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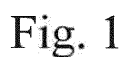
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(54) **Sacrificial substrate for use in wafer cutting**

(57) The invention relates to a sacrificial substrate (1) having a mounting surface (2) for holding a piece of material (3), such as an ingot, brick or core, for cutting a plurality of wafers from the piece of material (3), wherein the sacrificial substrate (1) has an E-modulus smaller than 6000 MPa, more preferably smaller than 5000 MPa, most preferably smaller than 4000 MPa.

The invention also relates to a method of making a plurality of wafers of a piece of material (3), such as an ingot, brick or core, comprising the steps of: mounting the piece of material (3) to a sacrificial substrate (1), preferably by gluing; mounting the sacrificial substrate (1) with the piece of material (3) in a cutting device; and cutting the piece of material (3) into a plurality of wafers.



Description

[0001] This invention relates to a sacrificial substrate (also named 'beam') for use in the cutting of bricks or wafers from a brick or ingot (photovoltaics/semiconductor industry) or a core (photonics).

[0002] In the following, the wafer cutting process according to prior art is described. A sawing device for cutting wafers has a wire web formed between at least two wire guiding rolls. A piece of material (ingot, brick or core) is lowered into the wire web, while the wire is cycling in a reciprocating motion and as such performing its sawing action, thereby the piece of material is cut into wafers. The same method is used for cutting bricks from an ingot. Here the number of wires is lower and the wire extend between multiple pulleys. The inventive sacrificial plate may be used for such wire saws (called bricking or cropping machines, or "Brick Master" at Meyer Burger) as well. The term wire saw is used here for any type of wire saw, bricks can have any shape. The cutting of bricks is e.g. disclosed in WO 2010/128011 A1, the disclosure of which is entirely included into the present specification by reference.

[0003] A Polycrystalline ingot is cut into bricks: For squaring (round) mono crystalline ingots are placed on a holder. Now a wire field like shown in Fig. 3 of WO 2010/128011 A1 cuts from above to make the cross section of the round ingot more or less square or any other desired form. Also the ingot is cut in the pieces so that the bricks get the desired length. For cropping the tapered ends of monocrystalline silicon ingots are removed.

[0004] Nowadays, wafers for semiconductor applications, solar cells or LEDs, are cut more and more using fixed abrasives. Cutting methods using abrasives that are suspended in a slurry and transported by a metal wire to make a cut, become rare. In the fixed abrasive method the abrasives are directly attached to the metal wire. Such a wire may be a diamond wire.

[0005] These sawing technologies are used in the industry of semiconductors, electronic components, photovoltaics and photonics. Typical materials sawn are GaAs, germanium, polycrystalline or monocrystalline or mono-like silicon, InP, quartzes, sapphire, or other ceramic materials.

[0006] When cutting a piece of material, such as a brick, ingot or core, it is attached to a sacrificial plate. The sacrificial plate in turn is attached to a fixture attachment usually made of metal. The fixture attachment is used to mount the assembly to the mounting of the sawing machine.

[0007] In the following, the function of the sacrificial substrate is described in detail. As the wire guide rolls turn, the brick is pushed through the wire field, making the sawing wire bend downwards. With increasing cutting depth the sawing wire develops to a so called "bow". Because of this bow, the (top) edges of the piece of material are cut before the middle part of the brick is completely cut thru. It is the purpose of the sacrificial substrate to keep the fixture attachment at a distance to the piece of material so that it is not cut (and thus damaged). The sacrificial substrate is thus a disposable part. Once the wafers have been cut, the fixture attachment, sacrificial substrate and the wafers are removed from the sawing machine. In the next process step, the individual wafers, which hang like a comb from the mounting assembly will be separated from the sacrificial substrate and the assembly system. The term "fins" is used to describe the structures formed in the sacrificial substrate (or "beam") when the sawing wire has partially sawn the substrate. A fin has today approximately the same thickness as the sawn wafers.

[0008] The sacrificial substrate may have various shapes according to the shape of the piece of material. Ingots, bricks or cores can have various shapes and sizes. E.g. the sacrificial substrate can have rectangular shape or a curved shape on one side for receiving a cylindrical core and a flat shape on the other side. For sapphire both types of shapes occur. For semiconductors the beam is mostly arc shaped on one side; for photovoltaic applications the sacrificial substrate is mostly rectangular.

[0009] Glycol versus water-based wafering process: A cutting fluid is used during the sawing process. The cutting fluid has at least a cooling and lubricating function. As cutting fluids for wafering with diamond wire two major systems are considered: a purely water-based cutting fluid containing water and additives, for example Synergy DWS500 (supplied by Diamond Wire Materials Technology, US) or a cutting fluid containing organic fluids besides water, mostly glycol based cutting fluids are known, for example Yumark® (supplied by Yushiro Manufacturing America Inc., US). The present invention relates to both, the water-based and glycol based process, and any other process. In particular, the water-based process is more demanding for the sacrificial substrate properties, mainly related to swelling and deformation.

[0010] Continuous wafering process (production like), sometimes also called back to back wafering: In comparison to the wire used in the wafering process with slurry, where typical 400 km of sawing wire is consumed in one cut, a limited length of sawing wire is used during a cut in the wafering process using diamond wire, typically 1-10 km. The diamond wire has a longer lifetime than a regular slurry wire and as such a smaller length of wire is used. However, the process is a pilgrim process whereby a part of the diamond wire web is moved towards a take-up spool in a cut, but also a major part of the wire used in this cut is still on the wire web and as such will also be used in the consecutive cut. As a consequence, to function properly, the cutting power of a diamond wire should not be adversely affected by the sacrificial substrate. Otherwise this will affect the cutting performance of the sawing wire in consecutive cuts.

[0011] This contrasts to a so called single cut, where the wire is only used in one cut and the remaining used portion of the wire in the web is renewed before the next ingot, brick or core is sawn. It is evident that the amount of wire

consumed in a series of consecutive single cuts is much higher than in a series of continuous back to back cuts. The latter process will be much more cost effective since the process can be optimized for the diamond wire lifetime.

[0012] Additional terminology is presented in the following: The wire web is supported by wire guiding rolls. Usually the rolls are coated with polyurethane having a groove profile for receiving the wire. The diamond wire is webbed over the wire guiding rolls in those grooves. The pitch of the grooves (i.e. distance over which the groove pattern repeats itself) together with the wire diameter that is used, will determine the thickness of the sawn wafers.

[0013] Wire jumps and wire pairing are drawbacks related to the repetitive wire web pattern and both will cause thickness deviation from the desired wafer thickness. When two wires stick together in the web, this is called wire pairing. When a wire is not lying in its groove, this is called a wire jump.

[0014] The total thickness variation (abbreviated with TTV) is the difference between the minimum and maximum thickness of a wafer. It is used as a measure for the quality of the cut.

[0015] Edge defects can be damaged edges, broken corners of wafers or an irregular edge. A chip is a shell shaped edge defect on only one side of the wafer. Micro cracks is another important defect that can be the result of improper cutting or the use of improper beams.

[0016] The costs of the process of fixed abrasive wafering can be reduced considerably if the fixed abrasive wire can be continuously used in consecutive cuts, even though part of the wire web was already used in a previous cut on condition that the remaining sawing capability of that used wire hasn't deteriorated too much. The sawing capability can be measured by the wire deflection in the cutting process (determining the shape or "bow" of the wire during cutting). Wire that has lost its sawing potential will deflect more (and have a higher or more pronounced bow) than new, unused wire.

[0017] At the end of the slicing process, to create wafers the sacrificial substrate is cut partially until all wafers are fully sliced, compensating for the wire bow caused by the sawing procedure. This sacrificial substrate should be as inexpensive as possible and should have no impact on the slicing quality of the wafers.

[0018] Prior art sacrificial substrates interact with the wire and the process in such a way that the wire deflection in the subsequent cut is at a much higher level than at the end of the first cut. As a result, the quality of the wafers obtained from the subsequent cut is lower than when no interaction with the sacrificial substrate was there. Accordingly the yield will be lower since more wafers will be out of specification. There is also an increased risk for wire fractures because the wire is exhausted more rapidly.

[0019] In the following, sacrificial substrates according to prior art are described. The current sacrificial substrate used in wafering with slurry is predominantly made of glass. It has the advantage that it is inexpensive. It also does not absorb moisture and has a comparable thermal coefficient as silicon and sapphire and is geometrically and thermally stable within the typical conditions observed in the wafering process. However, it has the disadvantage that it is detrimental to the quality of diamond wire. When the diamond wire starts cutting into the glass plate, the sawing wire is incapable of removing the created glass shards from the sawing channel (i.e. the channel created in the material being cut). As a result, the cutting quality of the sawing wire is impaired and the forces exerted on the sawing wire will increase if the movement of the work piece thru the web is not reduced.

[0020] Alternative sacrificial substrates available on the market are made from synthetic material, such as thermoplasts, thermosets or composites, mostly epoxy resin based materials filled with a diversity of fillers have been used so far.

[0021] One sacrificial substrate currently available is DMT111GB (supplied by Diamond Wire Materials Technology, US); a phenol-resin based substrate that is rather cheap compared to most other composite solutions and gives good results in glycol based sawing processes. The disadvantage of this beam is that it takes up moisture and swells in uncontrolled manner in the water-based wafering process, resulting in wafers falling down from the sacrificial mounting plate and/or are damaged.

[0022] Another alternative, Valtron® 190 Clean Beam (supplied by Valtech Corp, US), a mineral filled thermoset plastic material, has the advantage that it is geometrically stable, resulting in straight, undeformed fins (part of the cut sacrificial plate between two neighboring cutting wires). However, the interaction of the substrate material with the diamond wire results in a seriously deteriorated sawing performance of the diamond wire in subsequent cuts. Therefore, in the subsequent cut, more new wire will be consumed. As a result, the costs of the process increases.

[0023] EP 2 111 960 A1 discloses a mounting plate with hollow tubes as alternative to standard glass and more expensive polymer plates, but this is made of ceramic material, that is too hard for the diamond wire cutting process and results in early failure of the diamond wire.

[0024] The object of the invention is to overcome the problems arising in prior art solutions and to provide a cost-effective sacrificial substrate for wafer cutting that has no adverse effect on the sawing properties of the sawing wire, has no adverse effect on the cleanliness of the saw or wire guiding rolls, is cost effective, results in high quality wafers and high yield, does not damage the wafers and at the same time is compatible with both water based and glycol based cutting processes.

[0025] In contrast to prior art the inventive solution follows a completely different path. In the following the principle of the invention is discussed.

[0026] The general development trend with players in the field for sacrificial substrates is to move towards thermally,

geometrically and mechanically more stable materials. All solutions according to prior art try to provide materials that generate stiff, straight and stable fins in the sacrificial substrate during its use in the wafering process. Therefore, dense materials with very high E-moduli are used. This mechanical stability is believed to be a basic requirement in order to keep the wafers mechanically intact and keep a high yield in the wafering process.

[0027] The sacrificial substrate according to the invention is, however, characterized by a larger degree of geometrical deformability, combined with a low E-modulus so that the force on the wafers remains small and wafers are not damaged or even fall off.

[0028] The object of the invention is achieved with a sacrificial substrate having a mounting surface for holding a piece of material, such as an ingot, brick or core, for cutting a plurality of wafers from the piece of material, wherein the sacrificial substrate has a flexural modulus or E-Modulus according to ISO 178 smaller than 6000 MPa, more preferably smaller than 5000 MPa, most preferably smaller than 4000 MPa.

[0029] The use of a more flexible material as defined above has an advantageous effect on the quality of the produced wafers and the lifetime of sawing wires, as will be described in detail below.

[0030] The object is also achieved by a sacrificial substrate which is made from a porous material. The porosity of the material with open and/or closed cavities makes the sacrificial plate softer for the sawing wire. There is also less material (due to the cavities) to deposit on the sawing wire and wire guide rolls.

[0031] In an embodiment the sacrificial substrate has a porosity larger than 0,15 (or 15 %), more preferably larger than 0,30 (or 30 %), most preferably larger than 0,40 (or 40 %).

[0032] In an embodiment the porous material is a foam, preferably a polymer foam. This is a preferred embodiment, since it shows excellent performance and can be produced easily in a cost-effective manner. With foam any substance is meant that is formed by trapping many gaseous bubbles, more precisely, gaseous bubbles trapped in a solid. Foams may also be filled with a filler (= another solid) in order to alter or support certain functionalities of the beam such as for example the modulus, the thermal properties, etc.

[0033] The object is also achieved by a sacrificial substrate, wherein the sacrificial substrate is made from a polymer based material which has a water absorption smaller than 2%, more preferably smaller than 1.5%, most preferably smaller than 0.7%. The water absorption is a property of a material which corresponds to the capability of the material of absorbing water by diffusion. The water absorption of a material is determined under certain measurement conditions. The water content or absorption is related to the mass of the water absorbed in a material in relation to the mass of the material specimen. Water absorption is given in units of mg or in %. The measurement procedure and conditions are given in the DIN norm 53495. The water absorption according to the present application is related to the measurement conditions, where the material specimen is immersed in distilled water at 23°C during 24 hours.

[0034] The object is also achieved by a sacrificial substrate wherein the sacrificial substrate has a heat deflection temperature, which is larger than 50°C, more preferably larger than 60°C, preferably even higher than 70°C.

[0035] In an embodiment the sacrificial substrate is made from a duroplast material.

[0036] In an embodiment the sacrificial substrate is made of a foam, such as a polymer foam, a ceramic foam or a metal foam.

[0037] In an embodiment the sacrificial substrate is made of polyurethane.

[0038] In an embodiment the sacrificial substrate is made of foamed polyurethane, and wherein preferably the foamed polyurethane has a moisture absorption smaller than 0.7%.

[0039] The object is also achieved by method of making a plurality of wafers of a piece of material, such as an ingot, brick or core, comprising the steps of: mounting the piece of material to a sacrificial substrate, preferably by gluing; mounting the sacrificial substrate with the piece of material in a cutting device; and cutting the piece of material into a plurality of wafers, wherein the sacrificial substrate is a sacrificial substrate according to any of the embodiments described above.

[0040] In the following the advantages and principles of the invention are discussed in detail:

[0041] The sacrificial substrates according to the invention have the advantage that they don't deteriorate the cutting performance of the sawing wire (fixed abrasive wires, wires with the use of abrasive suspended in a slurry) and the consecutive cuts yield wafers with stable and in spec TTV's and saw marks. Note that also when cutting one beam, at the end of the cut the diamond wire is impaired. Since some cuts may have been completed already, the wire may pass thru the beam and in the next turn in the web still has to cut the work piece.

[0042] It is well known to people in the field that with the process of sawing, wafers tends to group together because of the capillary forces from the coolant.

[0043] The ideal situation, shown in figure 2, where the wafers are not suspected to capillary forces is actually not observed. In practice the wafers after being cut hang onto the fixture attachment and sacrificial substrate more like displayed in figure 9. Mainly due to capillary forces, a plurality of wafers will tend to cluster together. Figure 8 shows a typical picture of this.

[0044] This can result in rather large deflection of the wafers and will as a consequence stress the wafers, being a possible cause for microcracks and chips or even wafer loss.

[0045] Using finite element modeling, we have done further analysis to understand the magnitude of the deflection and stresses on a single wafer under certain force.

[0046] Therefore we modeled the system shown in figure 13: a completely sawn Si wafer with thickness t and length l , and width w ; hanging onto a beam by means of an adhesive. The beam being cut in to a certain depth, h .

[0047] At the end of the process, when the wire has also cut into the beam, the calculations learn us that for the same deflection, the stress on the wafers hanging onto a beam with lower E-modulus is less than when using a beam with higher E-modulus.

[0048] To describe this in some more detail 2 examples are explained. For these example, we took following values for the E-modulus of the Si wafer (159000MPa); wafer length l (156mm), wafer width w (156mm), wafer thickness t (0.180mm); adhesive thickness (0.300mm); adhesive strength (14MPa), height h into the beam (7mm).

[0049] In example 1, a beam according to prior art with a higher modulus is used (E-modulus of 12000MPa). A typical force F of 0.0342N is expected to work at the bottom of the wafer as shown in figure 12, resulting in a deflection of the wafer, Δd of 9.1mm and the resulting tension on the wafer at the interface with the glue σ is 10N/mm².

[0050] In example 2, a beam according to this invention with an E-modulus of 6000MPa is used. For the same force F of 0.0342N working in at the bottom of the wafer as in figure 14, the resulting deflection Δd is now 14.8mm resulting in the same tension on the wafer at the interface with the glue ($\sigma = 10\text{N/mm}^2$).

[0051] The force F of 0.0342N was obtained after a basic calculation using a finite elements model of the force required to deflect the distal end of a wafer of the mentioned dimensions over a distance Δd of 3.6mm side ways. The proximal end of the wafer was attached to a beam.

[0052] This is a basic example, in reality one might expect the created tensions and deflections to vary over a broader range. The conclusion of these calculations show however that the lower modulus materials will have advantages over the higher modulus variants because the beam will take up more of the deflection and as such reduces the stress on the wafer due to capillary forces.

[0053] We therefore suggest the use of materials with lower E-modulus. In further preferred embodiments showing enhanced positive effects one should look for materials for which the water absorption is relatively low as to avoid too much geometrical deformation of the fins causing too much shear stress on the wafers. It was found that a certain degree of geometrical deformation of the fins (created in the substrate by the sawing wire) is allowed as long as the deformation due to swelling is limited.

[0054] The sacrificial substrate may have an E-modulus smaller than 6000MPa (according to ISO 178); more preferably E-modulus smaller than 5000MPa; most preferably smaller than 4000MPa. The traditional substrate used in wafering with slurry, glass, has a typical modulus in the range of 50-90GPa. For glass reinforced plastics E-modulus values have been reported of $> 15\text{GPa}$; Ceramic substrates will typically have higher moduli e.g. calcite (CaCO_3 in the range 70-90GPa) and as such ceramic filled plastics usually tend to enhance the modulus of the matrix plastic material. Such reinforced epoxy plates with E-moduli above 10.000 MPa have been found in the field.

[0055] In order to avoid damage to the diamond wire, the invention suggests to use materials with a certain porosity while still allowing for sufficient geometrical stability of the substrate.

[0056] The invention provides the following advantages:

- Low cost substrate solutions compared to beams according to prior art (composites, ceramics, epoxy resin based materials with or without fillers).

- The inventive substrate allows for a maximum use of the diamond wire and as such allows to attain the lowest cost of ownership for the diamond wire wafering.

- Since the material of the sacrificial substrate is softer than in the state of the art, the diamond wire does not build up a bow in the sacrificial plate. This ensures that the cutting out process (say time needed for all wires to completely exit the work piece) in the saw is faster.

- The produced wafers are mechanically intact, resulting in low chipping and fewer micro cracks. Therefore high yields for the slicing of thin wafers can be obtained using the substrate according to the invention.

- The material can be shaped easily in the desired dimensions and shapes (for example for sapphire; to fit 2", 4", 6" cores), holes can be drilled, other shapes can be obtained easily due to the softness of the material.

- The substrate is light-weighted and thus easy to handle and transport.

- Substrates can be provided, which are compatible with water-based and/or glycol based cutting processes.

● Due to the fact, that the inventive sacrificial substrate is porous (softer) in comparison to prior art substrates (e.g. glass), the sawing wire goes into the sacrificial substrate more easily. Thereby the risk is reduced, that the sawing wire slides (or deflects) in lateral direction in the soft gluing layer, which is disposed between the sacrificial substrate and the piece of material. This positive effect allows to use more glue, which in turn reduces the transmission of forces between the sacrificial substrate and the wafers. Before the sawing wire is completely moved through the piece of material, it already cuts the edges of the sacrificial plate. Due to the deep penetration, the sawing wire gets an efficient guide in the substrate. Thus, the risk of a lateral movement of the sawing wire on the surface of the substrate is strongly reduced.

[0057] Another advantage of the invention is the following: Since the substrate relaxes the bow of the sawing wire (there is no bow in the substrate), the substrate doesn't have to be as thick as substrates according to prior art. Since less material will be used as a sacrificial substrate, this is much more economically and ecologically friendly.

[0058] Further embodiments of the invention are indicated in the figures and in the dependent claims. The list of reference marks forms part of the disclosure. The invention will now be explained in detail by the drawings. In the drawings:

Fig. 1 shows a part of wire sawing machine for cutting wafers from a work piece,

Fig. 2 shows schematically an ideal picture of a plurality of wafers held by the sacrificial substrate after the cutting process,

Fig. 3 shows a sacrificial substrate with a curved mounting surface,

Fig. 4 shows a sandwich assembly,

Fig. 5 shows the results of the sandwich test procedure using a sacrificial substrate according to the invention,

Fig. 6 shows the results of the sandwich test procedure using a sacrificial substrate according to prior art,

Fig. 7a shows the fins of an inventive substrate after removing the wafers,

Fig. 7b and 7c show the fins of a prior art substrates after removing the plurality of wafers,

Fig. 8 shows an actual picture of a plurality of wafers held by the sacrificial substrate after the cutting process,

Fig. 9 shows a schematic picture of a plurality of wafers held by the sacrificial substrate after the cutting process, with an expected wafer deflection due to capillary effects of the coolant,

Fig. 10 shows the total thickness variation (TTV) of the wafers in dependence of the number of consecutive test cuts using an inventive sacrificial substrate,

Fig. 11 shows the total thickness variation (TTV) of the wafers in dependence of the number of consecutive test cuts using an prior art sacrificial substrate,

Fig. 12 shows a deflected wafer hanging onto a sacrificial substrate,

Fig 13 shows a single wafer hanging onto the sacrificial substrate.

[0059] Fig. 1 shows a cutting device 5 for cutting a plurality of wafers from a piece of material 3, which is glued to a sacrificial substrate 1. The sacrificial substrate 1 is mounted to a fixture attachment 8 which in turn is connected to a support 9 of cutting device 5. A wire 7 forming a wire web is supported and driven by wire guiding rolls 6. In the cutting process the piece of material 3 is moved through the wire web.

[0060] Fig. 2 shows the comb like structure of the plurality of wafers 4 hanging on the sacrificial substrate 1 after the cutting procedure.

[0061] Fig. 3 shows that the shape of the sacrificial substrate may vary depending on the shape of the piece of material 3. In the embodiment of Fig. 3 the piece of material 3 is a cylindrical core and the sacrificial plate has a correspondingly curved mounting surface 4. Any other shape of the sacrificial substrate 1 would be possible.

[0062] Fig. 4 shows a test arrangement for testing the performance of the sacrificial substrate's material. A fixture attachment 8 to be connected to the cutting device 5 carries an alternating sequence of sacrificial substrates 1 and

pieces of material 3 (bricks). The experimental details are described in the following:

[0063] In order to mimic the back to back wafering process (the process whereby there is no wire web refreshment after finishing a sawing load of bricks, ingots or cores before starting to saw into a new load of bricks, ingots or cores) in one single sawing test, an experimental set up was designed called 'sandwich test'. The test arrangement is shown schematically in Fig. 4. In this test, a 20mm high mono Si brick 3 is glued with Delo-Duopox RM885 to a 12mm high sacrificial substrate 1 and this is glued again to a 20mm high mono Si brick 3, and so on in order to finally create a sandwich of sacrificial substrates 1 and mono Si bricks 3 whereby the transition of Si to substrate 1 and substrate 1 to Si is created 3 times (see figure 4).

[0064] The setup used for the above experiments is also beneficial for normal production.

[0065] All experiments were performed on a Meyer Burger DS264; using a wire speed of 15m/s; with a table speed of 0.9mm/s; with a wire tension of 25N; and with a water-based coolant Synergy DWS500 in a concentration of 5%. The used wire was a diamond wire from Asahi Diamond Industrial, specification 0.12mm core wire 10-20 grid. The material used was mono Si grinded into bricks of 125mm x 100mm x 20mm.

[0066] The wire bow of the wire was measured when the wire was moving through the sandwich construction. (for the results shown in figure 5, this was a substrate according to the invention; for the results shown in figure 6, this was a Valtron® 190 Clean Beam according to prior art.)

[0067] For the sandwich test with the sacrificial beam of the current invention, in this example a foamed polyurethane beam (figure 5), the sawing wire deflection falls down to approximately zero when the wire is cutting into the sacrificial substrate 1 and returns to the level it had at the end of the first silicon brick 3 at the start of sawing in the subsequent silicon brick. The process can thus be optimized towards the wire lifetime of the diamond wire used and as a consequence at the most efficient cost.

[0068] An additional advantage consists in the fact, that the last step of the sawing recipe, the cutting out process, is completed faster because of the "zero" bow in the sacrificial substrate 1.

[0069] The deformation of the substrate 1 (see Fig. 2) was visually inspected by looking at the fins created in the substrate 1 after de-gluing and separating the wafers 4. It was the general believe until now that the fins should not be deformed (cfr like in figure 7c) because this deformation would increase the risk for wafer damage and wafer loss, and results in thickness variation of the wafers. However, with the present invention, it could be shown, that some deformation is allowed (cfr figure 7a).

[0070] Because of the deflection, one can expect that a certain mechanical stress will be generated on the wafers. In general, one can expect that this will be undesirable since it can impact the mechanical integrity of the wafers. However, it was found, that if the sacrificial substrate material is very flexible and has a low E-modulus, the wafers sawn will not be affected. The wafers remain glued to the sacrificial substrate and no negative impact on the wafer quality is observed. The sacrificial substrate may have an E-modulus smaller than 6000 MPa (according to the ISO norm ISO 178); more preferably an E-modulus smaller than 5000 MPa; most preferably smaller than 4000 MPa.

[0071] An important feature is the thickness distribution of the fins that were generated. The thickness variation of the fins is an indication of how much the fins swell due to the used coolant system. If the fins swell too much because of the interaction with the cooling fluid, the risk for wafer loss and wafer damage is again increased. The standard deviation of the fin thickness was measured for several materials. The phenolresin beam DMT1111GB, a material according to prior art, (figure 7b) that performs well in glycol based system swells too much in the water-based system. The standard deviation of the lamella thickness is larger than 10 μ m (table 1). The Valtron® 190 clean beam (according to prior art) that provides very good wafer quality results in single cuts and has very limited deformation also has a very low thickness variation. However, this beam (substrate) is too demanding for the diamond wire. The substrate of the current invention, that has an apparent deformation of the fins in image 7a has a standard deviation of the fin thickness below 10 μ m (table 1). The polymer, used in one embodiment of the present invention, may have a moisture absorption (or water absorption) (according to the norm DIN 53495; in 24 hours at room temperature, distilled water at 23°C) smaller than 2%, more preferably smaller than 1.5%, most preferably smaller than 0.7%. The resistance of plastic materials against the action of water depends mostly on the chemical nature of the material and in the case when the plastic contains fillers, it is also dependent on the type of the filler. More hydrophilic materials will typically take up more material than hydrophobic materials. Typically, the measure of water absorption is done by mass increase measurements of a material when a certain mass is immersed in distilled water at 23°C during 24hours. The measurement is described in the DIN norm 53495.

Table 1:

Sacrificial substrate (Beam)	average thickness (μ m)	standard deviation thickness (μ m)
Substrate according to the invention, a polyurethane foam with a porosity of 50% and water absorption of 0.6%	199	6

(continued)

Sacrificial substrate (Beam)	average thickness (μm)	standard deviation thickness (μm)
Valtron® 190 Clean Beam, with a water absorption smaller than 0.6%	177	3
DMT111GB, with a water absorption in the order of magnitude of 2%	178	19

[0072] Another important parameter is the contamination of the saw and the wire guiding rolls, having a strong impact on the (diamond) wire lifetime:

[0073] During the slicing process, the material that is removed by the sawing wire needs to be dragged away with the wire and ideally needs to be removed by the cleaning process in the saw.

[0074] A porous material has the advantage over a solid or filled material, that there is less material to be sawn and removed from the sawing channel (grooves formed in the material as result of the wire sawing action). It was observed, however, that in a water-based diamond wire wafering process this removal and cleaning process is additionally complicated by the fact that substrate material has the tendency to deposit in the sawing machine and especially on pulleys and wire guiding rolls. This deposit clogs the grooves of the wire guiding rolls and pulleys that are supposed to guide the wire and as such generates the risk for wire pairing or wire jumps which results in wafer thickness variation and bad wafer quality. In order to avoid this issue, the sacrificial substrate has to be made of a material with such properties that it will not deposit on the wire guiding rolls nor anywhere else in the cutting machine, but can be cleaned/removed with the used water-based cleaning system.

[0075] Since sacrificial substrates are usually produced from a polymer matrix containing a filler, there are two possible sources of contamination: the filler(s) and/or the matrix material. Fillers are mostly added to a base resin to make the material cheaper or to improve the properties of the material, as for example the E-modulus (see before). Furthermore, both, filler(s) and matrix material, can interact negatively with the diamond wire. Therefore, the material selection and the concentration of the filler versus matrix are very important. It has been found that according to the invention the preferred sacrificial substrate has a filler content smaller than 30 mass%; more preferably smaller than 15 mass %; most preferably without fillers.

[0076] In this application, in order not to damage the wire, the hardness of the fillers, characterized by Mohs hardness, should be lower or equal to 2 (cfr. Gypsum); most preferably smaller or equal to 1,5 (cfr. Graphite).

[0077] The thermal stability of the material is another important criteria for two reasons:

[0078] The first reason is that a typical temperature (measured with an IR camera) range measured in a waterbased diamond wire wafering process is about 40°C. For glycol based processes, this is believed to yield higher temperatures (most probably in the order of magnitude 50°C). One can imagine that locally, especially in the sawing channel, higher temperatures might be achieved. Therefore, it is important that the beam material remains dimensionally stable at higher temperatures. The heat deflection temperature is measured through a three point bending test in which a sample is heated under constant bending load. The heat deflection temperature is the temperature whereby a certain deflection is attained, in accordance to ISO 75 (ISO75 - method B). Therefore, the thermal stability of the substrate, particularly its heat deflection temperature should be larger than 50°C, more preferably 60°C, preferably even higher than 70°C, in order not to deform by heat created in the cutting process.

[0079] The second reason is that also the polymer matrix is prone to deposition. One reason for this deposition can originate from the heat generated in the sawing process. Especially thermoplasts are proven very sensitive to this phenomenon. It is believed that this is due to the thermal energy created when the wire is cutting into the sacrificial substrate, as such softening the polymer matrix resulting in a contaminated polymer deposit on the wire. Therefore, duroplasts are more preferred.

Experimental proof of production conditions:

[0080] A continuous diamond wire sawing process was executed in order to proof the sacrificial substrate in a production like use. Eight consecutive cuts were performed in a time frame of less than 48h on a Meyer Burger DS271 using Asahi diamond wire with specification 0.12 core wire diameter and 10-20 diamond grid. The material used was 156mm x 156mm mono Si and a wafer thickness of 180 μm was targeted. The sacrificial substrate was a polyurethane foam with a porosity of 50%, E-modulus of 900MPa, heat deflection temperature of 77°C and a water absorption of 0.6%. The coolant was Synergy DWS500 in a concentration of 5%, an in-line membrane filtration system from Pall Corporation was used to recycle the coolant during the entire test series. In order to evaluate the beam effect on the wafer quality, the median of the total thickness variation of the plurality of wafers for each consecutive cut is shown (see figure 10) relative to the median total thickness variation of the first cut. The total thickness variation (TTV) of the first cut is the smallest since this is the only cut for which one starts off with a complete new unused diamond wire web. In the second and all following

cutting procedures, at least a part of the wire web has been already used in the previous cut. The increase in TTV for the consecutive cuts stays minimal and remains stable. In comparison, the same data are given for three consecutive cuts with DW111GB a substrate according to prior art in a water-based environment (figure 11). The sacrificial substrate is not stable and results of the consecutive cuts show that this translates into worse TTV results. The same experiment using the Valtron® 190 clean beam (also a substrate according to prior art) had to be aborted because of too high bow and risk for wire fracture in the second cut.

[0081] There are four mechanisms that are beneficial with respect to the inventive sacrificial substrate:

1. The force exerted on the wafers is kept low because of the low E-modulus
2. The material of the substrate does not impair the quality of the cutting wire
3. The sacrificial plate is less dense allowing the sawing wire to enter the substrate more easily, preventing it from "wandering" over the surface of the substrate.
4. Since the bow is smaller, the beams can be thinner.

[0082] In connection with these observations and with respect to different cooling fluids (e.g. water-based vs. glycol containing) and wire types (diamond wire vs. cutting with abrasives immersed in a slurry) following embodiments and combinations thereof are seen as inventive solutions achieving the objects of the invention.

[0083] Sacrificial substrates whose E-modulus is smaller than 6000 MPa (Mega Pascal), more preferably smaller than 5000 MPa, most preferably smaller than 4000 MPa.

[0084] Sacrificial substrates made of porous material with closed and or opened cells.

[0085] Sacrificial plates made of a foam (Polymer foams such as: polyurethane, polyisocyanurate, polystyrene, polyolefin, PVC, epoxy, latex, silicone, fluoropolymer, phenolic foams or syntactic foamed plastics (spheroplasts), or ceramic foams or metal foams)

[0086] This substrate may be used for both diamond wire (wire with fixed abrasive) as well as slurry based cutting.

Preferred material:

[0087] The preferred material is a polyurethane which has the advantage that it is cheap and doesn't deposit onto the polyurethane coated wire guiding rolls or pulleys. As a consequence a foamed polyurethane with a moisture absorption < 0.7% (DIN 53495) is the most preferred material.

[0088] The polyurethane may be foamed, with a fraction of pores larger than 0.15, more preferably larger than 0.30, most preferably larger than 0.40; having an E-modulus smaller than 6000 MPa (according to ISO 178); more preferably an E-modulus smaller than 5000 MPa; and most preferably smaller than 4000 MPa.

Porosity:

[0089] As pores is considered any kind of void space in a solid material, i.e. closed and/or opened cells. The porosity, or the volume fraction of pores, is defined as: $X_p = (d_0 - d_p)/d_0$ which is the ratio of the difference between d_0 , the density of the solid material (containing zero pores), and d_p , the density of the porous material, over d_0 . The porous material may be a foam (polymer foams such as: polyurethane, polyisocyanurate, polystyrene, polyolefin, PVC, epoxy, latex, silicone, fluoropolymer, phenolic foams or syntactic foamed plastics (spheroplasts), or ceramic foams or metal foams). The polymer based sacrificial substrate for diamond wire wafering may preferably have a porosity larger than 0.15 or (in terms of percent; multiplying with 100%) 15%; more preferably larger than 0.30 or 30 %; most preferably larger than 0.40 or 40 %.

Water absorption:

[0090] The inventive polymer substrate may have a water absorption (according to DIN 53495; submersed during 24 hours in distilled water at room temperature) smaller than 2% more preferably smaller than 1.5%; most preferably smaller than 0.7%. This is a typical measure for polymer materials. Glass will not absorb water. Solid epoxy resins might have an approximate value of 0.1 % or even lower. Whereas the logical trend of prior art would be to keep water absorption of the substrate to a minimal level, we found that there is flexibility in the boundaries of this criterion, because the mechanical properties of the substrate (E-modulus) can compensate for the deformation due to water absorption, also since porous materials, including foams typically have a higher water absorption.

Mechanical strength:

[0091] The sacrificial substrate may have an E-modulus smaller than 6000 MPa (ISO 178, short term (Kurzzeit) bending test on balkshaped material with dimensions 80mm x 10mm x 4mm tested at room temperature 23°C); more preferably an E-modulus smaller than 5000 MPa; most preferably an E-modulus smaller than 4000 MPa. The traditional substrate used according to prior art in wafering with slurry, glass, has a typical E-modulus in the range of 50-90 GPa (Giga Pascal). For glass reinforced plastics E-modulus values have been reported of greater than 15 GPa. Ceramic substrates will typically have higher E-moduli e.g. calcite (CaCO₃ in the range of 70-90 GPa) and as such ceramic filled plastics usually tend to enhance the E-modulus of the matrix plastic material. Such reinforced epoxy plates with moduli above 10 GPa have been found in the prior art field.

[0092] The heat deflection temperature (<http://www.matweb.com/reference/deflection-temperature.aspx>), which should be larger than 50°C (ISO 75), more preferably 60°C, preferably even higher than 70°C, in order not to deform by heat created in the cutting process. The deflection temperature is a measure of a materials resistance to distortion under a given load at elevated temperatures. The deflection temperature is also known as the 'deflection temperature under load'.

[0093] Duroplasts are most preferred material in this embodiment.

[0094] The invention is not restricted to the embodiments above. Any material showing the specifications according to the invention may be used. The specifications of the embodiments described above may be used as such or in combination with other embodiments of the invention.

List of reference signs

[0095]

- 1 - Sacrificial substrate
- 2 - Mounting surface
- 3 - Piece of material
- 4 - Wafers
- 5 - Cutting device
- 6 - wire guiding roll
- 7 - sawing wire
- 8 - fixture attachment

Claims

1. Sacrificial substrate (1) having a mounting surface (2) for holding a piece of material (3), such as an ingot, brick or core, for cutting a plurality of wafers (4) or bricks from the piece of material (3) in a wire saw, wherein the sacrificial substrate (1) has an E-modulus smaller than 6000 MPa, more preferably smaller than 5000 MPa, most preferably smaller than 4000 MPa.
2. Sacrificial substrate according to claim 1, wherein the sacrificial substrate (1) is made from a porous material.
3. Sacrificial substrate according to claim 2, wherein the sacrificial substrate (1) has a porosity larger than 0,15 (or 15 %), more preferably larger than 0,30 (or 30 %), most preferably larger than 0,40 (or 40 %).
4. Sacrificial substrate according to claim 2 or 3, wherein the porous material is a foam, preferably a polymer foam.
5. Sacrificial substrate according to any of the preceding claims, wherein the sacrificial substrate (1) is made from a polymer based material which has a moisture absorption smaller than 2% more preferably smaller than 1.5%, most preferably smaller than 0.7% (according to DIN 53495, 24h, distilled water at 23°C).
6. Sacrificial substrate according to any of the preceding claims, wherein the sacrificial substrate (1) has a heat deflection temperature, which is larger than 50°C, more preferably larger than 60°C, preferably even higher than 70°C.
7. Sacrificial substrate according to any of the preceding claims, wherein the sacrificial substrate (1) is made from a duroplast material.

8. Sacrificial substrate, according to any of the preceding claims, wherein the sacrificial substrate (1) is made of or contains a foam, such as a polymer foam, a ceramic foam or a metal foam.

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9. Sacrificial substrate, according to any of the preceding claims, wherein the sacrificial substrate (1) is made of or contains a polyurethane.

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10. Sacrificial substrate, according to any of the preceding claims, wherein the sacrificial substrate (1) is made of foamed polyurethane, and wherein preferably the foamed polyurethane has a water absorption smaller than 2%, preferably smaller than 0,7%.

11. Sacrificial substrate, according to any of the preceding claims, wherein the sacrificial substrate (1) is made of foamed polyurethane, and wherein preferably the foamed polyurethane has a water absorption greater than 0,1%.

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12. Method of making a plurality of wafers of a piece of material (3), such as an ingot, brick or core, comprising the steps of: mounting the piece of material (3) to a sacrificial substrate (1), preferably by gluing; mounting the sacrificial substrate (1) with the piece of material (3) in a cutting device; and cutting the piece of material (3) into a plurality of wafers, **wherein** the sacrificial substrate (1) is a sacrificial substrate according to any of the preceding claims.

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13. Method according to claim 12, wherein the sacrificial substrate (1) is attached to a brick and to a fixture attachment (8).

14. Method according to claim 12 or 13, wherein the sacrificial substrate (1) is attached to two bricks (3).

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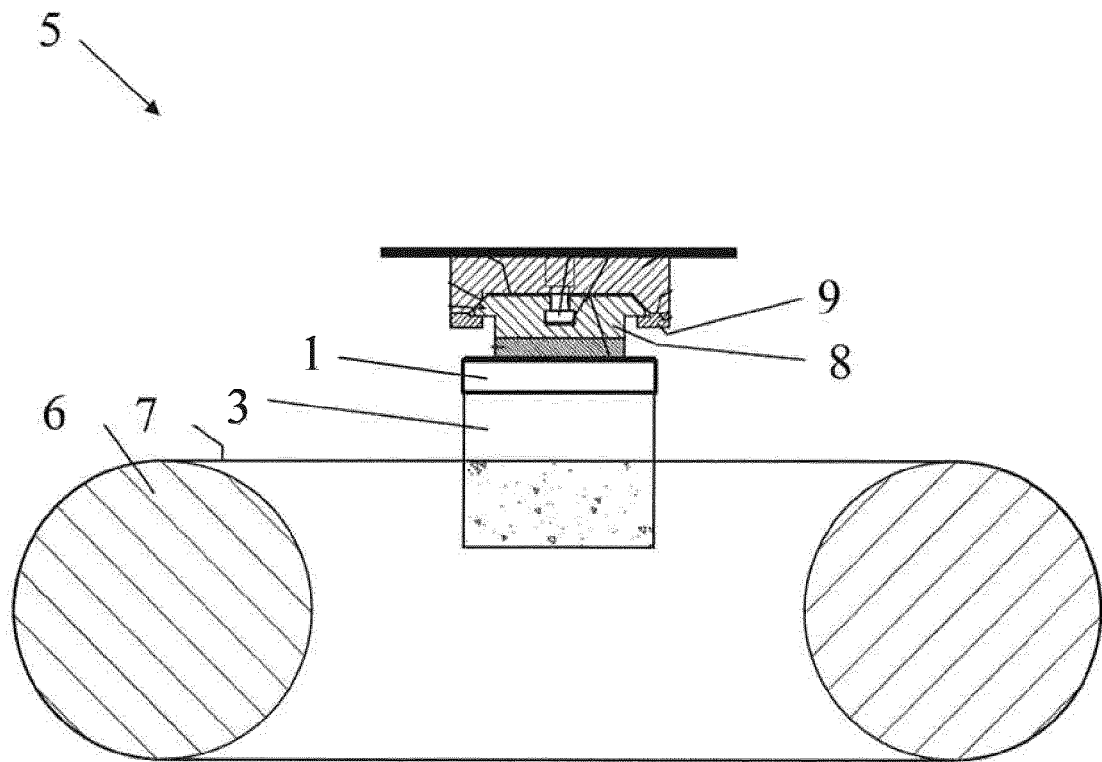


Fig. 1

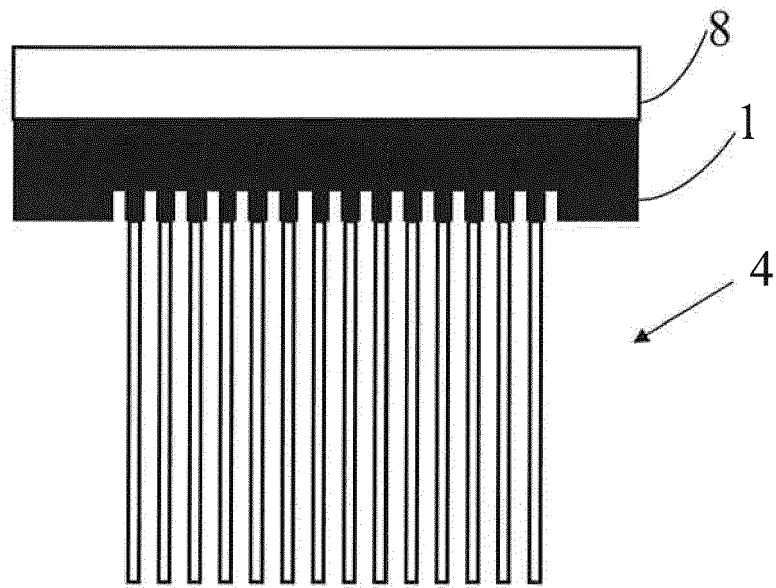


Fig. 2

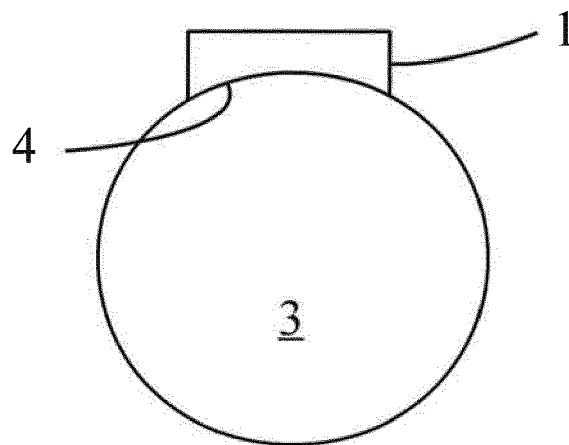


Fig. 3

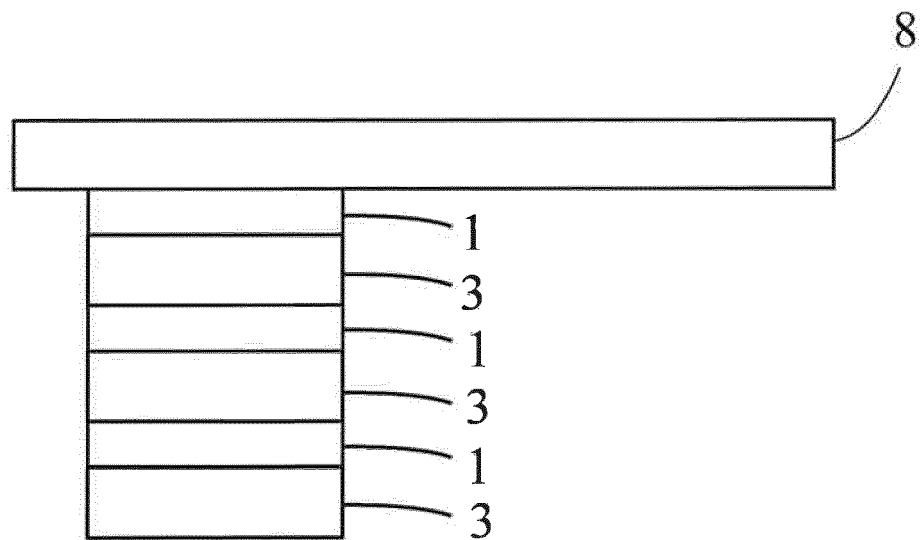


Fig. 4

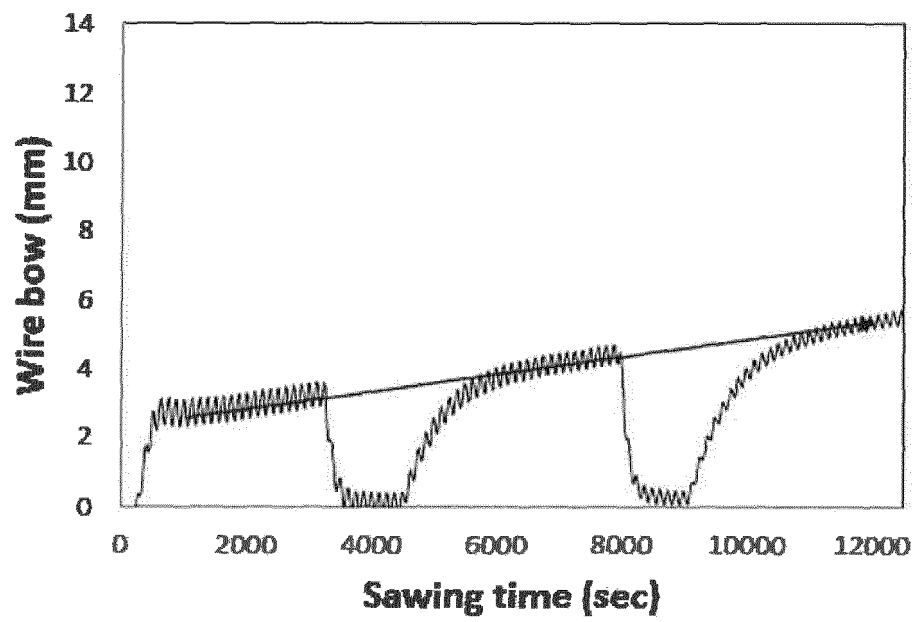


Fig. 5

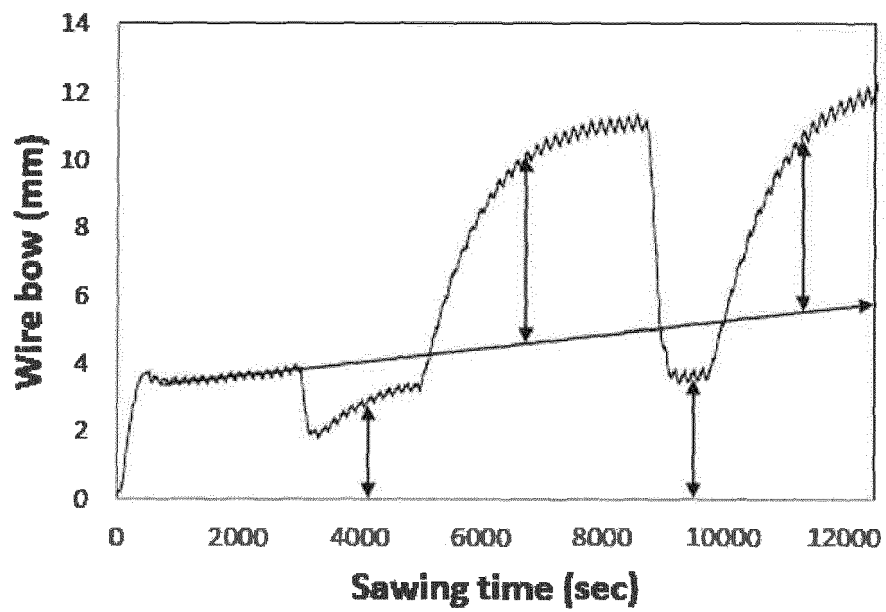


Fig. 6

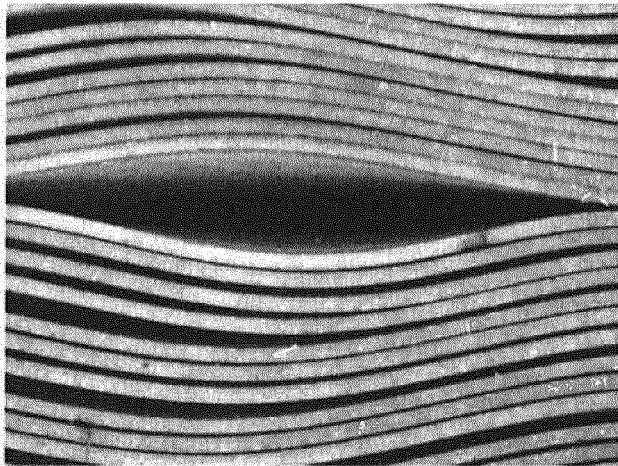


Fig. 7a

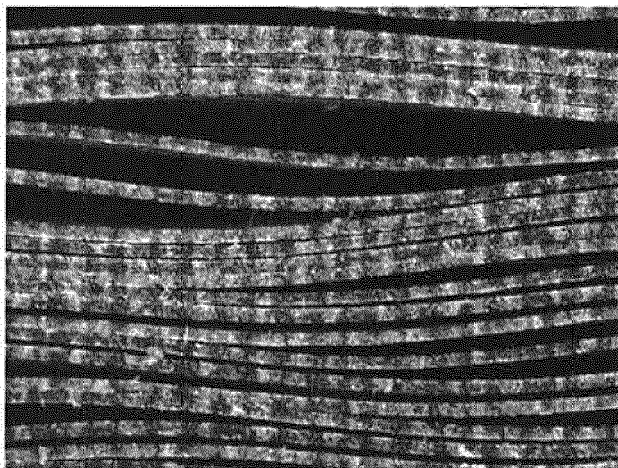


Fig. 7b

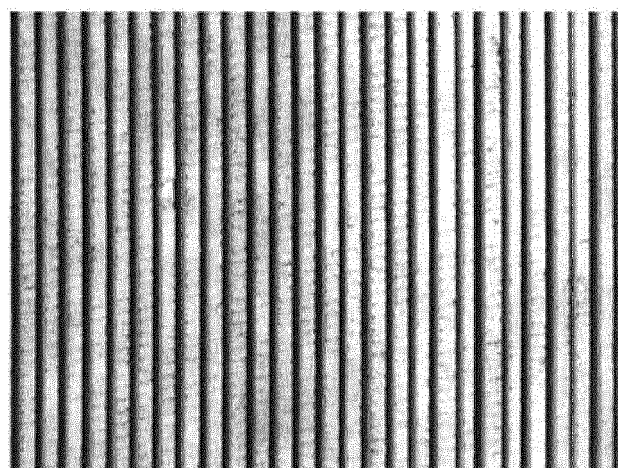


Fig. 7c



Fig. 8

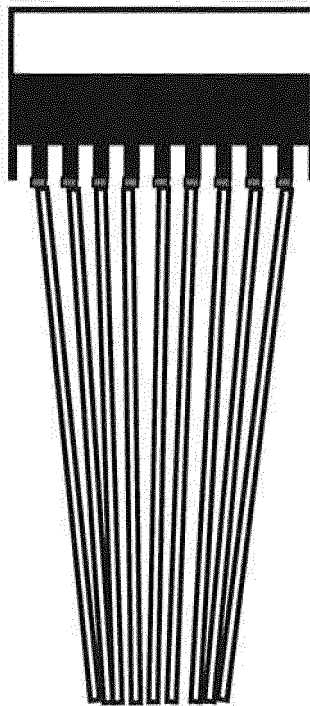


Fig. 9

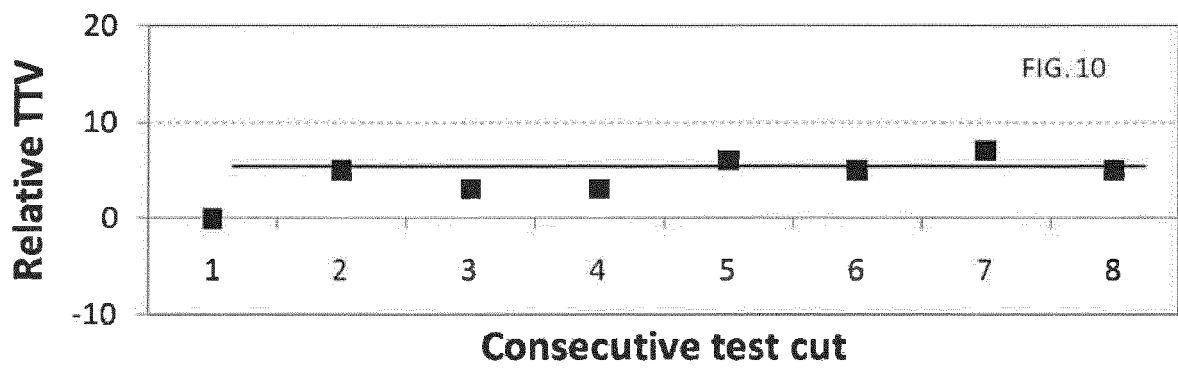


Fig. 10

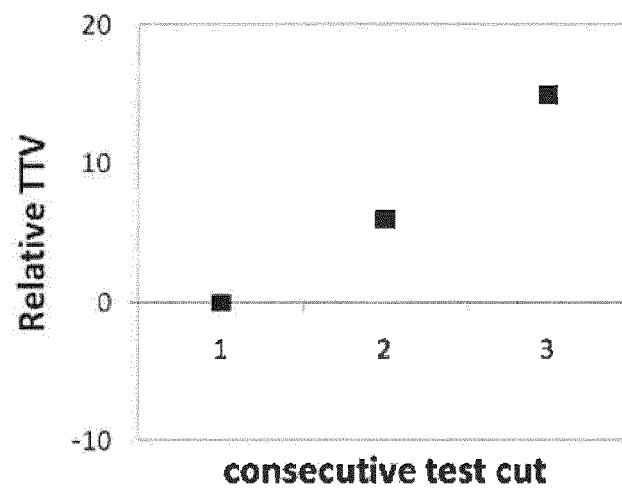


Fig. 11

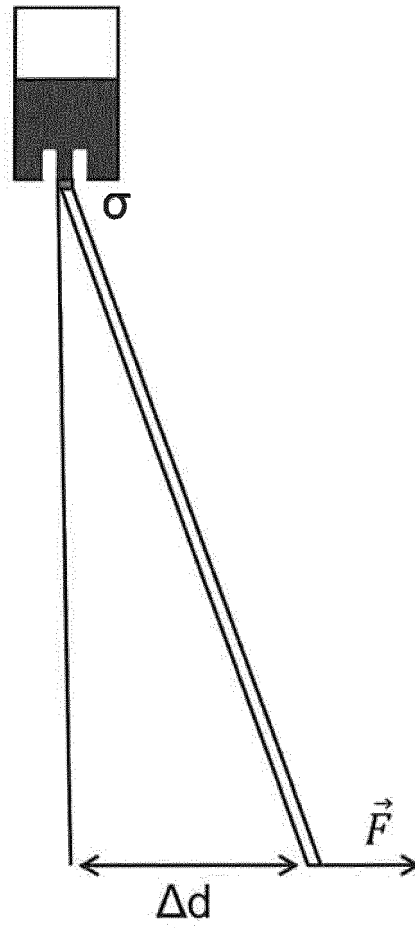


Fig. 12

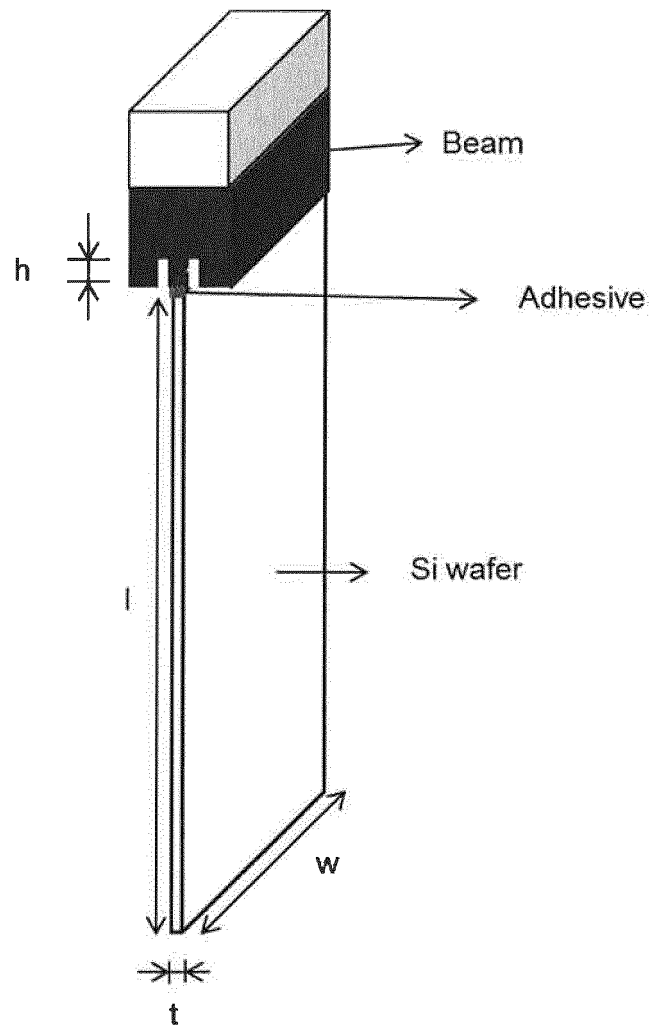


Fig. 13



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Application Number
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Place of search The Hague		Date of completion of the search 9 May 2012	Examiner Matzdorf, Udo
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