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(54) **Wire guide monitoring device and method for monitoring a wire guide**

(57) A wire guide monitoring device for a wire saw, a wire saw including the wire guide monitoring device and a method for monitoring the wire guide is described. The wire guide monitoring device (500) includes an optical sensor device (510) for measuring surface charac-

teristics of a wire guide (200), and a coupling element (530) for coupling the wire guide monitoring device to a kinematic mechanism structure (350) of an ingot feeding system (300) of the wire saw.

500

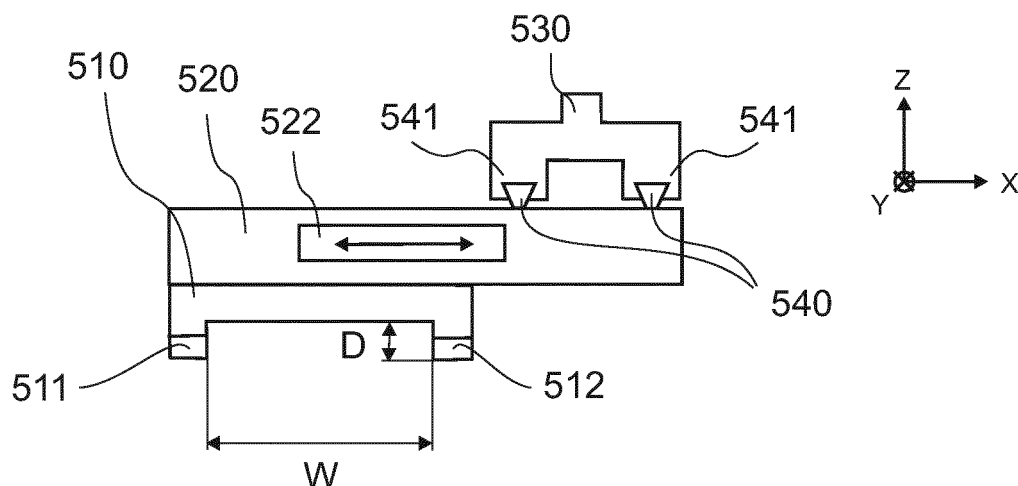


Fig. 5

Description

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to a wire guide monitoring device for a wire saw, a wire saw and a method for monitoring a wire guide of a wire saw. Existing wire saws may be retrofitted with the wire guide monitoring device according to the present disclosure. More particularly, the disclosure relates to a wire monitoring device for measuring surface characteristics of a wire guide, in particular wire guide grooves. Wire saws of the present disclosure are particularly adapted for cutting or sawing hard materials such as blocks of silicon or quartz.

BACKGROUND

[0002] Wire saws are used for cutting blocks or bricks, thin slices, e.g., semiconductor wafers, from a piece of hard material such as silicon. In such devices, a wire is fed from a spool and is both guided and tensioned by wire guide cylinders. The wire that is used for sawing can be provided with an abrasive material. As one option, the abrasive material can be provided as slurry. This may be done shortly before the wire touches the material to be cut. Thereby, the abrasive is carried to the cutting position by the wire for cutting the material. As another option, the abrasive can be provided on the wire with a coating, e.g. as with diamond wire. For example, diamond particles can be provided on a metal wire with a coating, wherein the diamond particles are imbedded in the coating of the wire. Thereby, the abrasive is firmly connected with the wire.

[0003] The wire is guided and/or tensioned by wire guides. These wire guides are generally scored with grooves having precise geometry and size. The wire is wound around the wire guides and forms a web or wire web. During the sawing process, the wire is moved with considerable speed. Usually, the piece to be sawed, e.g. an ingot connected to a support beam or a support holding is urged towards the web. During sawing, the piece to be sawed is moved through the wire web, wherein the speed of this movement determines the cutting speed and/or the effective cutting area that can be sawed within a given amount of time.

[0004] Generally, there is a tendency to use thinner wires in order to reduce the thickness of the cut and, thereby, to decrease the material wasted. There is also a desire to use diamond wires. These thinner wires and diamond wires are generally more susceptible to damage and under high strain the wires may break more easily. Further, there is a desire to increase the cutting speed for improving the throughput of wire saws. The maximum speed for moving the piece through the web and also the maximum effective cutting area within a given amount of time is limited by several factors including wire speed, feeding speed of the material to be sawed, hardness of

the material to be sawed, disturbing influences, desired precision, and the like. When the speed is increased, the strain on the wire is generally increased as well. The above-mentioned issues of avoiding damage, undue wear of the wire guide grooves, as well as wear, failure or breakage of the wire are even more critical at higher sawing speeds.

[0005] In general, there is a demand to operate the wire saw in a manner so as to avoid or reduce varying sawing quality, varying sawing width, oscillations of the wire, or even breakage of the wire. In wire saws for cutting wafers, the wafer quality is strongly impacted by the wire guides. Several aspects of the wire guides can impact the wafer cutting process. A first aspect is that a high quality and uniformity of the wire guide grooves have to be ensured during the production of the wire guide. As the cutting wire is guided by the wire guide grooves, the geometry of each individual groove may influence the cutting position of the wire with respect to the ingot during wafer cutting. Therefore, a second aspect is that grooves are subject to wear during the cutting process and after several cuts, groove geometry may change. Such a change in groove geometry may induce wire vibrations during rotation of the wire guide during the cutting process which has a detrimental effect on the wafer quality.

SUMMARY

[0006] In view of the above, the present disclosure provides a wire saw that overcomes at least some of the problems in the art. This object is achieved at least to some extent by a wire guide monitoring system for a wire saw, a wire saw and a method for monitoring a surface characteristic of a wire guide according to the independent claims. Further aspects, advantages, and features of the present disclosure are apparent from the dependent claims, the description, and the accompanying drawings.

[0007] In view of the above, a wire guide monitoring device for a wire saw is provided. The wire guide monitoring device for a wire saw includes an optical sensor device for measuring surface characteristics of a wire guide, and a coupling element for coupling the wire guide monitoring device to a kinematic mechanism structure of an ingot feeding system of the wire saw.

[0008] According to one aspect of the present disclosure, an existing wire saw may be retrofitted with the wire guide monitoring device as described herein. A method for retrofitting a wire saw is disclosed including providing a wire saw with the wire guide monitoring device as described herein.

[0009] According to another aspect of the present disclosure a wire saw including at least two wire guide cylinders and a wire guide monitoring device as described herein is provided.

[0010] According to a further aspect of the present disclosure a wire saw including at least two wire guide cylinders, a coupling element configured for coupling an ingot and a wire guide monitoring device, and a wire guide

monitoring device is provided, wherein the wire guide monitoring device includes an optical sensor device for measuring surface characteristics of a wire guide, a coupling element for coupling the wire guide monitoring device to a kinematic mechanism structure of an ingot feeding system of the wire saw, and at least one actuator configured for performing a movement of the optical sensor device relative to the coupling element, wherein the sensor device includes a radiation source and an optical sensor. Preferably the radiation source is arranged opposite to the optical sensor, particularly the sensor device is a fork type sensor.

[0011] According to yet a further aspect of the present disclosure a method for monitoring a surface characteristic of a wire guide is provided, wherein the method includes: coupling a sensor device to a kinematic mechanism structure of a wire saw, moving the sensor device to the surface of a wire guide installed inside the wire saw by moving the kinematic mechanism structure, and measuring a surface characteristic of the wire guide using the sensor device.

[0012] The present disclosure is also directed to an apparatus for carrying out the disclosed methods and including apparatus parts for performing each described method steps. These method steps may be performed by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, the disclosure is also directed to methods by which the described apparatus operates. It includes method steps for carrying out every function of the apparatus.

[0013] Further aspects, advantages, and features of the present disclosure are apparent from the dependent claims, the description, and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. Typical embodiments are depicted in the drawings and are detailed in the description which follows. In the drawings:

Fig. 1 shows a schematic side view of a wire saw according to embodiments described herein with which the wire guide monitoring device described herein may be used;

Fig. 2 shows a schematic side view of a wire saw with a wire guide monitoring device according to embodiments described herein which is coupled to a kinematic mechanism structure;

Fig. 3 shows a schematic side view of a wire saw with two wire guide monitoring devices according to embodiments described herein

which are coupled to a kinematic mechanism structure;

Fig. 4 shows a schematic side view of a wire guide monitoring device according to embodiments described herein;

Fig. 5 shows a schematic side view of a wire guide monitoring device according to embodiments described herein;

Fig. 6 shows a schematic side view of a wire guide monitoring device according to embodiments described herein in an exemplary position for monitoring a wire guide;

Fig. 7 shows a schematic view of a wire guide having grooves according to embodiments described herein;

Fig. 8 shows a schematic view of a section of the wire guide shown in Fig. 6;

Fig. 9 shows a schematic view of an exemplary groove geometry in a wire guide according to embodiments described herein;

Fig. 10 shows a schematic perspective view of a wire guide monitoring device according to embodiments described herein which is coupled to a kinematic mechanism structure for moving the wire guide monitoring device relative to the wire guide; and

Fig. 11 shows a flow chart of a method for monitoring a wire guide according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0015] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations.

[0016] Within the following description of the drawings, the same reference numbers refer to the same or to similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment applies to a corresponding part or aspect in another embodiment as well.

[0017] Before describing embodiments of the wire guide monitoring device and the method for monitoring

a wire guide, exemplary embodiments of a wire saw with which the wire guide monitoring device can be used will be briefly discussed.

[0018] Generally, a wire saw device as understood herein may be a wafer cutting wire saw.

[0019] In the present disclosure the term "surface characteristics of a wire guide" relates to structural surface characteristics of the wire guide, e.g. its geometry of the surface structure, such as grooves or elevations and their corresponding dimensions such as width, depth or height etc.

[0020] In the present disclosure the term "monitoring a surface characteristic of a wire guide" includes measuring the surface characteristic, particularly measuring the surface characteristic at different points in time. Further "monitoring a surface characteristic of a wire guide" may include comparing at least two different measurements carried out at different points in time.

[0021] In the present disclosure the term "kinematic mechanism structure" refers to any means configured for providing a rotational and/or transversal movement. Particularly, a "kinematic mechanism structure" as described herein relates to an arrangement of at least two elements, typically connecting at least two bodies, wherein the at least two elements are connected to each other such that at least one of the at least two elements is movable relative to the other element or elements of the at least two elements of the arrangement, e.g. by rotation around an articulation and/or translation along an axis.

[0022] In the present disclosure the term "parallel kinematic mechanism structure" relates to a "kinematic mechanism structure" wherein at least one of the typically at least two bodies is connected to the "parallel kinematic mechanism structure" at two or more different locations. Thereby, a movement of one of the elements of the parallel kinematic mechanism structure typically translates into a movement of at least a part of the kinematic mechanism structure (e.g. another element of the kinematic mechanism structure).

[0023] Generally, and not limited to any specific embodiment described herein, the term "cutting plane" includes the cutting direction. Typically, the orientation of the cutting plane remains constant throughout the complete cutting process. Typically, the orientation of the cutting plane corresponds to the orientation of the wires of the wire saw

[0024] In the present disclosure the term "cutting direction" is defined as the direction in which the cut advances during the cutting process. Typically, the cutting direction is a vertical direction.

[0025] Further, in the present disclosure the term "working area" is defined as the area spanned by the wires of a wire saw, typically a web of wires is also referred to as a layer of wires. Typically the working area is the area in which a single piece to be sawed, typically an ingot, interacts with the wires of a wire saw during cutting.

[0026] According to embodiments, as exemplarily

shown in Fig. 1 the wire saw 100 may be a multi-wire saw. A multi-wire saw allows high productivity and high quality slicing of silicon wafers for the semiconductor and photovoltaic industries. A multi-wire saw includes typically a high-strength steel wire that may be moved unidirectionally (i.e., only in the forward direction) or bidirectionally (i.e., backwards and forwards) to perform the cutting action. The wire may be provided with diamonds on its surface.

[0027] Fig. 1 shows a schematic side view of a wire saw 100 including, as an example, four wire guides 112, 114, 116, 118 according to embodiments disclosed herein. Each wire guide 112, 114, 116, 118 may be connected to a motor or drive 122, 124, 126, 128 (shown in dashed lines in Fig. 1) for rotating the wire guide. Each drive may be adapted for performing a back-and-forth movement of the wire 120. The back-and-forth movement of the wire is denoted with reference number 225 in Fig. 1. The wire guides may be rotated by drives that cause each wire in the wire-web to move at a relatively high speed of, for instance, 5 to 25 m/s. The motors driving the wire can be motors having a small momentum in order to stop and accelerate within a short time period. This is particularly useful in the embodiments of the present disclosure providing a back-and-forth movement. For instance, the direction of wire movement may change at least every 10 sec, at least every 30 sec, or at least every 1 min. Alternatively, a wire saw device according to embodiments as described herein may include only two wire guides, e.g. only wire guides 112 and 114 as exemplarily shown in Fig. 2.

[0028] According to embodiments, with exemplary reference to Fig. 1, a wire supply spool 134 may be provided with a wire reservoir. The wire supply spool 134, if still complete, can hold for example about 50 kilometers or even several hundred kilometers of wire. According to embodiments, the wire 120 can be fed to the wire guides 112, 114, 116, 118 from the wire supply spool 134 and wound about the wire guides 112, 114, 116, 118 to form a layer of parallel wires between the wire guide cylinders. This layer is typically referred to as a wire web. The wire 120 can then be returned to a suitable receiving device, such as a take-up spool 138.

[0029] Further, as schematically shown in Fig. 1, the wire saw 100 according to embodiments described herein, further includes an ingot feeding system 300 including a kinematic mechanism structure 350, particularly a parallel kinematic mechanism structure. The effect of a parallel kinematic mechanism structure according to the embodiments described herein, is that it enables a translational movement of the ingot within a cutting plane and a rotational movement around a rotational axis which typically is perpendicular to the cutting plane.

[0030] According to embodiments the kinematic mechanism structure 350 may be used for urging an ingot 102 against the wires for wafer cutting and/or for positioning and/or moving a wire guide monitoring device 500 as described herein relative to the wire guides. As exem-

plarily shown in Fig. 1, according to embodiments described herein, the ingot feeding system 300 further includes a support table 312 for coupling an ingot 102 to the kinematic mechanism structure 350. According to embodiments, as exemplarily shown in Fig. 2, the support table may also be configured for coupling a wire guide monitoring device 500, as described herein. Therefore, the support table 312 may include a clamping mechanism for releasable coupling a ingot 102 or a wire guide monitoring device 500, as described herein. Therefore, according to embodiments as described, the wire guide monitoring device 500 as described herein provides a removable device for measuring a wire guide, particularly the geometry of grooves in the surface of the wire guide before and in-between cutting ingots. Accordingly, by providing a wire guide monitoring device which can releasable be coupled to the kinematic mechanism structure 350 of the a wire saw, surface characteristics of the wire guides may be checked between individual cuts or between a preselected number of cuts. Further, the wire guides can be measured when the wire guides are installed inside the wire saw. Therefore, down times of the wire saw can be reduced as it is not necessary to remove the wire guide from the wire saw for measuring its surface. Further, the wire guides can be measured in their actual position during cutting, such that also the coaxial alignment of the wire guides may be checked when they are installed inside the wire saw.

[0031] According to embodiments, the kinematic mechanism structure is configured to enable at least a translational movement of a coupled ingot or a coupled wire guide monitoring device within a cutting plane. Typically, the cutting plane includes a cutting direction. Alternatively, the kinematic mechanism structure is configured to enable a translational movement and/or a rotational movement. Typically the rotational movement is carried out around a rotational axis which is perpendicular to the cutting plane. Typically, the orientation of the cutting plane remains constant throughout the complete cutting process. Typically, the orientation of the cutting plane corresponds to the orientation of the wires of the wire saw. For better understanding of the performable movements within a cutting plane with the kinematic mechanism structure as described herein, in Fig. 1 a horizontal movement is indicated by arrow 351 (x-direction in Fig. 1), a vertical movement is indicated by arrow 352 (z-direction in Fig. 1) and a rotational movement is indicated by arrow 353 (rotation around y-axis 354 indicated in Fig. 1), respectively. According to embodiments, the kinematic mechanism structure 350 includes an actuator assembly which is configured for performing translational and rotational movements of the kinematic mechanism structure.

[0032] Figure 2 shows a schematic side view of a wire saw, wherein instead of an ingot as shown in Figure 1, a wire guide monitoring device 500 according to embodiments described herein is coupled to the kinematic mechanism structure 350. Compared to the wire saw de-

vice shown in Fig. 1, the wire saw device as exemplarily shown in Fig. 2 includes only two wire guides 112 and 114. As exemplarily shown in Figure 2, the wire guide monitoring device 500 can be coupled to the kinematic mechanism structure 350 via a support table 312. According to embodiments, the wire guide monitoring device 500 includes a sensor device 510, a support element 520 and a coupling element 530 for coupling the wire guide monitoring device 500 to the support table. According to embodiments, the support element 520 may include an actuator 522, particularly a linear actuator, configured for translating the sensor device in a direction perpendicular to the wire guide axis, particularly parallel to the wire web spanned between two wire guides. As exemplarily shown in Fig. 2, according to embodiments, the coupling element 530 is arranged on the support element 520, such that the coupling element 530, e.g. a male clamping element, can be coupled to a mating coupling element of the ingot feeding system 300, for example to a female clamping element of the support table 312. According to embodiments, the mating coupling element of the ingot feeding system can be arranged on the kinematic mechanism structure 350 or on the support table 312 which is coupled to the kinematic mechanism structure 350. Therefore, the wire guide monitoring device is configured for direct coupling with the kinematic mechanism structure and/or for coupling with the kinematic mechanism structure via the support table 312.

[0033] In Figure 3, a schematic side view of a wire saw having four wire guides as described in connection with Fig. 1 is shown, wherein two wire guide monitoring devices according to embodiments described herein are employed. For example a first wire guide monitoring device 500a may be coupled to a first kinematic mechanism structure 350a, whereas a second wire guide monitoring device 500b may be coupled to a second kinematic mechanism structure 350b. As exemplarily shown in Fig. 3, the first wire guide monitoring device 500a may be arranged for monitoring a first group of wire guides, e.g. wire guides 112 and 114 between which a upper wire web is formed and the second wire guide monitoring device 500b may be arranged for monitoring a second group of wire guides, e.g. wire guides 116 and 116 between which a lower wire web is formed.

[0034] Figure 4 shows a schematic side view of a wire guide monitoring device according to embodiments described herein which are configured for coupling to a kinematic mechanism structure 350 of a wire saw as exemplarily described in connection with Figs. 1 and 2. According to embodiments, the wire guide monitoring device 500 includes a sensor device 510, a support element 520 to which the sensor device 510 is attached. As exemplarily shown in Figure 3, according to embodiments of the wire guide monitoring device 500 described herein, the support element 520 is configured for supporting the coupling element 530 as well as the sensor device 510. According to embodiments, the coupling element 530 may be one-piece with the support element 520. Alter-

natively, the coupling element 530 may be a separate element attached to the support element 520.

[0035] According to embodiments as exemplarily shown in Fig. 4, the sensor device 510 is arranged on a side of the support element 520 which is opposite to the side of the support element on which the coupling element 530 is arranged. According to embodiments, in a coupled state of the wire guide monitoring device, as exemplarily shown in Figure 2 and 3, the coupling element 530 is arranged on a side of the support element 520 facing the kinematic mechanism structure and the sensor device is arranged on a side of the support element 520 facing the wire guides. As exemplarily shown in Fig. 4, the support element 520 may include an actuator 522, particularly a linear actuator, configured for translating the sensor device in a direction perpendicular to the wire guide axis, particularly parallel to the wire web spanned between two wire guides, when the wire guide monitoring device 500 is coupled to a kinematic mechanism structure as described herein.

[0036] According to embodiments of the wire guide monitoring system as described herein, the sensor device 510 can be a fork-type sensor device. The sensor device 510 may include a radiation source 512 and a sensor 511, for example an optical sensor. According to embodiments, the radiation source 512 and the optical sensor 511 may be arranged opposite and/or parallel to each other. The sensor device may have a sensing slot width W of at least 100 mm, particularly of at least 150 mm, particularly of at least 200 mm. Further, the sensor device may have a sensing slot depth D of at least 20 mm, particularly of at least 40 mm, particularly of at least 60 mm.

[0037] According to embodiments of the wire guide monitoring device 500, the optical sensor 511 may include the capability to process visible radiation. For instance, in the case of an optical sensor that may be adapted to process radiation in the optical range (400-800 nm), environmental light or the use of a LED might act as the respective light source. The optical sensor may be applied in the form of a photo sensor or a CCD-sensor (charged coupled devices). According to alternative embodiments, the optical sensor may be adapted for processing radiation in the extra-optical range, such as infrared, ultraviolet radiation, X-rays, alpha particle radiation, electron particle radiation, and/or gamma rays. According to embodiments, the radiation source for one or more of the listed radiation types may be part of the wire guide monitoring system, particularly of the sensor device such as a fork type sensor as exemplarily shown in Figs. 4 to 6 and 10.

[0038] According to embodiments, the optical sensor may be connected to a data processing unit (not shown) via a cable or wireless connection. The data processing unit can be adapted to inspect and analyze the signals of the optical sensor. If the wire guide surface exhibits any surface characteristics that is defined as non-normal or exceeding a preselected threshold of a predefined sur-

face geometry of the wire guide, the data processing unit may detect the change and trigger a reaction. Such a reaction rate can be a warning signal indicating that the preselected threshold has been exceeded which for example relates to a critical surface wear value of the wire guide surface. Further, the data processing unit may be connected to or be part of a control unit of the wire saw for controlling the sawing process. Thereby, sawing process parameters such as sawing speed, feeding rate of an ingots, slurry supply etc. May be adapted in accordance to detected changes of surface characteristics of the wire guide before a critical surface wear value has been exceeded. Thus, the sawing process can be optimized with respect to the operation time of the wire saw between an exchange of the wire guide.

[0039] According to embodiments, the optical sensor may be adapted to detect a change in the geometry of wire guide grooves (e.g. shape, depth, width etc. of the wire guide grooves) by analyzing the acquired data taken by the sensor device, for example, having an optical sensor e.g. CCD-sensor. In case the wire guide grooves exhibit a change in the geometry with respect to a reference geometry exceeding a preselected threshold or critical value, the data processing unit detects that change and may initiate a reaction. Such a reaction can be a warning signal indicating that a critical threshold has been exceeded. Alternatively the reaction can be an adaption of sawing process parameters of the wire saw (e.g. cutting speed, a rocking movement of the ingot, slurry supply etc.) in order to compensate the influence of the change of the wire guide grooves, if the change of the wire guide grooves is below a critical value, above which the wire guides need to be exchanged or regrooved, before continuing the cutting process. Thereby, the sawing process can be optimized with respect to the operation time of the wire saw between a necessary exchange or regrooving of the wire guide. Accordingly, down-times of the wire saw can be reduced.

[0040] As exemplarily shown in Fig. 5, according to embodiments of the wire guide monitoring as described herein, the wire guide monitoring device 500 may further include at least one actuator 540 configured for performing a movement of the optical sensor device 510 relative to the coupling element 530. According to embodiments as described herein, the at least one actuator 540 is configured for performing a movement of the optical sensor device in a direction which is parallel to the longitudinal axis of the wire guide which is intended to be measured when the wire guide monitoring device is coupled to a kinematic mechanism structure as described herein. Further, as exemplarily shown in Fig. 5 the wire guide monitoring device can include at least one guide rail 541 for guiding the movement of the optical sensor device 510 relative to the coupling element 530. According to embodiments as described herein, the at least one actuator is a linear actuator which is arranged such that in a couple state of the wire guide monitoring device a linear movement of the optical sensor device parallel to the longitu-

dinal axis of the wire guide can be performed.

[0041] According to embodiments of the wire guide monitoring device as described herein, the at least one actuator 540 has a positioning range of at least 250 mm, particularly of at least 400 mm, particularly of at least 660 mm. Accordingly, the at least one guide rail 541 may extend along the moving direction of the actuator 540 for at least 250 mm, particularly for at least 400 mm, particularly for at least 660 mm. Thereby, the wire guide monitoring device can be moved during monitoring the surface of the wire guide along at least a longitudinal section of the wire guide. Particularly, the wire guide monitoring device can be moved during monitoring the surface of the wire guide along the complete length of the wire guide. Further, according to embodiments, the actuator is configured for performing movements with a minimal incremental motion distance of maximal 10 μm , particularly of maximal 5 μm , particularly of maximal 1 μm . Thereby, during measuring the surface of the wire guide the movement of the sensor device in direction of the axis of the wire guide can be performed very accurately.

[0042] Fig. 6 shows a schematic side view of a wire guide monitoring device according to embodiments described, wherein the wire guide monitoring device is in a position for monitoring the wire guide 200. The exemplarily shown wire guide 200 in Fig. 5 may correspond to any of the wire guides 112, 114, 116, and 118 of the wire saw as exemplarily shown in Figs. 2 or 3. Accordingly, the description of the wire guide monitoring device 500 in connection with the wire guide 200 is an representative example for using the wire guide monitoring device for monitoring any wire guide of the wire saw, such as the exemplary wire guides 112, 114, 116, and 118 as illustrated in Figs. 2 or 3.

[0043] As illustrated in Fig. 6, in a position for monitoring a wire guide 200, in particular for measuring a surface characteristic of the wire guide, the sensor device 510 is positioned by means of a kinematic mechanism structure 350, for example a kinematic mechanism structure 350 of an ingot feeding system 300, such that the surface of the wire guide 200 is in the field of view of the sensor device 510. The dotted line 513 in Fig. 6 indicates an exemplary optical path between the radiation source 512 and the optical sensor 511 of the sensor device 510. According to embodiments described herein the optical path of the field of view of the sensor device can have a rectangular cross-section, as exemplarily shown by reference number 515 in Figure 8. Alternatively, the cross section of the optical path of the field of view may be of a circular, square or other suitable shape. According to embodiments, the cross section of the optical path defines a plane which is perpendicular to the cutting plane.

[0044] As indicated in Fig. 6, according to embodiments described herein the kinematic mechanism structure is configured for moving the wire guide monitoring device relative to the wire guide, e.g. within the cutting plane corresponding to the z-x plane in Figure 6. In detail, the kinematic mechanism structure as described herein

can be configured for performing a horizontal movement as indicated by arrow 351, a vertical movement as indicated by arrow 352 and a rotational movement is indicated by arrow 353, respectively. As described in connection with Fig. 5 above, according to embodiments of the wire guide monitoring device, the wire guide monitoring device may include at least one actuator 540. The at least one actuator 540 can be configured for performing a movement of the optical sensor device 510 relative to the coupling element 530. Particularly, the least one actuator 540 is configured for performing a movement of the sensor device 510 perpendicular to the cutting plane. In Figure 6, a movement of the sensor device perpendicular to the cutting plane corresponds to the y-direction as indicated in the depicted coordinate system. As exemplarily shown in Figure 6, the wire guide 200 may have a longitudinal axis 240, about which the wire guide 200 may be rotated. As exemplarily shown in Fig. 6, according to embodiments described herein, the at least one actuator 540 is configured for performing a movement in direction of the longitudinal axis 240 of the wire guide 200, e.g. in the y-direction in Fig. 6. Additionally or alternatively, the support element 520 may include an actuator 522, particularly a linear actuator, configured for translating the sensor device in a direction perpendicular to the wire guide axis, particularly horizontally.

[0045] In Figure 7 a schematic view of a wire guide is shown of which the surface characteristics can be monitored by the wire guide monitoring device as described herein. According to embodiments, the wire guide 200 may have a longitudinal axis 240, about which the wire guide 200 may be rotated. Further, the wire guide 200, as described herein, may include a cylindrical portion 210, on the circumferential surface of which a plurality of grooves 220 can be formed. As an example, the first groove of the plurality of grooves is denoted with reference sign 221, and the last groove is denoted with the reference sign 222 in Figure 6.

[0046] On the right side of Fig. 7, a frontal view of the wire guide 200 is shown, indicating the radial direction 292 and the circumferential direction 291 of the wire guide or the cylindrical portion. The grooves are generally formed on the circumferential surface of the wire guide and have an extension in the radial direction 292 into the wire guide. Further, the wire guide 200 may provide a length 290 which is substantially perpendicular to its radial direction 292. In the exemplary embodiment shown in Fig. 7, grooves 220 are formed over the whole length 290 of the wire guide 200.

[0047] According to embodiments described herein, the cylindrical portion 210 of the wire guide 200 as described herein, may have a length along the longitudinal axis 240 of the wire guide of typically about 500 mm to about 1000 mm, more typically between about 600 mm to about 800 mm, and even more typically of about 700 mm. The length 290 of the cylindrical portion along the longitudinal axis 240 is exemplarily shown in Fig. 7. The number of grooves formed on the surface of the cylindri-

cal portion of the wire guide may exemplarily be between typically about 1000 and about 6000 grooves, more typically between 1200 and about 4000 grooves, and even more typically between about 1700 and about 3500 grooves on one wire guide.

[0048] Fig. 8 shows an enlarged section 280 of the cylindrical portion 210 of the wire guide 200 shown in Fig. 6. In section 280 of Fig. 8, the grooves 220, which are exemplarily shown as V-shaped grooves, can be seen in more detail. Further, the section 280 of Fig. 8 shows that each groove of the plurality of grooves 220 has an extension in several directions (the extension in one direction may also be referred to as a dimension of the groove), such as a depth in the cylindrical portion, a width and a pitch, which will be explained in detail below with respect to Fig. 9. As exemplarily shown in Figure 8, the field of view 515 of the sensor device 510 may have a size and shape suitable for measuring several grooves (e.g. at least two or more) at the same time. According to embodiments, the field of view can have a width between a lower limit of 0.05 mm, particularly of 0.10 mm, more particularly of 0.3 mm, and an upper limit of 2 mm, particularly of 3 mm, more particularly of 4 mm.

[0049] Generally, grooves of a wire guide have a nominal dimension, which may be a predetermined value of a dimension, or a desirable or ideal value of a dimension. In some embodiments, a nominal dimension value is equal for every groove in the cylindrical portion so that exactly one nominal dimension value exists for one dimension of the grooves. According to some embodiments, each groove may have a nominal dimension, which may, for instance, depend on the position of the groove on the wire guide. The actual dimension of the groove is the dimension which the groove exhibits after the formation in the cylindrical portion. Due to process and material variations, the actual dimension may differ from the nominal dimension. In embodiments described herein, the actual dimension of each of the grooves in the cylindrical portion has a deviation of typically less than about 5% from the nominal dimension, more typically less than about 3% from the nominal dimension, and even more typically less than about 2% of the nominal dimension for the groove.

[0050] When measuring the grooves, for example after production for quality control of the grooves or after cutting for inspection of wear, it is desirable to measure the grooves very accurately as the groove geometry has an impact on different factors, such as the thickness of the wafers to be cut by the wire saw, or wire vibrations during the cutting process, which are caused when the grooving pitch is irregular along the width of the wire guide.

[0051] Generally, the wire position and holding in the groove, the geometry of the groove, in particular the depth and the shape of the groove, ensures that the wire is maintained at a defined position while the wire guide rotates. If the grooving profile is irregular, the wire could vibrate and/or jump out of one groove during the cut, thus generating wire jumps. These vibrations and/or wire

jumps damage the wafers and are a source of wire breaks. The resulting interruption of the cutting process is expensive and time-consuming.

[0052] Thus, it is desirable to measure the grooves regularly, for example between a preselected number of cuts (e.g. after each individual cut or after every second, third, or more cut) in order to gain information about the state of the groove. Thereby, if a change in groove geometry is detected which is above a preselected threshold the wire guide may be exchanged or regrooved. Alternatively process parameters of the wire saw, e.g. ingot feeding rate, sawing speed, slurry supply etc. may be adapted for the next wafer cutting process to compensate for the change in groove geometry.

[0053] In Fig. 9, a schematic view of exemplary groove geometry in a wire guide according to embodiments described herein is shown. As an example of a groove shape, the grooves 420 in Fig. 8 are formed in a V-like shape. However, the dimensions related to the groove geometry such as depth 430, width 440, pitch 450 opening angle 460, and the like, as exemplarily shown in Fig. 8 are not limited to a V-like shape of the groove in the wire guide. According to embodiments described herein the grooves can have a U-type cross-sectional shape, a V-type cross-sectional shape, a shape providing a flat bottom of the groove, a shape providing a round bottom of the groove or any other suitable shape for guiding a wire.

[0054] In Fig. 9, the grooves 420 can be seen being formed in the circumferential surface 415 of the cylindrical portion 210 of the wire guide, as explained above. According to some embodiments, the grooves 420 are formed in a coating, particularly a coating of polyurethane, being arranged at the circumferential surface of a body of the cylindrical portion 210. For example, the wire guide can be made by a solid cylinder coated with a polymer layer (e.g. polyurethane) of several millimeters, in which about 1000 - 6000 parallel grooves may be scribed.

[0055] The grooves of the wire guide have several geometrical dimensions. For instance, a groove 420 in a wire guide according to embodiments described herein, may have a depth 430 measured from the surface 415 of the cylindrical portion 210, a width 440 in a cross direction of the cylindrical portion at the surface 415 of the cylindrical portion 210, a pitch 450 being defined as the distance between the center of one groove to the center of the adjacent groove, a distance 470 between the end of one groove and the beginning of the adjacent groove at the surface 415 of the cylindrical portion 210, an opening angle 460, and the like.

[0056] According to some embodiments, which may be combined with further embodiments described herein, the depth 430 of a groove ranging from the surface 415 of the cylindrical portion 210 to the bottom of the groove 420 may be typically between about 100 μm and about 250 μm , more typically between about 120 μm to about 200 μm , and even more typically between about 150 μm

and about 200 μm , such as 170 μm . The width 440 of a groove may be typically between about 120 μm and about 250 μm , more typically between about 150 μm and about 230 μm , and even more typically about 220 μm . According to some embodiments, the pitch 450 may typically be between about 100 μm and about 400 μm , more typically between about 150 μm to about 350 μm , and even more typically between about 150 μm and about 200 μm . In one example, the pitch may be about 355 μm . It should be noted that the center of a groove may be defined by the middle point between the beginning of the groove at the surface of the cylindrical portion and the end of the groove at the surface of the cylindrical portion.

[0057] According to some embodiments described herein, the distance 470 between the beginning of one groove, at the surface of the cylindrical portion, and the beginning of an adjacent groove, at the surface of the cylindrical portion, may typically be between about 10 μm and about 50 μm , more typically between about 15 μm and about 30 μm , and even more typically about 20 μm . The opening angle 460 may typically be between about 30° to 100°, more typically between about 40° to about 90°, and even more typically at about 80°.

[0058] It should be understood that the values given are only examples for the respective dimension. For instance, a dimension value, such as the value for the width may depend on the groove shape and may deviate from the above discussed example values dependent on the shape.

[0059] The geometry of the grooves, e.g. V-shaped with an opening angle, deepness and a pitch from one groove to the next groove, is selected according to the type of wire used. For instance, the above described parameters of the grooves depend on wire characteristics such as the outer wire diameter, the wire material, or whether the wire material is straight, structured or diamond coated. The pitch of the grooves also depends on the desired thickness of the slices obtained at the end of the cutting process.

[0060] In Fig. 9, one wire 480 is exemplarily shown in one of the grooves 420. The wire 480 may have an outer wire diameter 485 of typically about 50 μm to 200 μm , more typically about 70 μm to 150 μm , and even more typically between about 80 μm to about 140 μm .

[0061] According to some embodiments described herein the sensor device 510 is configured for measuring dimensions of grooves on the circumferential surface of a wire guide as described herein. In particular, the sensor device 510 may be configured for measuring dimensions of grooves as described herein within an accuracy of at least $\pm 2 \mu\text{m}$, particularly within an accuracy of at least $\pm 1 \mu\text{m}$, particularly within an accuracy of at least $\pm 0.5 \mu\text{m}$.

[0062] According to embodiments described herein, the wire guide monitoring device is configured for detecting deviations of the above described dimensions like depth 430, width 440, pitch 450, opening angle 460, and

distance 470 of the wire guide of less than about 2 μm , particularly of less than 1 μm , particularly of less than $\pm 0.5 \mu\text{m}$. Alternatively, the wire guide monitoring device may be configured for detecting deviations from of the above described dimensions like depth 430, width 440, pitch 450, opening angle 460, and distance 470 of the nominal dimension of the wire guide of less than about 10 %, particularly of less than 5 %, particularly of less than 2%.

[0063] As explained above, a nominal value for a dimension of the groove may change over the width of the cylindrical portion. For instance, referring back to Fig. 6, the groove 221 at the left side of the cylindrical portion may have a different dimension than groove 222 at the right side of the cylindrical portion due to different nominal values for these grooves. In one example, the nominal value for the pitch differs when going from the left side of the wire guide to the right side of the wire guide. In other words, the values for the pitch of the groove may differ from each other (and may for instance have a difference to each other greater than 5% of the pitch), but may differ from the specific nominal value for the respective pitch only by 5% or even less.

[0064] With the deviation of a dimension of less than about 5% from the nominal dimension, the following dimension deviations may occur in a wire guide according to embodiments described herein. For instance, the deviation of the depth 430 from a nominal depth may typically be less than about 12 μm , more typically less than about 8 μm , and even more typically less than about 5 μm . The deviation of the width 440 from a nominal width may typically be less than about 12 μm , more typically less than about 10 μm , or even more typically less than about 5 μm . The deviation of the pitch 450 from a nominal pitch may typically be less than 20 μm , more typically less than about 10 μm , and even more typically less than about 7.5 μm .

[0065] The deviation of the opening angle 460 from a nominal opening angle may typically be less than 5°, more typically less than about 4°, and even more typically less than about 3°. The deviation of the distance 470 from a nominal distance may typically be less than about 3 μm , more typically less than about 2 μm , and even more typically less than about 1 micron.

[0066] In some embodiments, especially when the deviation of the actual dimension of the groove from the nominal dimension of the groove is less than 3%, the deviation of the depth 430 from the nominal depth may typically be less than about 7 μm , more typically less than about 5 μm , and even more typically less than about 3 μm . The deviation of the width 440 from the nominal width may typically be less than about 7 μm , more typically less than about 5 μm , or even more typically less than about 4 μm . The deviation of the pitch 450 from the nominal pitch may typically be less than about 12 μm , more typically less than about 6 μm , and even more typically less than 4.5 μm .

[0067] The deviation of the opening angle 460 from the

nominal opening angle may typically be less than about 3°, more typically less than about 2°, and even more typically less than about 1°. The deviation of the distance 470 from the nominal distance may typically be less than about 2 µm, more typically less than about 1 micron and less than about 0.6 micron.

[0068] In some embodiments, however, about 1% of the grooves may have a deviation of the actual dimension from the nominal dimension which exceeds the above referenced values, e.g. about 1% of the grooves may have a deviation of the actual dimension from the nominal dimension being larger than 5%.

[0069] The cylindrical body of the wire guide according to embodiments described herein may be made of steel or carbon fiber reinforced polymer (CFRP) material and may be coated on the cylindrical surface with a soft material, such as a polymer material, e.g. a polyurethane compound. According to some embodiments, the grooves having the above described reliability in the geometrical dimensions from the first to the last groove may be formed in the soft material coating of the cylindrical portion by laser ablation.

[0070] Fig. 10 shows a perspective view of a wire guide monitoring device 500 according to embodiments described herein which is coupled to a kinematic mechanism structure 350 of an ingot feeding system 300 of a wire saw. As explained above in connection with Figs. 1 and 2, the kinematic mechanism structure as described herein, is configured for performing horizontal movements (indicated by arrow 351), vertical movements (indicated by arrow 352) and rotational movements (indicated by arrow 353) of the wire guide monitoring device relative to the wire guide 200 within the cutting plane.

[0071] As exemplarily shown in Fig. 10, a parallel kinematic mechanism structure 350 as described herein includes three arms 343 having first ends and second ends, and two or more actuators 355. As illustrated in Fig. 10 the first ends of the arms are rotatably connected to the support table 312, e.g. via a hinged joint, whereas the second ends of the arms are rotatably connected to the actuators 355, e.g. via a hinged joint. According to embodiments not shown, the parallel kinematic mechanism structure may include four arms, wherein two arms are arranged on a left side of the support table and the other two arms are arranged on the right side of the support table.

[0072] Typically the actuators 355 are configured to realize a movement along a translational axis, typically a vertical axis (e.g. the z-axis as exemplarily shown in Figure 10). Typically, the actuators are guided via guide rails (not shown) provided on the frame 305 of the wire saw, wherein the guide rails are typically arranged along an axis of the cutting direction, particularly in a vertical direction. Further, the actuators are configured such that each can move separately. Hence, by moving the actuators 355, the arms 343, the support table 312 and thus the wire guide monitoring device 500 coupled to the support table can be moved.

[0073] For example, when all three actuators are moving in the same direction with the same speed the monitoring device 500 is moved downwards in the representation of Fig. 10, in particular towards the surface of the wire guide 200 of the wire saw. In the case that at least one of the actuators is moving at a different speed and/or in a different direction compared to the other actuators, a rotational movement of the monitoring device 500 can be realized, e.g. a rotation as indicated by arrow 353 (e.g. around the y-axis as indicated in Fig. 10). Accordingly, a relative motion of the actuators to each other and can be used to move the monitoring device 500 in a cutting plane, for example in the z-x-plane of Fig. 10, and/or also to provide a rotation of the monitoring device 500, e.g. with an angle relative to a horizontal as indicated by arrow 351.

[0074] Additionally or alternatively, the arms 343 of the kinematic mechanism structure may be expandable and/or contractable in order to provide translational and/or rotational movements. Therefore, according to embodiments of the kinematic mechanism structure the expanding/contracting arms 343 may include an actuator capable of expanding and contracting the arms. Thereby, also a rotational movement of the wire guide monitoring device coupled to the kinematic mechanism structure can be realized by simple expansion or contraction of arms 343.

[0075] According to another aspect of the present disclosure, with exemplary reference to Figure 2, a wire saw including at least two wire guide cylinders and a wire guide monitoring device as described herein is provided. According to embodiments of the wire saw, the wire saw includes a coupling element configured for coupling an ingot and a wire guide monitoring device as described herein. The coupling element of the wire saw configured for coupling an ingot and/or the wire guide monitoring device may be arranged on the kinematic mechanism structure 350 or on the support table 312. According to embodiments, the coupling element of the wire saw for coupling an ingot and a wire guide monitoring device may be configured to match with the coupling element of the wire guide monitoring device as described herein and a coupling element employed for coupling an ingot, respectively. According to embodiments, the coupling element of the wire saw, can be configured as a clamping mechanism for releasable coupling a ingot 102 and/or a wire guide monitoring device, as described herein. Thereby, a wire saw is provided which can be used for cutting an ingot and measuring the wire guides of the wire saw, in particular surface characteristics of the wire guides, such as wire guide grooves. Accordingly, by providing a wire saw having a coupling element for coupling an ingot and/or a wire guide monitoring device as described herein, surface characteristics of the wire guides may be checked between individual cuts or between a preselected number of cuts. Further, the wire guide can be measured when the wire guide is installed inside the wire saw. Therefore, down times of the wire saw can be reduced

as it is not necessary to remove the wire guide from the wire saw for measuring its surface. Further, the wire guides can be measured in their actual position during cutting, such that also the coaxial alignment of the wire guides may be checked when they are installed inside the wire saw

[0076] Fig. 11 shows a flow chart of a method for monitoring 600 a wire guide according to embodiments described herein. The method 600 for monitoring a surface characteristic of a wire guide, includes coupling 610 a sensor device to a kinematic mechanism structure of a wire saw, moving 620 the sensor device to the surface of a wire guide installed inside the wire saw by moving the kinematic mechanism structure, and measuring 630 a surface characteristic of the wire guide using the sensor device. Thereby, by providing a method for measuring the surface characteristics of a wire guide in which the wire guide can be measured when the wire guide is installed inside the wire saw, down times of the wire saw can be reduced as it is not necessary to remove the wire guide from the wire saw for measuring its surface. Further, the wire guides can be measured in their actual position during cutting, such that also correct the coaxial alignment of the wire guides may be checked when they are installed inside the wire saw. Accordingly, the method as described herein also provides a method for quality control when the wire guides are installed inside the wire saw for first time.

[0077] According to embodiments of the method for monitoring 600 a wire guide, coupling 610 a sensor device to a kinematic mechanism structure of a wire saw includes coupling the wire guide monitoring device 500 as described herein, particularly to a kinematic mechanism structure as described herein.

[0078] According to embodiments of the method for monitoring 600 a wire guide, moving 620 the sensor device includes moving the sensor device by means of the kinematic mechanism structure as described herein to which the sensor device is coupled. In particular, the wire guide monitoring device can be moved by means of the kinematic mechanism structure within the cutting plane which typically includes a cutting direction. Accordingly, moving the sensor device includes performing translational and/or a rotational movements using the kinematic mechanism structure as explained in connection with the embodiments of the wire saw as described herein

[0079] (e.g. the description with respect to Figs. 1, 2, 3 and 10).

[0080] Further, according to embodiments of the method for monitoring 600 a wire guide as described herein may further include moving the sensor device in a direction which is substantially parallel to the longitudinal axis of the wire guide relative to the surface of the wire guide to be measured. According to embodiments, moving the sensor device in a direction which is substantially parallel to the longitudinal axis of the wire guide is performed by means of an actuator included in the wire guide monitoring device as described (e.g. the description with respect

to Figs. 5, 6 and 10).

[0081] According to embodiments of the method for monitoring 600 a wire guide as described herein measuring 630 a surface characteristic of the wire guide includes conducting at least two measurements at different locations on the surface of the wire guide. Further, measuring 630 may include analyzing of measurement data with respect to the surface characteristic of the wire guide surface, particularly statistical analyzing of measurement data with respect to the surface characteristic of the wire guide surface. Further, the measuring 630 in particular includes measuring surface characteristics of the wire, e.g. groove geometry, as exemplarily described in connection with Figs. 7, 8 and 9.

[0082] According to embodiments of the method for monitoring 600 a wire guide as described herein, the measuring 630 may include analyzing of measurement data with respect to the surface characteristic of the wire guide surface, in particular statistical analyzing of measurement data with respect to the surface characteristic of the wire guide surface. Statistical analyzing may include statistical analysis of measurements taken at different location on the wire guide surface and/or statistical analysis of measurements taken at different points in time, e.g. at the same location but after a different number of cuts. Thereby, valuable information about the cutting process, in particular information with respect to wear caused by a particular set of process parameters (e.g. wire speed, ingot feeding rate, slurry supply etc.), may be obtained. Further, according to embodiments analyzing of measurement data may include accounting for deviations between nominal and actual dimensions of surface characteristics, such as explained in connection with the groove geometry with respect to Figs. 7, 8 and 9.

[0083] According to embodiments described herein, the methods for monitoring physical characteristics of at least one wire can be conducted by means of computer programs, software, computer software products and the interrelated controllers, which can have a CPU, a memory, a user interface, and input and output means being in communication with the corresponding components of the wire saw. These components can be one or more of the following: motors, wire break detection units, wire tracking devices, and the like.

[0084] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims

1. A wire guide monitoring device (500) for a wire saw, comprising:

an optical sensor device (510) for measuring surface characteristics of a wire guide, and

- a coupling element (530) for coupling the wire guide monitoring device to a kinematic mechanism structure of an ingot feeding system of the wire saw.
2. The wire guide monitoring device (500) for a wire saw according to claim 1, further comprising at least one actuator (540) configured for performing a movement of the optical sensor device (510) relative to the coupling element (530).
 3. The wire guide monitoring device (500) for a wire saw according to claim 1 or 2, wherein the optical sensor device (510) comprises at least one guide rail for guiding a movement of the optical sensor device (510) relative to the coupling element (530).
 4. The wire guide monitoring device (500) for a wire saw according to claim 2 or 3, wherein the actuator is a linear actuator which is arranged such that in a coupled state of the wire guide monitoring device a linear movement of the optical sensor device in direction of the longitudinal axis of a wire guide can be performed.
 5. The wire guide monitoring device (500) for a wire saw according to any of claims 2 to 4, wherein the actuator has a positioning range of at least 250 mm, particularly of at least 400 mm, particularly of at least 660 mm.
 6. The wire guide monitoring device (500) for a wire saw according to any of claims 2 to 5, wherein the actuator has a minimal incremental motion distance of maximal 10 μm , particularly of maximal 5 μm , particularly of maximal 1 μm .
 7. The wire guide monitoring device (500) for a wire saw according to any of claims 1 to 6, wherein the sensor device (500) comprises a radiation source (512) and an optical sensor (511), preferably wherein the radiation source (512) is arranged opposite to the optical sensor (511), particularly wherein the sensor device is a fork type sensor.
 8. The wire guide monitoring device (500) for a wire saw according to any of claims 1 to 8, wherein the sensor device has a sensing slot width (W) of at least 100 mm, particularly of at least 150 mm, particularly of at least 200 mm.
 9. The wire guide monitoring device (10) for a wire saw according to any of claims 1 to 9, wherein the sensor device has a sensing slot depth (D) of at least 20 mm, particularly of at least 40 mm, particularly of at least 60 mm.
 10. A wire saw (100) comprising at least two wire guide cylinders and a wire guide monitoring device (500) according to any of claims 1 to 10, particularly wherein the wire saw comprises a coupling element configured for coupling an ingot and the wire guide monitoring device.
 11. A wire saw (100) comprising at least two wire guide cylinders, a coupling element configured for coupling an ingot and a wire guide monitoring device, and a wire guide monitoring device (500) comprising: an optical sensor device (510) for measuring surface characteristics of a wire guide, a coupling element (530) for coupling the wire guide monitoring device to a kinematic mechanism structure of an ingot feeding system of the wire saw, and at least one actuator (540) configured for performing a movement of the optical sensor device (510) relative to the coupling element (530), wherein the sensor device (500) comprises a radiation source (512) and an optical sensor (511), preferably wherein the radiation source (512) is arranged opposite to the optical sensor (511), particularly wherein the sensor device is a fork type sensor.
 12. A method (600) for monitoring a surface characteristic of a wire guide, wherein the method comprises:
 - coupling (610) a sensor device to a kinematic mechanism structure of a wire saw,
 - moving (620) the sensor device to the surface of a wire guide installed inside the wire saw by moving the kinematic mechanism structure, and
 - measuring (630) a surface characteristic of the wire guide using the sensor device.
 13. The method (600) for monitoring a surface characteristic of a wire guide according to claim 12, wherein the method further comprises moving the sensor device in a direction of the longitudinal axis of the wire guide relative to the surface of the wire guide.
 14. The method (600) for monitoring a surface characteristic of a wire guide according to claim 12 or 13, wherein measuring (630) a surface characteristic of the wire guide includes conducting at least two measurements at different locations on the surface of the wire guide.
 15. The method (600) for monitoring a surface characteristic of a wire guide according to any of claims 12 to 14, wherein measuring (630) includes analyzing of measurement data with respect to the surface characteristic of the wire guide surface, in particular statistical analyzing of measurement data with respect to the surface characteristic of the wire guide surface.

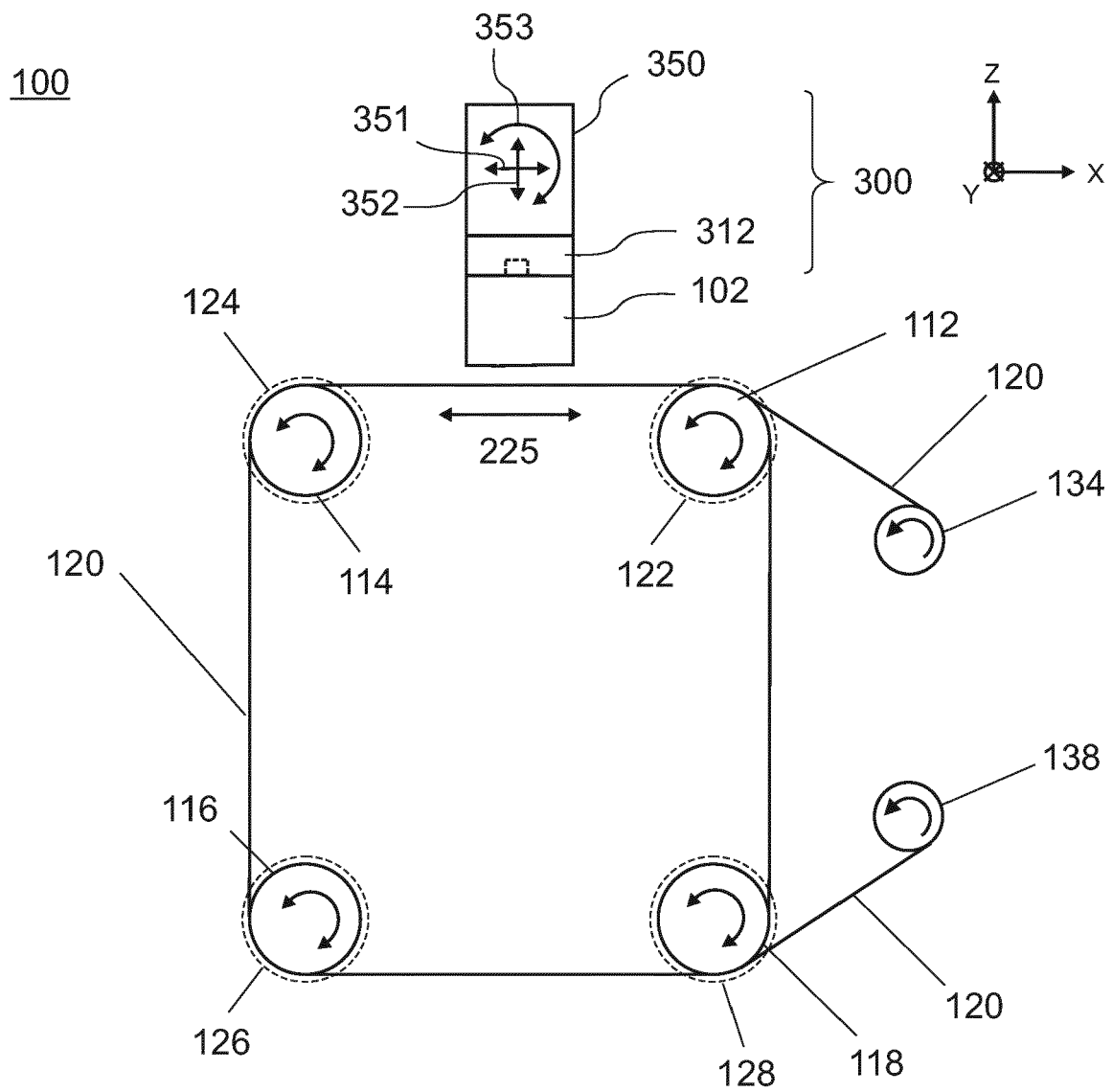


Fig. 1

100

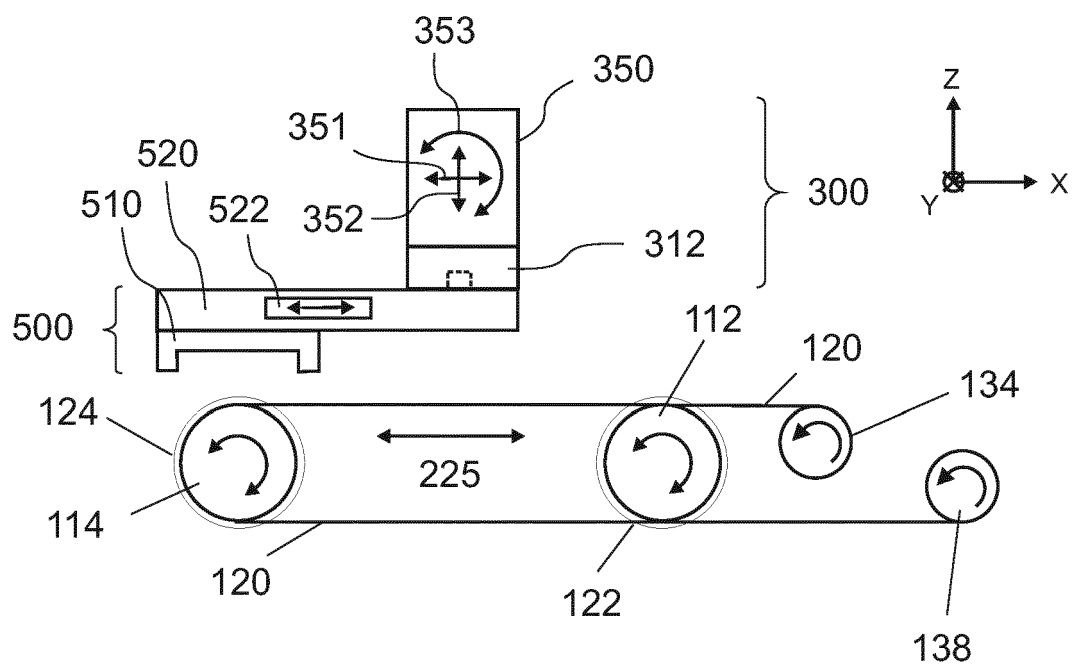


Fig. 2

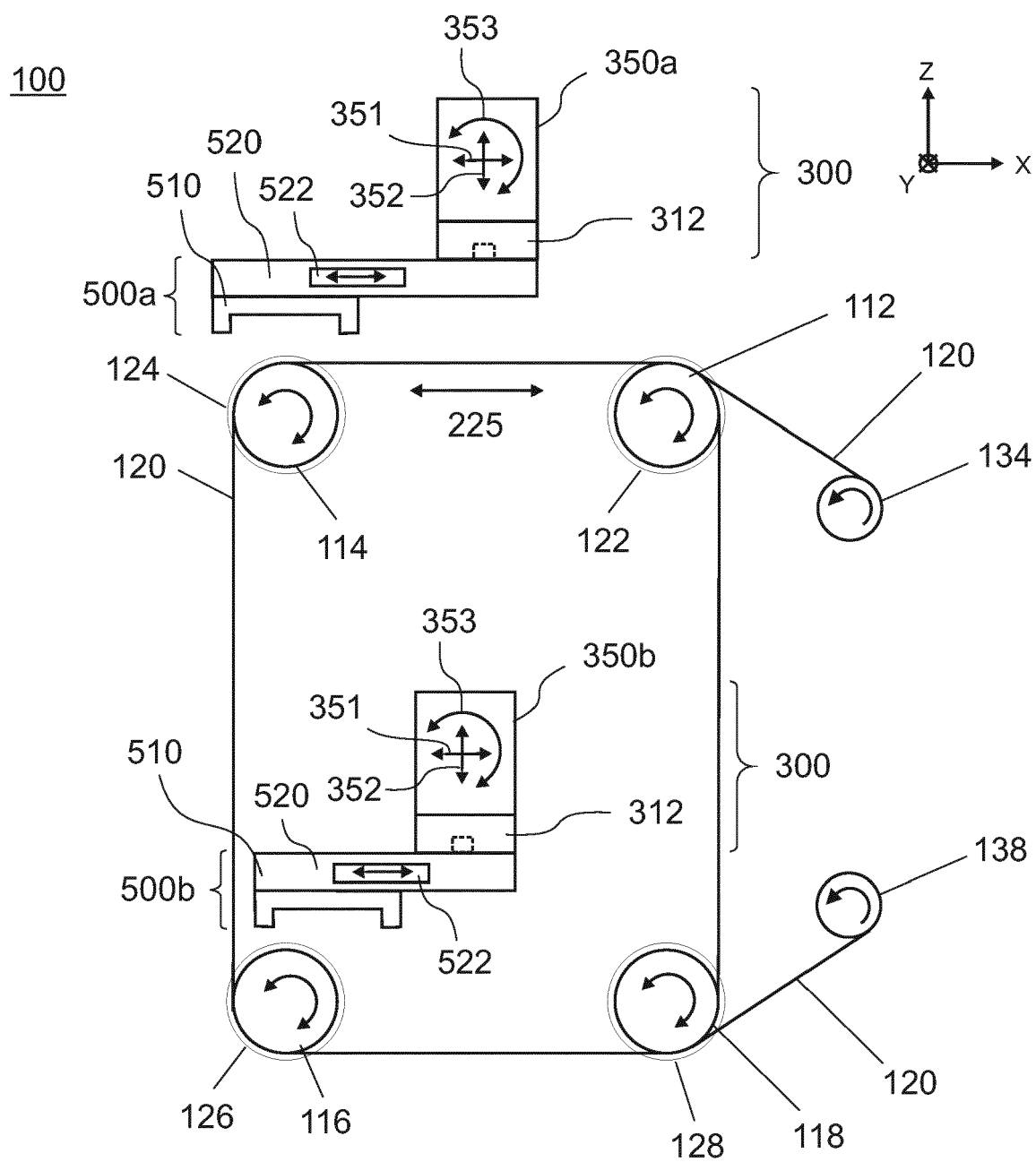


Fig. 3

500

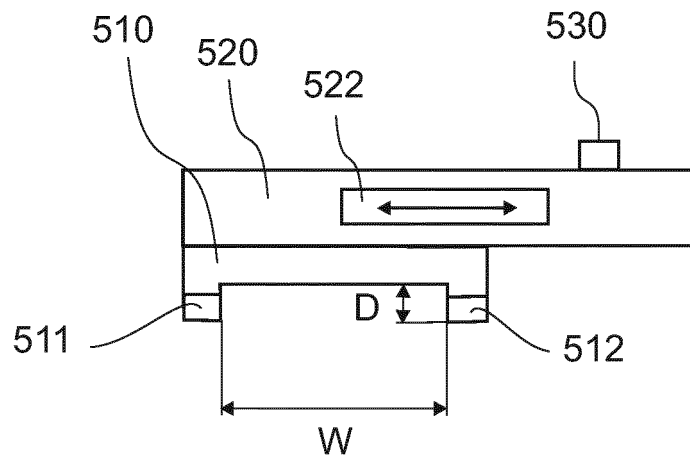


Fig. 4

500

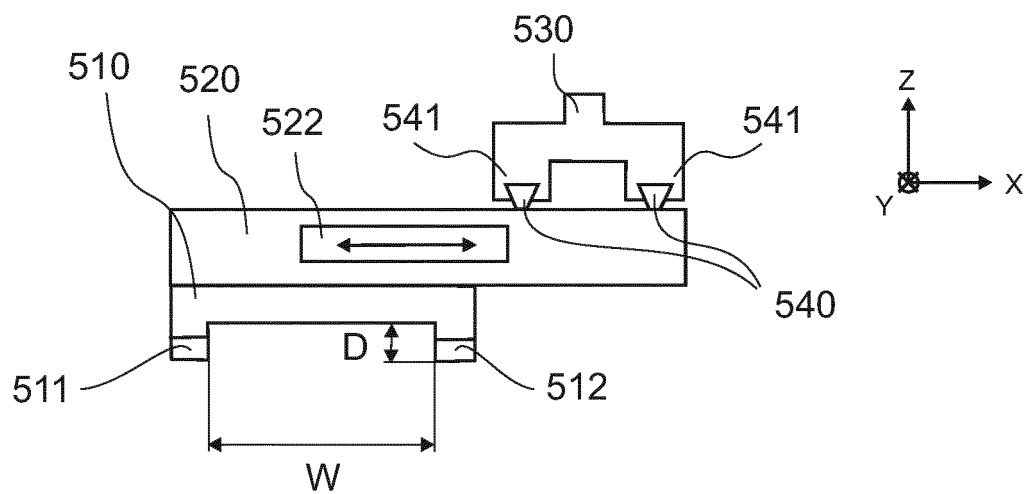


Fig. 5

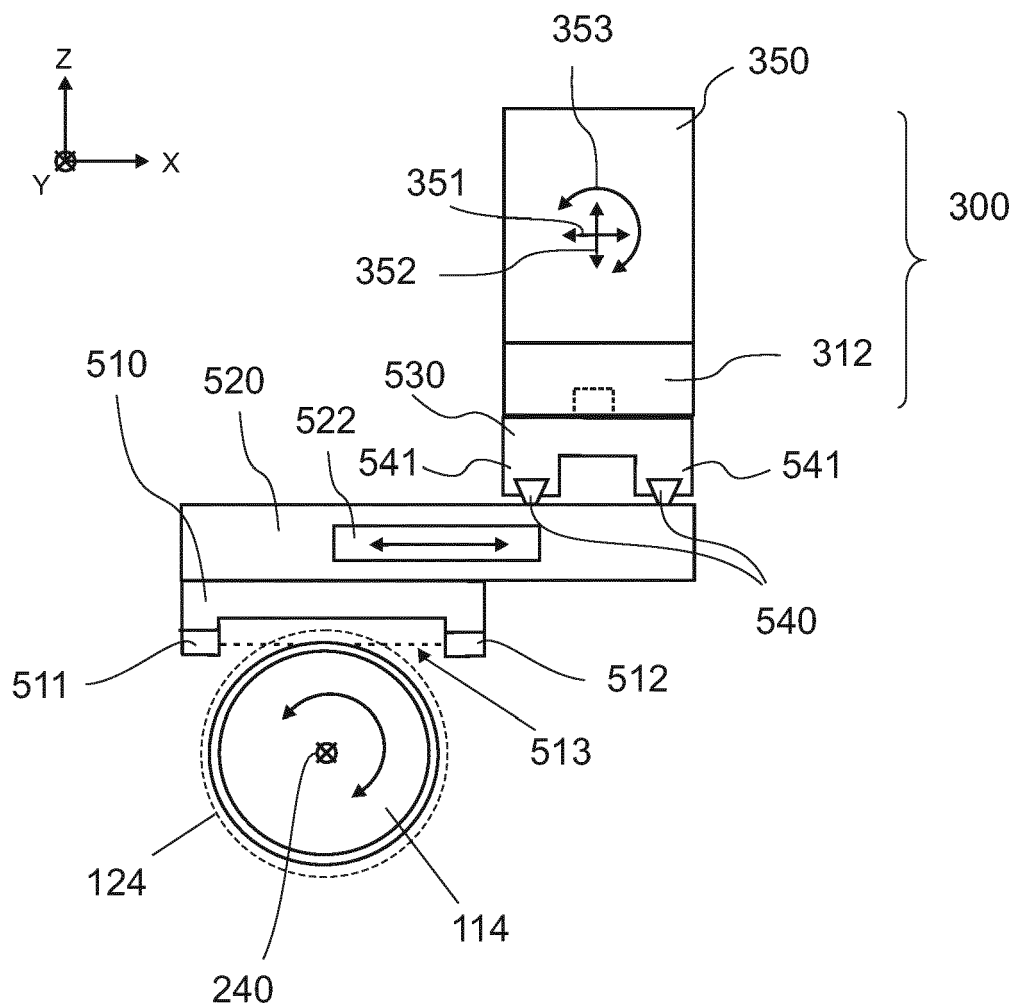


Fig. 6

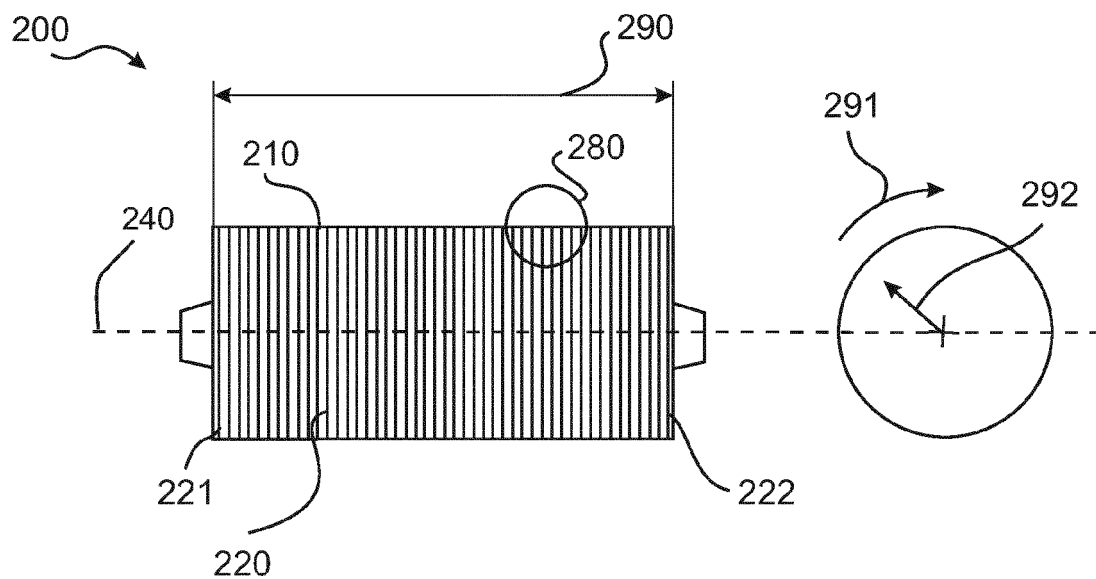


Fig. 7

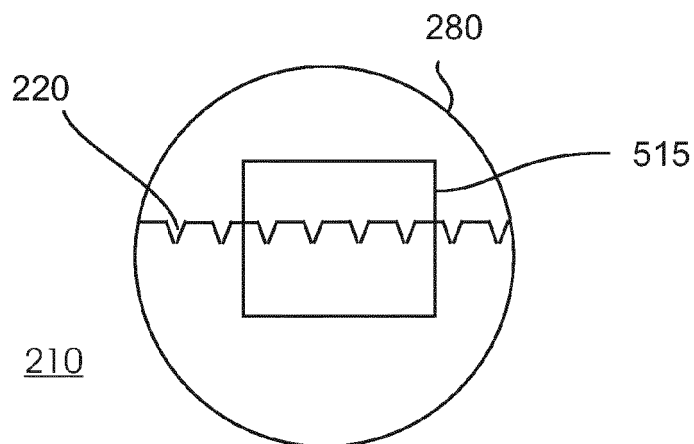


Fig. 8

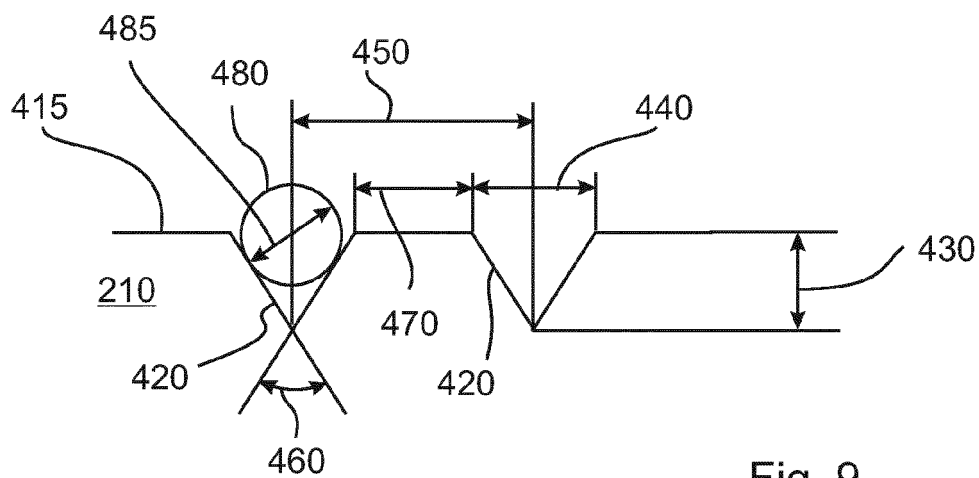


Fig. 9

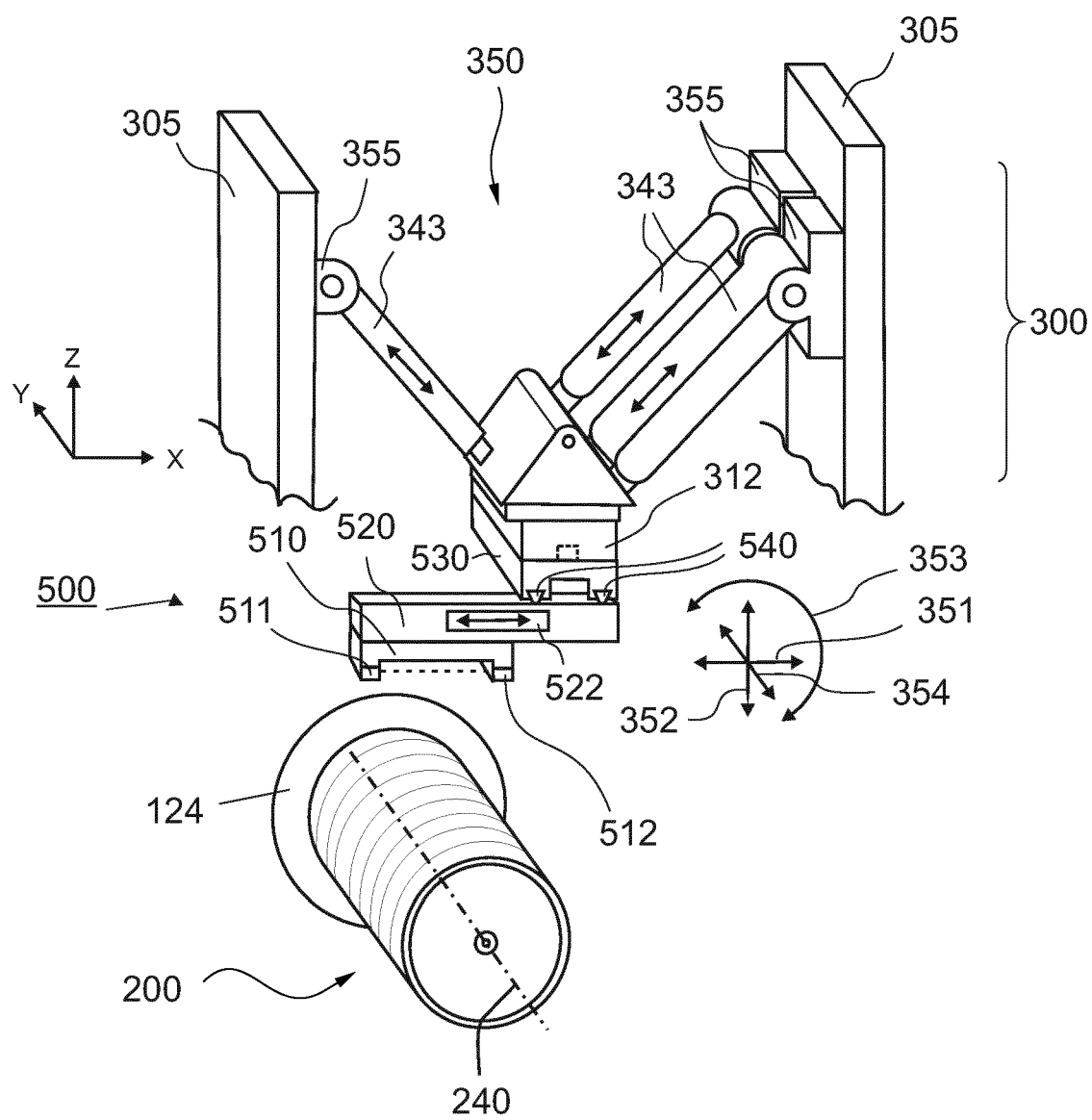


Fig. 10

600

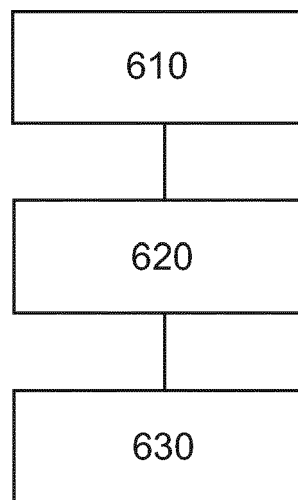


Fig. 11



EUROPEAN SEARCH REPORT

Application Number
EP 14 16 5254

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Place of search		Date of completion of the search	Examiner
The Hague		22 September 2014	Garella, Mario
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 14 16 5254

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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