithm.

According to another configuration, it can be envisaged that the at least one thickness measurement apparatus is arranged in a vibration-dampened manner on the upper working disk and/or the lower working disk. Due to the mounting in a vibration-dampened or, at best, vibration-insulated manner of the thickness measurement apparatus, for example a spectrometer of an evaluation unit of the thickness measurement apparatus, a falsification of the measurement results can be reduced or avoided by vibrations. Vibrations with typical frequencies between 10 Hz and 1000 Hz, in particular between 100 Hz and 1000 Hz, occur in the processing operation concerned here. The vibration dampening can be an active, electronic vibration dampening or a passive vibration dampening, for example an elastic mounting, adjusted to the respective frequency band. In this way, a mechanical or thermally induced mechanical bracing between the working disk and the thickness measurement apparatus, for example of an evaluation unit of the thickness measurement apparatus, can be avoided.

The control apparatus can be arranged in a separate location from the working disks. The data transfer between the at least one thickness measurement apparatus and the control apparatus and the electrical supply of the at least one thickness measurement apparatus can then take place via at least one sliding contact. An evaluation unit of the at least one thickness measurement apparatus arranged on the upper and/or lower working disk regularly has an optical grid and, for example, a CCD sensor. On the one hand, the data transfer, i.e. the transfer of electrical measuring signals, between the thickness measurement apparatus located on the rotating working disk and the non-rotating control apparatus of the double-side processing machine, which is arranged separately from the working disk, must be ensured. A slip ring, in particular having gold contacts, can be used as a suitable sliding contact. On the other hand, the same is also true of the electric supply of the thickness measurement apparatus. The signals can thereby be exchanged directly or indirectly or via a BUS system, for example ProfiBUS or ProfiNET.

One exemplary embodiment of the invention will be explained in greater detail below with reference to the figures, wherein:

Fig. 1 schematically shows a double-side processing machine for carrying out the method according to the invention,

Fig. 2 schematically shows a histogram in order to illustrate a method of the prior art, and

Fig. 3 schematically shows a histogram in order to illustrate the method according to the invention.

Unless otherwise indicated, the same reference numerals denote the same objects in the figures.

The double-side processing machine shown in Fig. 1 can, for example, be a double-side polishing machine. The double-side processing machine has an upper working disk 10 and a lower working disk 12 opposite the upper working disk 10. Part of the upper working disk 10 and the lower working disk 12 can, in each case, be a working coating 14, for example a polishing cloth. With this working coating 14, the upper and lower working disks 10, 12 delimit between them a working gap 16 for material-removing processing of workpieces. The reference numeral 18 shows, by way of example for illustrative purposes, a workpiece, for example a wafer. It is understood that, for example, rotatably arranged rotor disks can in practice be provided in the working gap 16, which rotor disks each receive multiple workpieces for simultaneous processing in the working gap 16.

In the example shown a through-hole 20, in particular a through-bore, is configured in the upper working disk 10. A focusing optic 22 of a thickness measurement apparatus that is attached to the upper working disk 10 is located in the through-hole 20. The focusing optic 22 can, for example, comprise suitable lenses. In the example shown, a protective window 24 is arranged in the through-hole 20 between the focusing optic 22 and the working gap 16. The other end of the through-hole 20 is illustrated by a suitable sealing element 26. The thickness measurement apparatus additionally comprises a measurement and evaluation unit 28 which is attached by means of vibration dampers 30 to the top side of the upper working disk 10. An optical radiation source, for example a laser, preferably an infrared laser, is arranged, on the one hand, in the measurement and evaluation unit 28. The radiation emitted from the optical radiation source is conducted via a fiber-optic cable 32, in particular a glass fiber, to the focusing optic 22 and is focused by the latter through the protective window 24 which is at least partially transparent to the optical radiation onto the workpiece 18. In addition, an optical radiation sensor, for example a CCD sensor and for example an optical grid, is additionally located in the measuring and evaluation unit 28. The measurement and evaluation unit 28 controls the radiation source in order to emit optical radiation. This is partially reflected by the top side of the workpiece 18, partially enters the workpiece 18, is reflected by the bottom side of the workpiece 18 and then exits again at the top side after passing through the workpiece 18 again. The optical radiation coming back from the top side of the workpiece and the bottom side of the workpiece is conducted via the focusing optic 22 and the fiber-optic cable 32 to the sensor arranged in the measurement and evaluation unit 28 and interfere with one another. The measuring signals received by the sensor can be evaluated in the measurement and evaluation unit 28, in order to determine the workpiece thickness 18. In particular, the workpiece thickness can be ascertained interferometrically as described, for example, in WO 2010/037452 A1.

The measured values arrive via a signal line 34 at a rotary joint 36, for example a slip ring, which is provided in the area of the drive shaft 38 of the double-side processing machine, by means of which the upper working disk 10 is rotatingly driven during operation. The rotary joint 36 is connected at its other end via an additional signal line 40 to a control apparatus 42 (PLC) of the double-side processing machine. A power supply for the thickness measurement apparatus is also shown with reference numeral 44. The supply is provided via a first power line 46, a further rotary joint 48, for example a slip ring again, which is in turn arranged on the drive shaft 38, and a second power line 50 connected to the thickness measurement apparatus.

The workpiece thickness can be ascertained during processing in a reliable and precise manner with the method according to the invention which is carried out with this double-side processing machine. If the control apparatus 42 establishes that a previously specified target thickness has been reached on the basis of the measurement results provided, the control apparatus 42 terminates the current processing operation. The control apparatus 42 can subsequently start the specified subsequent processing step or terminate the processing of the workpieces altogether.

For illustrative reasons, Fig. 1 only shows a thickness measurement apparatus which measures the workpiece thickness via only one through-hole. It is of course possible for the workpiece thickness to be measured through multiple through-holes simultaneously or at staggered times, whether this is by means of multiple thickness measurement apparatuses arranged on the upper working disk 10 and/or the lower working disk 12 or only by means of a thickness measurement apparatus, the light path of which is divided up in a suitable manner, as described in principle above.

Fig. 2 shows a frequency distribution of the thickness measured values ascertained for the workpieces following processing or their deviation from the target thickness for a conventional double-side processing method without the thickness

measurement according to the invention for a plurality of processed workpieces, in this case wafers. Fig. 3 shows a frequency distribution of the thickness measured values ascertained following processing or their deviation from the target thickness for the same double-side processing machine, but in this case with the thickness determination according to the invention, for a plurality of processed workpieces, in this case wafers again. It is obvious that the thickness deviation when using the process according to the invention is considerably lower than it is for the conventional method. In particular, double the standard deviation 2σ in the method according to the invention is only 0.25 μm while it is 1.11 μm in the conventional method.

Claims

1. A method for measuring the thickness of flat workpieces (18) processed in a double-sided processing machine, comprising the following steps:
 - the workpieces are processed in a working gap (16) formed between an upper working disk (10) and a lower working disk (12) of the double-sided processing machine, involving rotating the working disks (10, 12) relative to one another in such a way that material is removed,
 - the workpiece thickness is optically measured during the processing of the workpieces (18) by means of at least one optical thickness measurement apparatus arranged on the upper working disk (10) and/or the lower working disk (12), wherein the at least one thickness measurement apparatus measures the workpiece thickness of the workpieces (18) located in the working gap (16) through at least one through-hole (20) in the upper working disk (10) and/or the lower working disk (12),
 - the measurement results of the at least one thickness measurement apparatus are supplied to a control apparatus (42) of the double-sided processing machine,
 - once a previously specified target thickness of the workpieces (18) is reached, the control apparatus (42) terminates the processing operation of the workpieces,
 - characterized in that at least one focusing optic (22) of the at least one thickness measurement apparatus is arranged in the at least one through-hole (20).
2. The method according to Claim 1, characterized in that the at least one thickness measurement apparatus measures the thickness of the workpieces (18) by means of an interferometric thickness measurement method.
3. The method according to any one of the preceding claims, characterized in that

an optical radiation source of the at least one thickness measurement apparatus emits infrared radiation.

4. The method according to Claim 3, characterized in that the focusing optic (22) has a focus depth of at least 1 mm, preferably at least 2 mm.
5. The method according to any one of the preceding claims, characterized in that the at least one through-hole (20) is flushed with compressed air in the region of its entry to the working gap (16).
6. The method according to any one of the preceding claims, characterized in that an excess pressure with respect to the working gap (16) is generated in the at least one through-hole (20).
7. The method according to any one of the preceding claims, characterized in that at least one protective window (24) which is at least partially transparent to optical radiation from an optical radiation source of the at least one thickness measurement apparatus is arranged in the at least one through-hole (20) between the thickness measurement apparatus and the working gap (16).
8. The method according to Claim 7, characterized in that the at least one protective window (24) consists of aluminum oxide or calcium fluoride.
9. The method according to any one of Claims 7 or 8, characterized in that the at least one protective window (24) is recessed by a maximum of 10 mm with respect to the surface delimiting the working gap (16) of the working disk provided with the at least one through-hole (20), preferably by a maximum of 3 mm, more preferably by a maximum of 1 mm, most preferably by a maximum of 0.3 mm.

10. The method according to any one of Claims 7 to 9, characterized in that the at least one protective window (24) is cleaned from the side of the working gap (16) by a cleaning apparatus by means of a cleaning fluid.
11. The method according to any one of the preceding claims, characterized in that the workpiece thickness during the processing of the workpieces (18) is optically measured through multiple through-holes (20) configured in the upper working disk (10) and/or the lower working disk (12).
12. The method according to Claim 11, characterized in that the workpiece thickness is measured through the different through-holes (20) simultaneously during the processing.
13. The method according to Claim 11, characterized in that the workpiece thickness is measured through the different through-holes (20) at different times during the processing.
14. The method according to any one of the preceding claims, characterized in that multiple workpieces (18) are processed simultaneously in the double-sided processing machine, wherein the measurement results of the at least one thickness measurement apparatus are in each case clearly allocated to one workpiece (18).
15. The method according to any one of the preceding claims, characterized in that the at least one thickness measurement apparatus is arranged in a vibration-dampened manner on the upper working disk (10) and/or the lower working disk (12).
16. The method according to any one of the preceding claims, characterized in that the control apparatus is arranged at a separate location from the working disks

(10, 12).

17. The method according to Claim 16, characterized in that the data transfer takes place between the at least one thickness measurement apparatus and the control apparatus (42) and the electrical supply of the at least one thickness measurement apparatus via at least one sliding contact.