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(54) Method for fixing a single-crystal workpiece to be treated on a processing device

(57) The invention relates to a method for fixing a single-crystal workpiece (1) on a holding means (2), the holding means (2) comprising a mounting surface (4) for mounting the holding means (2) on a processing device (6);
wherein the method comprising the steps of:
- measuring the crystal orientation of said single-crystal workpiece (1) with respect to a workpiece surface (5),
- forming, in dependence of the crystal orientation of said single-crystal workpiece (1) with respect to said workpiece surface (5), on the holding means (2) a holding surface (3) for abuttingly receiving said workpiece surface (5), thereby defining the crystal orientation of the single-crystal workpiece (1) with respect to the mounting surface (4) of the holding means (2), and
- gluing said workpiece surface (5) to said holding surface (3).

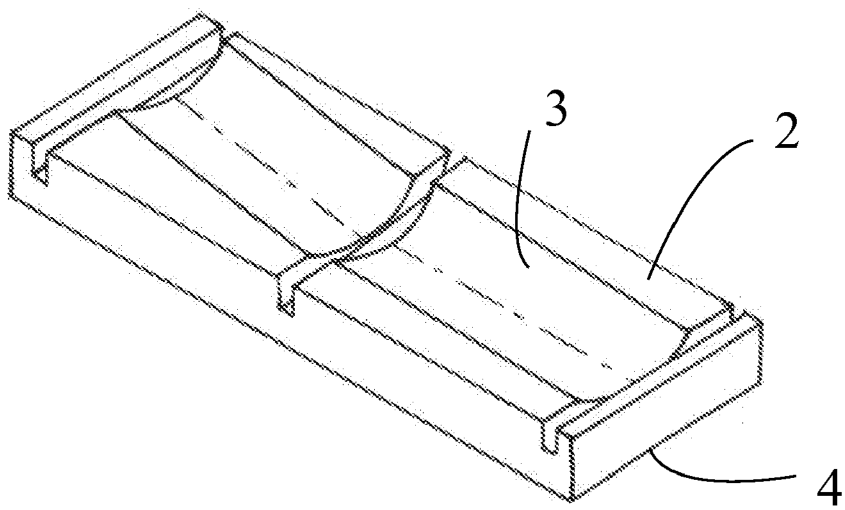

Fig. 6

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Description

[0001] The invention relates to a method for fixing a single-crystal workpiece on a holding means, the holding means comprising a mounting surface for mounting the holding means on a processing device, e.g. a cutting device so that the single-crystal workpiece can be treated on said processing device in a precise manner.

[0002] In particular, the invention relates to the cutting of crystalline materials, e.g. sapphire crystals, crystals containing silicon or boron, etc.. In wafer technology, single-crystal workpieces (usually denoted as ingots, boules or cores) are cut into thin slices for further processing.

[0003] When a sapphire crystal is grown, one obtains a boule: a single-crystal ingot produced by synthetic means. The crystal orientation of the boule is determined by X-ray diffraction. Once the crystal orientation and a 3D model of the outer surface of the boule has been made, cores (cylinders) are drilled out from the boule with a hollow drill in accordance with the determined orientation. After the drilling process, the cores are ground or polished. Unfortunately, the true angle between the mechanical (geometrical) axis of the core and the orientation of the crystal axis normally does however not lie within the required tolerances.

[0004] When cutting crystalline materials with a wire saw, the angle between the cutting plane and the planes of the crystal structure can be an extremely important and crucial parameter. Choosing the wrong orientation may result in the sawing wires being pushed aside, resulting in a curved cut. Especially for sapphire which is used for epitaxial growth of silicon, the cutting plane has to be very flat. It was found that the cuts are ideally made in an offset angle of 0° to 0,35° to the M-plane and 0° to 0,2° to the A-plane of the sapphire crystal.

[0005] Sapphire is a crystalline material with the chemical formula Al_2O_3, i.e. aluminum oxide or alumina. Sapphire is cut around (not necessarily perfectly parallel to) the C-planes for epitaxial growth of materials used for LED's.

[0006] The cores are glued to a holding means, also called sacrificial plate, that is in turn glued to a carrier plate. During the cutting process the usual positioning is as follows: the crystal is below and the holding means is on top. During the cutting process, the sawing wires bend in a bow-like manner. This means that at the end of the cutting process the sacrificial plate is cut by the sawing wires, hence its name. Thus, a holding means in form of a holding plate can be used only once.

[0007] As already mentioned above, one of the sapphire's areas of application is in epitaxy, in particular for the production of LEDs (light emitting diodes). Epitaxy refers to the method of depositing a monocrystalline film on a monocrystalline substrate. The deposited film is denoted as epitaxial film or epitaxial layer. Epitaxial films may be grown from gaseous or liquid precursors. Because the substrate acts as a seed crystal, the deposited film takes on a lattice structure and orientation identical to those of the substrate. This is different from other thin-film deposition methods, which deposit polycrystalline or amorphous films, even on single-crystal substrates. If a film is deposited on a substrate of the same composition, the process is called homoepitaxy; otherwise it is called heteroepitaxy.

[0008] In LED and semiconductor technology, sapphire is used as a substrate for the growth of epitaxial films, e.g. from silicon, GaN and/or GaInN. For the growth of epitaxial films, which are free from defects, it is vital to have an exact match between the surface orientation of the substrate and its respective crystal planes. Thus, the cutting of the sapphire core into multiple wafers is performed parallel to the crystal planes. However slight deviations in a particular angle/orientation from the crystal planes may be desirable to optimize the cutting performance. The desired orientation of the cutting plane with respect to the crystal orientation also depends on the substrate-film combination.

[0009] In the following some known methods are described for orienting the ingot prior to the cutting process.

[0010] Grinding a plane surface parallel to the long axis of a core or ingot marks a certain direction. When the ingot is cut, the wafer will show that mark of a missing segment along the circumference.

[0011] For flat-face grinding an ingot is mounted into a holder, so that the main axis runs horizontal. For so called C-type ingots, the main axis is the C-direction (Fig. 4). The flat direction for C-type wafers is usually the A-direction. Therefore, in an initial step, the A-direction is marked. The ingot is then mounted into the holder, such that the marked direction points upwards.

[0012] In this position, measurements are taken and the ingot is adjusted for the desired flat-direction. The ingot mounted in the holder is sent to the grinding machine and returned for re-checking. If the marked direction is not within the desired precision, the adjustment may be corrected and the grinding step repeated. When using corrections for the systematic deviation of individual grinding machines, the number of correction steps can be minimized.

[0013] The above method is characterized by the fact that for a correct alignment of the ingot in a saw, the surface of the ingot is formed by the use of grinding machines correspondingly.

[0014] In a further state of the art it is known to glue the sapphire core to a holding plate. In order to correct any misalignment of the crystal axis and the mechanical axis of the core, the core and the holding plate are glued together under an angle. In a first step, glue is applied to the holding plate. Then, the core is held under an angle relative to that core and the exact angle is measured. Prior to gluing, the misalignment between the crystal axis and the mechanical axis of the core is measured by means of X-ray diffraction. The angle between the mechanical axis of the core and the holding plate is measured. This angle is corrected as long as the crystal axis of the core is at the desired angle with respect to the holding plate. Now, the glue is given time to cure. Due to the angle between holding plate and core, there are regions with different glue thickness.

[0015] The above method is characterized by the fact that by try and error the gluing step is used for a correct alignment of the ingot in a saw.

[0016] Another known method is based on the orientated stacking of cores. Cores are typically smaller than 300 mm, so that more than one core fits into a sawing device. Stacking machines (such as produced by EFG Berlin) are used that are designed for building larger assemblies of individually and consistently orientated cores. Assemblies are then glued to a suitable support for the sawing device and sliced as a whole.

[0017] The stacking process begins with the marking of the reference direction, which typically is the A-direction for the C-type crystals. In the marked direction, plastic beams are glued to the core in order to provide a sufficiently large attachment surface for subsequent gluing.

[0018] Cores with plastic beams are mounted in an adjustment holder, and the holder is attached to a turnable plate. Measurements are then made and the desired orientation is adjusted. Thereafter a new stage is used for another core.

[0019] Each stage consists of a ring and an adapter for ingots of various sizes from 2" to 10". 12" ingots are mounted without an adapter. For the adjustment of the ingot orientation, there are two sets of screws for each stage. The orientation variation range is in the order of 1-1,5°.

[0020] Epoxy resin is usually used to glue the specimens to the support/holding plate. After curing of the resin, the stacking units can be disassembled. The resulting assembly can then be mounted in a wire saw for cutting the wafers.

[0021] The above method is characterized by the fact that by a mechanical adjustment holder which is removed after adjusting positioning the gluing process is performed for a correct alignment of the ingot in a saw.

[0022] The following disadvantages have to be considered for this prior art. The core (or ingot) has to be positioned very accurately to the holding plate which is difficult (requires a huge apparatus used by EFG) and cumbersome (the position has to be altered by screws or the like means). The desired position has to be fixed while the glue is curing. This means that the positioning means for positioning the cores cannot be used as long as the glue has not cured. The cores cannot be positioned by using robot arms, because they cannot hold a position for such a long time. They have to readjust their position consistently, rendering them unsuitable for gluing.

[0023] The object of the invention is to provide a new method for fixing at least one single-crystal workpiece to a holding means, the method allowing an accurate positioning of the workpiece with respect to the holding means. The method shall do without positioning means/ adjustment holders known from prior art. The method shall be reliable, time-saving and cost-effective and shall provide a strong assembly of the workpiece and the holding means. The assembly shall exactly define the crystal orientation of the workpiece with respect to a processing machine.

[0024] This object is achieved by a method as given in the pre-characterizing part of claim 1 and the following steps:

- measuring the crystal orientation of said single-crystal workpiece with respect to a workpiece surface,
- in dependence of the crystal orientation of said single-crystal workpiece with respect to said workpiece surface, forming on the holding means a holding surface for abuttingly receiving said workpiece surface, thereby defining the crystal orientation of the single-crystal workpiece with respect to the mounting surface of the holding means, and
- gluing said workpiece surface to said holding surface.

[0025] The holding surface is formed such, that a desired (or pre-specified) crystal orientation with respect to the mounting surface is achieved. The holding surface then ascertains the crystal orientation of the single-crystal workpiece with respect to the mounting surface, when the workpiece fittingly abuts against the holding surface.

[0026] According to the inventive solution, a holding surface is formed on the holding means for receiving the outer surface of the core. Now, the core can be placed on the holding means such that its surface engages with the holding surface on the holding means and the core can be glued to the holding means without mechanical aids securing the angle between the holding means and the crystal axis of the core. The holding surface on the holding means is formed in such a way that, when the core is placed on it and abuttingly engages on it, the crystal axis extends in the desired direction.

[0027] In contrast to prior art, the holding means is formed or adapted, respectively, which is much easier, time-saving and cost-effective than adapting the ingot or using complicated positioning means. The advantage of the invention consists in the simplicity and effectiveness of the holding means, which does not require any additional positioning means when fixing the workpiece. Due to the fact that the holding surface has already the "correct" orientation within the holding means, the workpiece just has to be placed on the holding surface. The term "correct" orientation refers to an orientaion, resulting in the desired crystal orientation with respect to the mounting surface, when the workpiece abuts against the holding surface.

[0028] With the inventive method, only the holding surface of the holding means has to be machined according to the deviation of the crystal axis from the mechanical axis of the workpiece. In the case of a cylindrical workpiece, e.g. a sapphire core, the cylinder axis or the lateral workpiece surface may be used as geometrical reference orientation. In general, the workpiece surface to be received by the holding surface of the holding means serves as geometrical reference surface.

[0029] The holding surface can be formed automatically using known CAD/CAM programmable machine tools, such as a milling machine.

[0030] The inventive method is reduced to the steps of measuring the angle between the crystal axis and a workpiece surface, machining a holding surface on a holding means correspondingly to a workpiece surface and gluing the workpiece surface to the holding surface.

[0031] It is preferred that data relating to the measured crystal orientation of said single-crystal workpiece with respect to said workpiece surface are fed to a programmable forming machine before forming said holding surface on said holding means. This allows an easy and automatical machining of the holding surfaces.

[0032] The single-crystal workpiece may be an ingot, a boule, a pre-grinded or pre-cut single crystal, a core with cylindrical shape or a single-crystal specimen of any other shape and geometry.

[0033] It is of course possible to fix not only one but multiple cores to one holding means. The cores are selected, their crystal orientation is defined, the off-plane orientation and tilt is determined, and their geometrical parameters are measured (in the case of a cylinder in length and in diameter). The core data and orientation corrections are programmed into a milling machine. Pockets for each core are milled into the holding means with the desired offset and tilt. Finally, the cores are glued into the pockets which are defined by the holding surfaces.

[0034] The slicing is then done in the correct offset and tilt. The assembly of the workpieces glued on the holding means can be positioned manually, semiautomatically or automatically in a machine tool such as a wire saw, a milling, drilling or grinding device, etc..

[0035] In order to define a volume for the glue between the core and the holding surface, at least one recession may be formed in the holding surface adjacent to the workpiece surface. This can be done by forming protrusions on the holding surface or by forming depressions in the holding surface. In either way, the amount of glue applied to the holding surface can be exactly dosed to fill this volume. By this the workpiece lies against the protrusions without glue as intermediate layer. This makes the positioning even more precise, since no positioning error is introduced by the glue. Channels in the holding surface may be provided to let the glue escape if more glue is applied than there is space for in the volume between the protrusions.

[0036] The holding means may be mounted directly in the machine tool, such as a wire saw. Alternatively, the holding means can be glued to an additional mounting support, e.g. a mounting plate (also called carrier plate). Since the cutting wires do not cut the mounting support (and the mounting support has not to be machined for each workpiece individually), this support can be made of more robust materials, such as steel. An additional intermediate plate between the holding means and the mounting support may be used to adjust for a special mounting support. An intermediate plate is not necessary and is usually used only if the mounting support is heavy or expensive or in order to have a simpler gluing plate. This intermediate plate may then be screwed to the mounting support.

[0037] Multiple cores can be glued to one plate. Since all the cores do not have the same mismatch, multiple holding surfaces may be used.

[0038] Further embodiments of the invention are indicated in the figures and in the dependent claims.

[0039] The list of reference marks forms part of the disclosure.

[0040] The invention will now be explained in detail by the drawings. In the drawings:

Fig. 1 shows a single-crystal ingot with cores taken from it by means of a hollow drill.
Fig. 2 shows a single-crystal core,
Fig. 3 shows the A- and M-planes of the sapphire-crystal structure,
Fig. 4 shows the C- and R-planes of the sapphire-crystal structure,
Fig. 5 shows a wire cutting device with a workpiece mounted on a holding means,
Fig. 6 shows an inventive holding means with two holding surfaces,
Fig. 7 shows an inventive holding means with three workpieces mounted thereon,
Fig. 8 shows schematically an x-ray diffraction device with a workpiece,
Fig. 9 shows a forming machine for forming the holding surface,
Fig. 10, 11 and 12 show, in a cross-sectional view, the workpiece glued on the holding means, and
Fig. 13 and 14 show a workpiece glued on the holding means with indicated cutting planes.

[0041] In the following, the invention will be described in relation to a sapphire workpiece, but the ideas can be applied to any other crystals as well (such as e.g. containing Bor or Silicon).

[0042] Fig. 1 shows a sapphire ingot or boule 15 as being pulled out of the melt. During pulling out, the ingot is slowly rotated. This process is also known as Czochralski process. Normally however, the Kyropulous process is used, where a cold rod is immersed into the melt and the crystalization process starts at the end of the rod, while the melt surrounding the rod slowly cools down.

[0043] The 3-dimensional outer surface of the ingot is modeled, and the crystal orientation is measured with respect to the outer surface. Once the crystal orientation and the 3D model of the outer surface of the boule has been made, cores are drilled out from the boule with a hollow drill. Fig. 1 shows the resulting holes in the ingot 15. The direction of drilling is chosen with respect to the crystal orientation of the ingot 15, in order to obtain cylinders with their geometrical axis matching a certain crystal axis. Unfortunately, in most cases there is a deviation of the crystal axis from the mechanical axis of the core and the orientation of the crystal axis normally does not lie within the required tolerances.

[0044] Fig. 2 shows a single-crystal workpiece 1 of cylindrical shape as being drilled out of the ingot 15. A workpiece surface 5 is indicated for being glued on the holding means.

[0045] Fig. 3 and Fig. 4 show without the atomic arrangement the crystal structure of sapphire. In Fig. 3 the so-called A- and M-planes and the A- and M-axis, which run perpendicular to the respective planes, are indicated. Fig. 4 shows the C- and R-planes as well as the corresponding C- and R-axis of the crystal structure. It was found that the cut is ideally made in an offset angle of 0°to 0,35° to the M-plane and 0°to 0,2° to the A-plane of the sapphire crystal.

[0046] However, any other desired direction (including off-plane directions) may be exactly adjusted by the inventive method. Depending on the type of crystal and its application, appropriate cutting planes (and their exact deviation from the crystal planes) may be chosen.

[0047] Fig. 5 shows a wire cutting device 6 for cutting the single-crystal workpiece 1. The workpiece 1 is glued on a holding means 2 which is mounted to the cutting device 6. A multiple wire arrangement 11 is operated to cut the workpiece. Usually the workpiece 1 is arranged below the holding means 2, and the wires 11 are guided from the bottom to the top of the workpiece 1.

[0048] Fig. 6 shows a plate-like holding means 2 comprising a mounting surface 4 for mounting the holding means 2 on a processing device 6, e.g. the wire cutting device of Fig. 5. On the opposite side, the holding means 2 has holding surfaces 3 for receiving two single-crystal workpieces 1. The holding surfaces 3 fittingly match with the respective workpiece surface 5 to be glued to it.

[0049] The holding means 2 can be made of any material, preferably a material that can be machined easily such as plastic, and preferably fiber reinforced plastic.

[0050] For each workpiece 1, a holding surface 3 is individually formed in dependence of the crystal orientation of the workpiece 1 with respect to its workpiece surface 5, which is glued to the holding surface 3. The holding surface 3 receives that workpiece 1 and thus ascertains the crystal orientation of the workpiece 1 with respect to the mounting surface 4 of the holding means 2. When the workpiece 1 is placed in the holding surface 3, the workpiece surface 5 abuts against the holding surface 3, thus defining an exact orientation.

[0051] As can be seen from Fig. 6, the two holding surfaces 3 have different orientation with respect to the mounting surface 4. This accounts for two different workpieces 1, having different mismatch between crystal and mechanical orientation. The dashed lines in Fig. 6 denote to the bottom lines of the holding surfaces 3.

[0052] The invention is described here in relation to cylindrical workpieces. However, the inventive idea may apply to any workpiece shape, especially rectangular shapes, such as with Silicon bricks.

[0053] Fig. 7 shows a holding means 2 with three different workpieces 1 mounted on it. The crystal orientation with respect to the mechanical axis is different for each workpiece 1, as can be seen by the dashed top lines of the cores. Correspondingly, the holding surfaces 3 formed in the holding means 2 have different shape and orientation. However, the crystal orientation of all workpieces 1 with respect to the reference surface 4 is the same as indicated by the dashed line and the arrows lying on that dashed line.

[0054] The mounting surface 4 is fixed to a mounting support 12, e.g. a mounting plate, for mounting the assembly within a processing device 6 (Fig. 5). It would be also possible that the mounting surface 4 of the holding means 2 is directly mounted to the processing device 6. It is not necessary that the mounting surface 4 is flat as in Fig. 6. Embodiments having mounting surfaces of any other shape may be used. Also multiple mounting surfaces are possible. The mounting surface 4 may be e.g. comprised of mounting notches or any other means for being (directly or indirectly) attached to the machine tool.

[0055] The holding means 2 is usually glued to the mounting plate 12. The glue used is typically a two-component epoxy resin which loses its adhesive power when heated to a temperature above 70 degrees C. After the cutting step, the mounting support 12 with the holding means 2 is placed in hot water to demount the holding means 2. The mounting support 12 can be reused.

[0056] In the following, the method for positioning and fixing the workpiece 1 on a holding means 2 is described in detail. Fig. 8 shows the step of measuring the crystal orientation of the workpiece 1 with respect to its outer surface by means of X-ray diffraction. An X-ray source 13 directs an X-ray beam to the workpiece 1. The diffracted beam is measured with a detector 14. The obtained data allow the determination of the crystal orientation.

[0057] In a next step, a holding surface 3 is formed on the holding means 2 in dependence of the crystal orientation of said single-crystal workpiece 1 with respect to its workpiece surface 5. In the embodiment of Fig. 9, this step is performed by means of a programmable processing machine 9, preferably a milling machine. The data relating to the crystal and mechanical orientation and shape of the workpiece 1 are fed into the forming machine 9 before the forming step. A 3-dimensional holding surface 3 is modeled from that data and transferred to the raw material of the holding means 2. As indicated by the 3-dimensional coordinate system of Fig. 9, the drill of the milling machine 9 is movable in all three spatial directions. During the forming step, a 3-dimensional gluing mould results from a raw holding plate 2 (see Fig. 6).

[0058] When the holding surface 3 (or multiple holding surfaces 3) is (are) completed on the holding means 2, the workpieces 1 are glued with their workpiece surface 5 to the respective holding surface 3. The workpiece 1 is uniformly pressed against the holding surface 3 which is covered with glue. The shape and orientation of the holding surface 3 defines the crystal orientation of the individual workpiece 1 with respect to the reference surface 4.

[0059] During curing of the glue, the workpieces 1 may be pressed onto the holding means 2.

[0060] Fig. 10 shows, in a cross-sectional view, a preferred embodiment with the workpiece 1 being glued to the holding means 2 by means of a glue 16. Preferably, an epoxy glue, e.g. a two-component epoxy resin, is used, however, any other type of glue may be also used. The holding surface 3 has recessions for receiving glue. In the embodiment of Fig. 10 the holding surface 3 is formed with multiple protrusions 7 extending towards the workpiece surface 5, in parallel to the surface 3. The protrusions 7 contact the workpiece surface 5 and the glue 16 is distributed in the space (recessions) between that protrusions 7. Such an embodiment allows an exact positioning of the workpiece 1, since the contact sites formed by the protrusions 7 exactly define the resulting crystal orientation of the workpiece 1. Deviations due to glue thickness and or shrinkage of the glue when curing may be avoided in such an embodiment.

[0061] Fig. 11 shows another preferred embodiment with the holding surface 3 comprising at least one channel 8. Excessive glue 16 may escape through the channel 8.

[0062] Fig. 12 shows an embodiment with a part of the workpiece surface 5 having flat shape. As already mentioned above, any shape of the workpiece surface is possible. The forming of the holding surface 3 is performed in dependence of the respective abutting workpiece surface 5.

[0063] Fig. 13 and 14 show an assembly of a workpiece 1, glued on a holding means 2. The dashed and dotted lines indicate future cutting planes when mounted in a wire saw.

[0064] In the following, a method of optimization of the pitch of the cutting wires is described. The spacing between the workpieces 1 on a holding means 2 may be optimized towards the wire pitch. Meaning that if no attention is paid to the spacing, the wire cutting of the first and last wafer of a workpiece may not reveal a usable wafer (see Fig. 13). In Fig. 14 the cuts along the dashed lines results in five proper wafers. Cuts along the dotted lines result in six proper wafers.

[0065] Clearly, the position of a second core can be optimized in the same manner.

[0066] Fixation in lateral direction: In order to obtain the advantage described above, the core needs to be fixated in the lateral direction (from left to right in the above drawings). This may be done by forming a stop 10 e.g. defining a surface (see arrow) where the core abuts against.

[0067] Other stop means 10 for fixing the core in lateral direction may be provided as well: a clamp, rubber bands, glue that hardens (melt glue) or cures (instant glue, hard plaster) very rapidly, etc.

[0068] A method of correction of wire saw imperfections may be applied as well. Any error in the cutting properties of the wire saw can be measured and corrected. In an initial measurement, the exact orientation of the cutting plane can be determined and the deviation from the theoretical plane can be used to align the cores perfectly with the true cutting plane.

[0069] If the core has a rotational symmetry (which is usually the case), a flat (see Fig. 12) or notch (indentation parallel to the mechanical axis of the core) may be provided on the core. The holding surface may be made such as to receive this flat or notch and thus determine the orientation of the core.

[0070] The invention is not restricted to the embodiments described above. In particular, the application area is not limited to sapphire crystals. The invention may be applied to any other type of crystal to be processed (cutting, milling, drilling, grinding, etc.). Among them are various semiconductor crystals, silicon crystals for electronic devices or solar cell applications, etc..

[0071] It is clear that the inventive method and holding means can be used for all kind of machines such as drills, polishing machines, grinders, etc.

This invention and the following claims cover also a method and a holding means (2) wherein the holding means (2) is not formed/machined after the measurement of the crystal orientation of the workpiece (1) but wherein a set of different holding means are provided in order to allow a user to select the right holding means (2) with an individual holding surface (3) for an individual workpiece (1).

[0072] Such a holding means (2) could be made from prefabricated plastic material.

[0073] The Invention covers also semi finished holding means (2) which have a soft upper part which hardens out after a press form cylinder pressed the required form into said part, wherein said cylinder has the shape of a crystal work piece (1) and wherein the orientation of the cylinder when being pressed into the soft upper part is (eventually automatically) controlled in dependence from the crystal orientation of the workpiece (1).

List of reference marks

[0074]

1 - single-crystal workpiece

2 - holding means

3 - holding surface

4 - mounting surface

5 - workpiece surface

6 - processing device

7 - protrusion

8 - channel

9 - forming machine

10 - stop

11 - sawing wire of a cutting device

12 - mounting plate

13 - X-ray tube

14 - detector

15 - ingot

16 - glue

Claims

1. Method for fixing a single-crystal workpiece (1) on a holding means (2), the holding means (2) comprising a mounting surface (4) for mounting the holding means (2) in a defined orientation on a processing device (6);
wherein the method comprising the steps of:

- measuring the crystal orientation of said single-crystal workpiece (1) with respect to a workpiece surface (5) of said workpiece (1),
- in dependence of the individual crystal orientation of said single-crystal workpiece (1) with respect to said workpiece surface (5), forming on the holding means (2) a holding surface (3) for abuttingly receiving said workpiece surface (5), thereby defining the crystal orientation of the single-crystal workpiece (1) with respect to the mounting surface (4) of the holding means (2), and
- gluing said workpiece surface (5) to said holding surface (3).

2. The method according to claim 1, **wherein** the step of forming said holding surface (3) is done by a programmable forming machine (9), preferably a milling machine.

3. The method according to claim 2, **wherein** data relating to the measured crystal orientation of said single-crystal workpiece (1) with respect to said workpiece surface (5) are fed to the programmable forming machine (9) before forming said holding surface (3) on said holding means (2).

4. The method according to any of the preceding claims, **wherein** at least one recession is formed in said holding surface (3) for receiving glue.

5. The method according to any of the preceding claims, **wherein** at least one channel (8) is formed in said holding surface (3) for draining excessive glue.

6. The method according to any of the preceding claims, **wherein** said holding surface (3) has a stop (10) for positioning the single-crystal workpiece (1) on the holding means (2).

7. The method according to any of the preceding claims, **wherein** the holding means (2) is formed by a plate.

8. The method according to any of the preceding claims, **wherein** the single-crystal workpiece (1) has a cylindrical shape and wherein the holding surface (3) is formed to receive the lateral surface of the single-crystal workpiece (1).

9. The method according any of the preceding claims, **wherein** the single-crystal workpiece (1) is a sapphire.

10. The method according to any of the preceding claims,
wherein multiple single-crystal workpieces (1) are fixed on a holding means (2) and the crystal orientation of each single-crystal workpiece (1) is measured with respect to one of its workpiece surfaces (5), and comprising the steps of:

- forming for each single-crystal workpiece (1), in dependence of its crystal orientation with respect to its workpiece surface (5), on the holding means (2) a separate holding surface (3) for abuttingly receiving the respective workpiece surface (5), thereby defining for all single-crystal workpieces (1) the same crystal orientation with respect to the mounting surface (4) of the holding means (2), and
- gluing the workpiece surface (5) of each single-crystal workpiece (1) to the respective holding surface (3).

11. Method for cutting a single-crystal workpiece (1) into slices, **wherein** the method comprises the steps of any of the preceding claims and the steps of:

- mounting the holding means (2) with the singe-crystal workpiece (1) in a saw, and
- sawing the single-crystal workpiece (1).

12. Holding means (2) for fixing a single-crystal workpiece (1), the holding means (2) comprising:

- a mounting surface (4) for mounting the holding means (2) in a defined orientation on a process-

ing device (6),
- a holding surface (3) for abuttingly receiving a workpiece surface (5) of the single-crystal workpiece (1) to be glued on the holding surface (3), wherein said holding surface (3) is individually formed in dependence of the crystal orientation of said single-crystal workpiece (1) with respect to said workpiece surface (5), thereby defining the crystal orientation of the single-crystal workpiece (1) with respect to the mounting surface (4) of the holding means (2).

13. The holding means according to claim 12, **wherein** at least a recession is formed in said holding surface (3) for receiving glue and/or, **wherein** at least one channel (8) is formed in said holding surface (3) for draining excessive glue.

14. The holding means according to any of the claims 12 to 13, **wherein** said holding surface (3) has a stop (10) for positioning the single-crystal workpiece (1) on the holding means (2).

15. Set of a number of holding means (2) according to claim 12 with different oriented holding surfaces (3) for selection of an appropriate holding means (2) to be used in a method of claim 1.

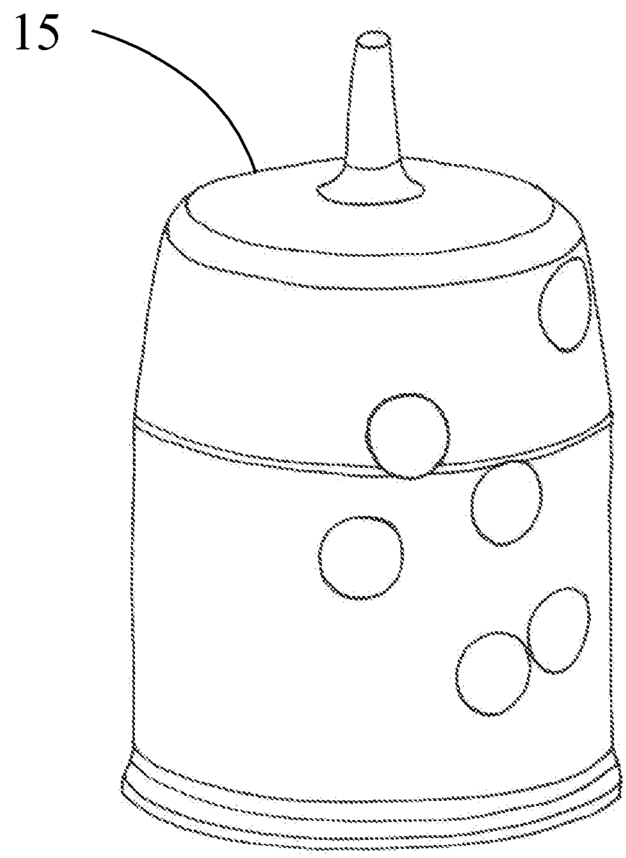

Fig. 1

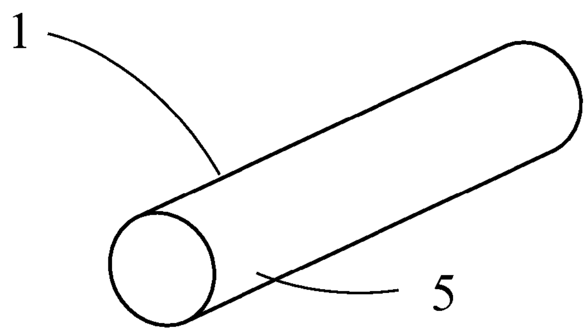

Fig. 2

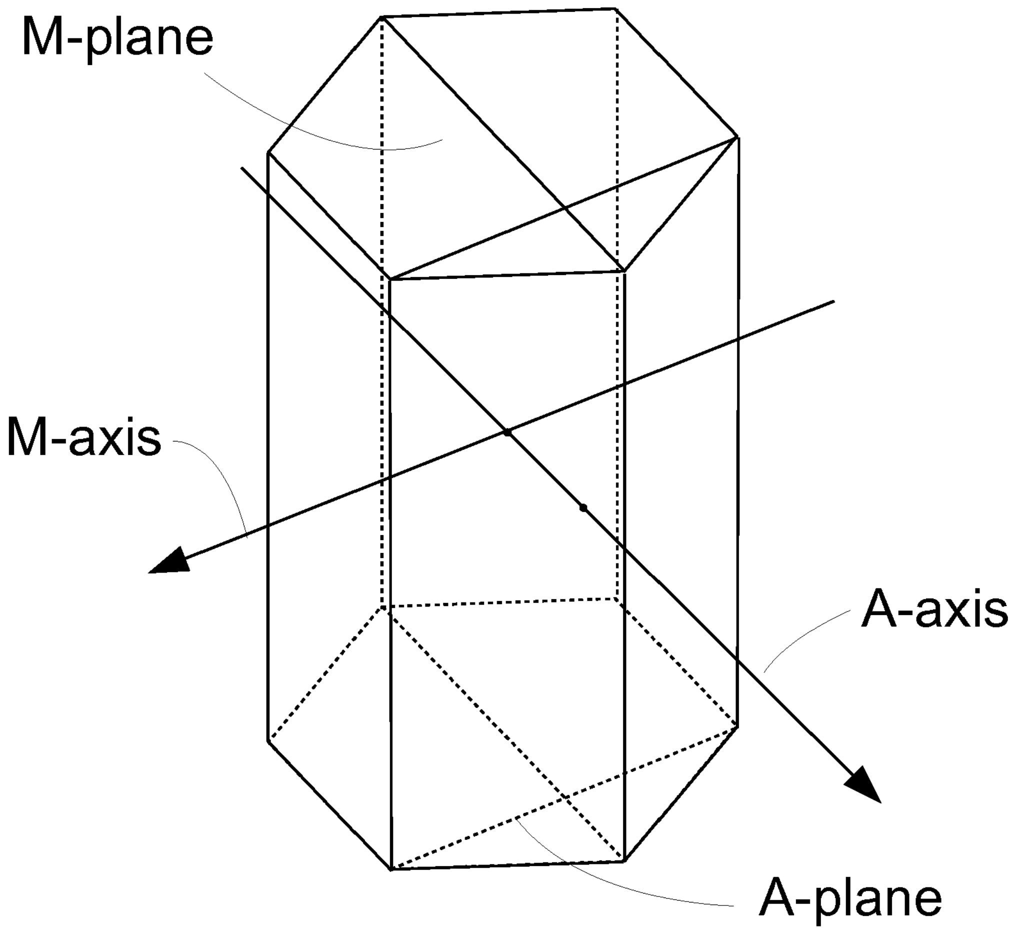

Fig. 3

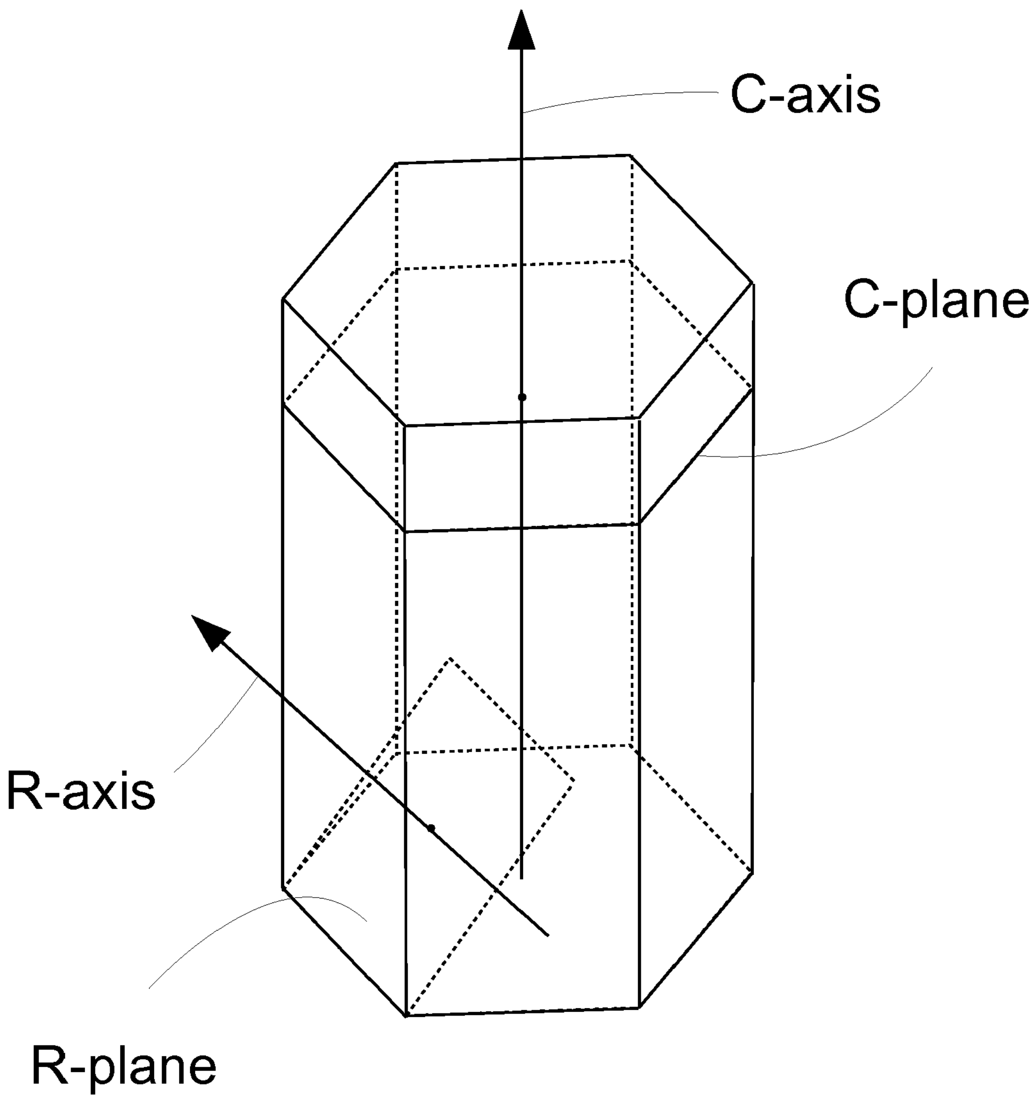

Fig. 4

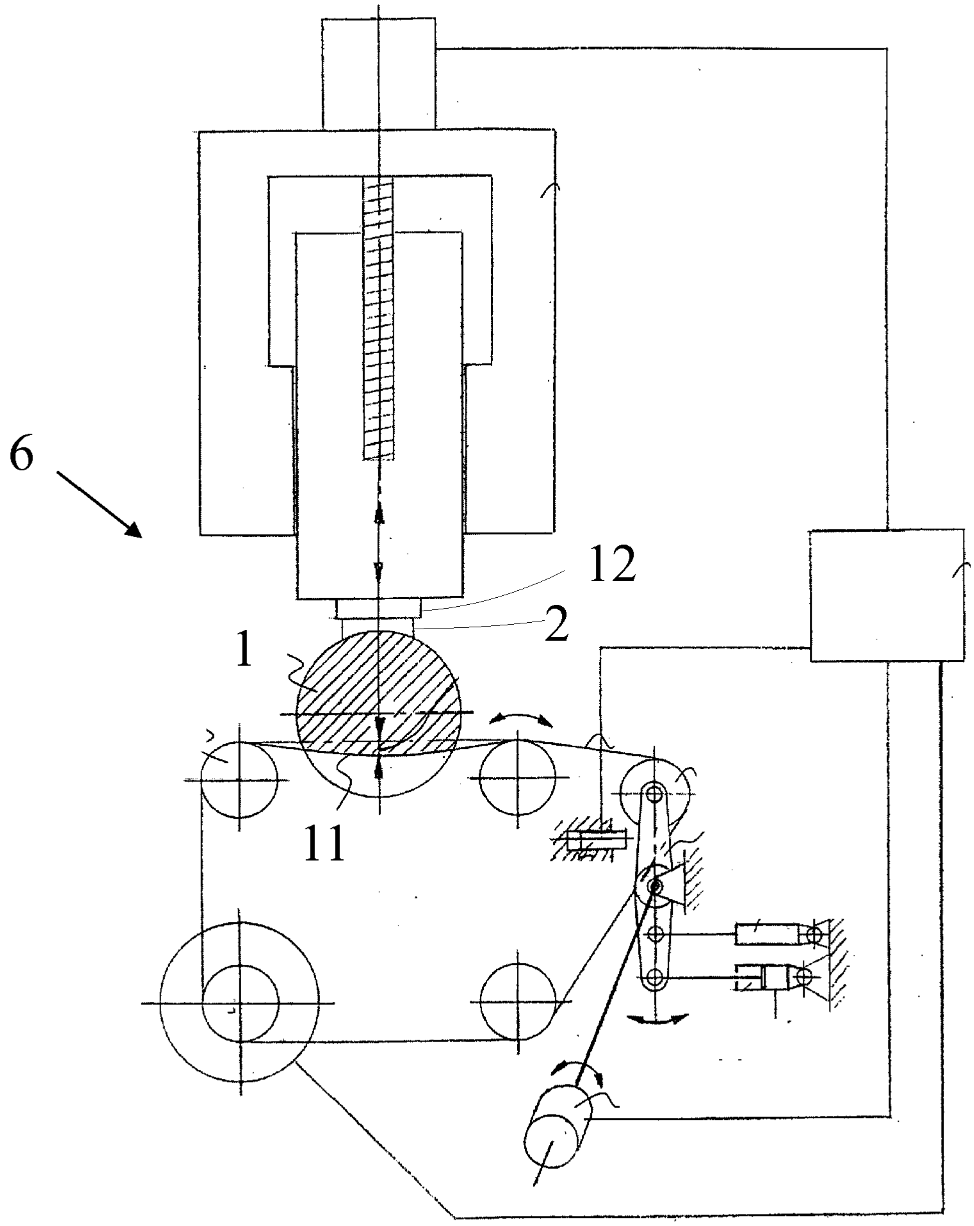

Fig. 5

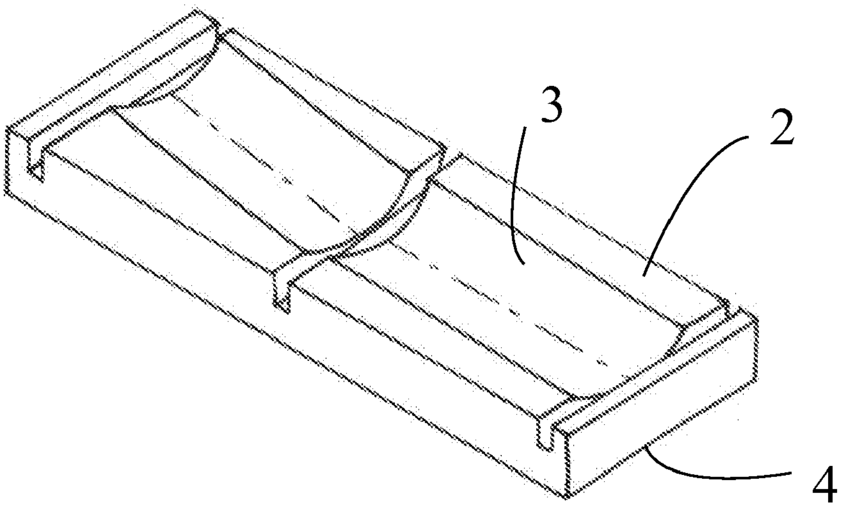

Fig. 6

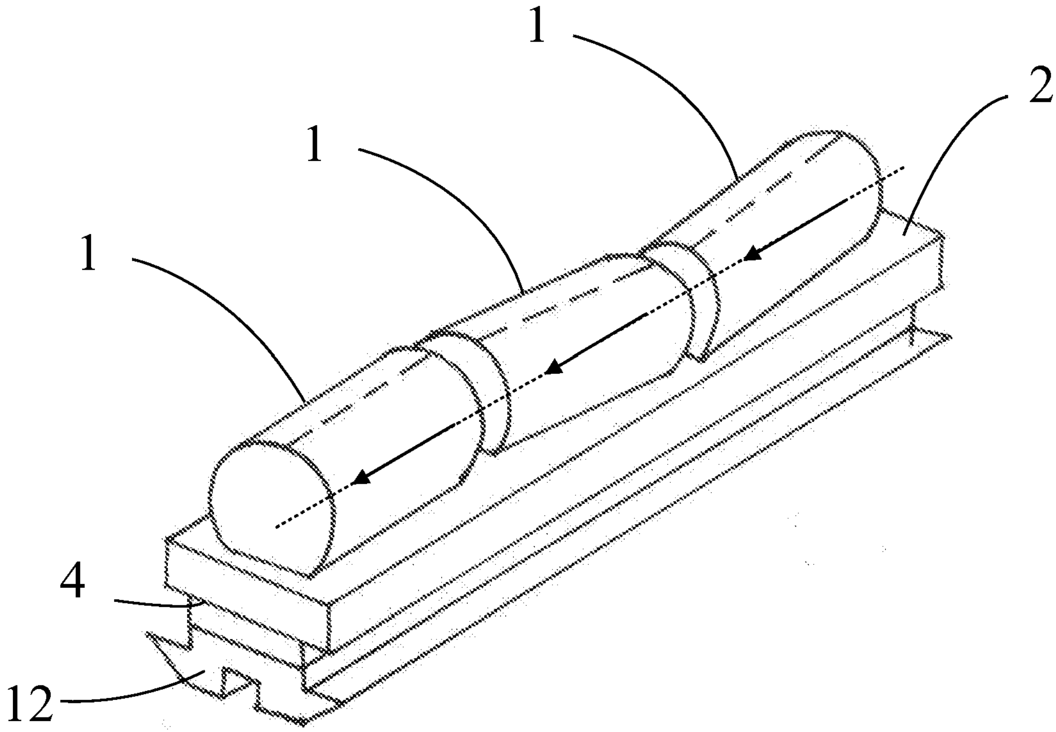

Fig. 7

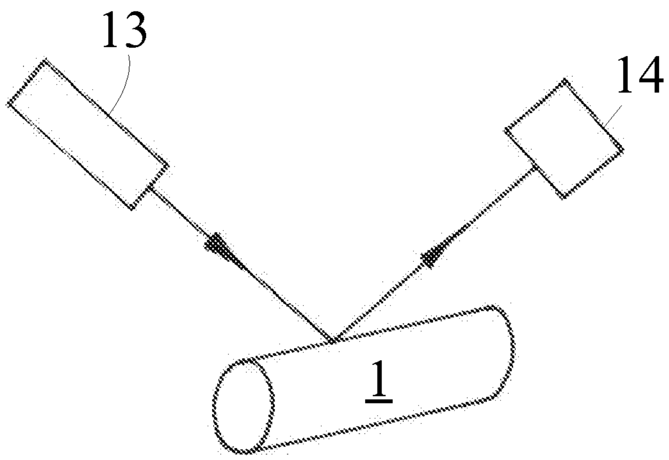

Fig. 8

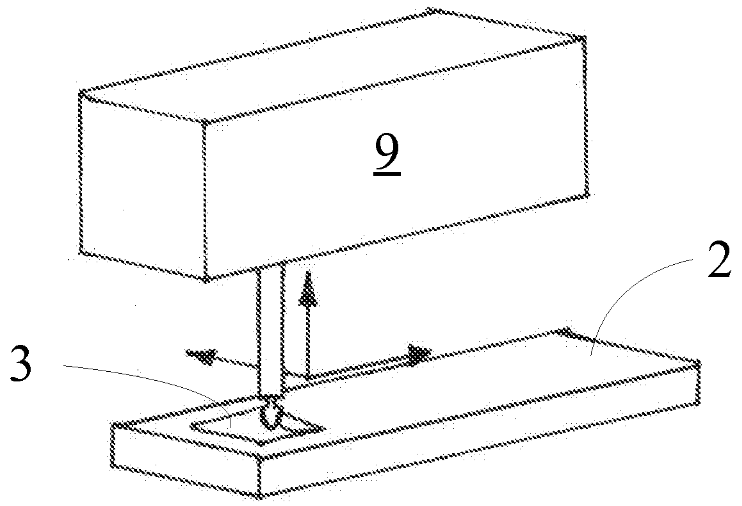

Fig. 9

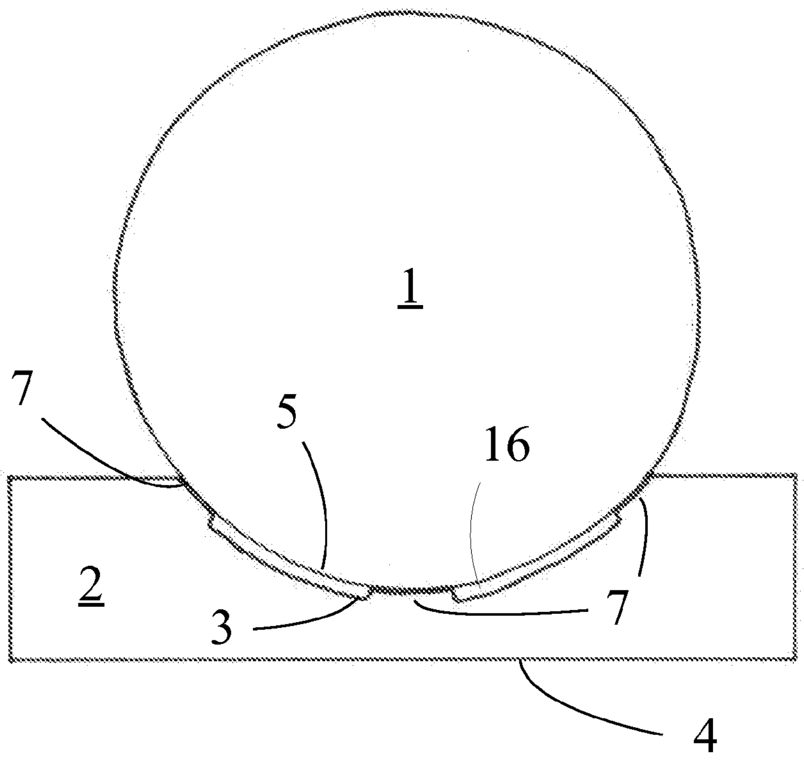

Fig. 10

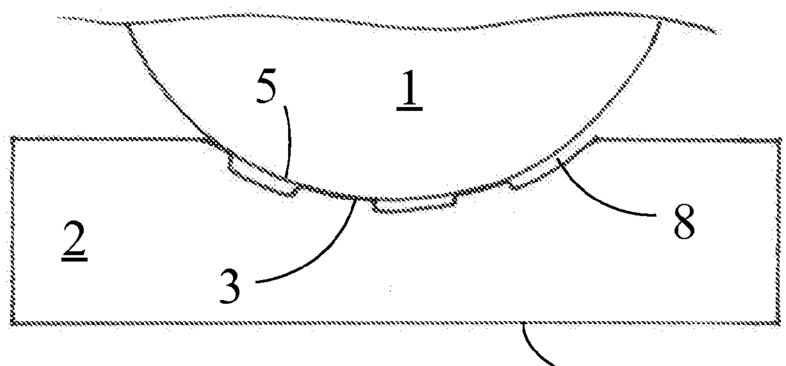

Fig. 11

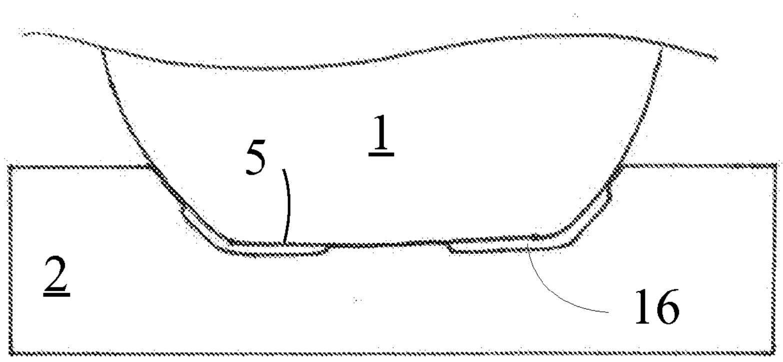

Fig. 12

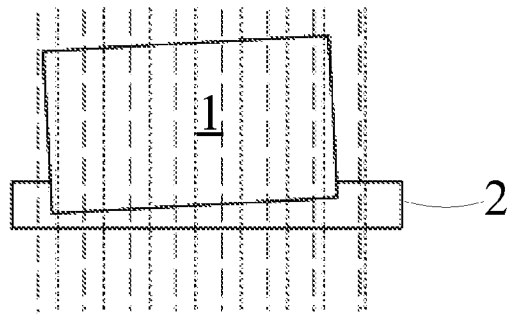

Fig. 13

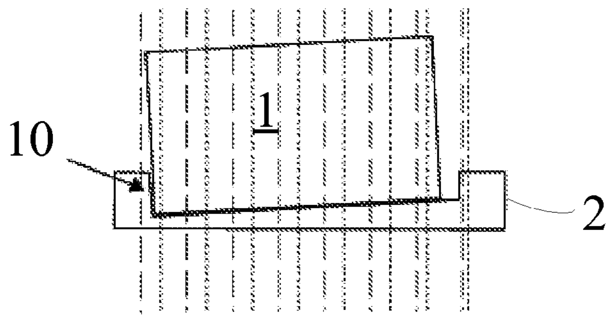

Fig. 14

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EUROPEAN SEARCH REPORT

Application Number
EP 11 16 5009

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A	WO 2009/028756 A1 (DOW BEAM CO LTD [KR]; KIM KYUNG-JOONG [KR]) 5 March 2009 (2009-03-05) * paragraphs [0011], [0057]; figures *	1-15	
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	13 October 2011	Popma, Ronald

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The Hague	13 October 2011	Popma, Ronald

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