SUBSTRATE - LAYER CUTTING DEVICE AND EMTHOD ASSOCIATED THEREWITH

This invention generally relates to the treatment of materials, and particularly substrates for electronics, optics or optoelectronics.

More precisely, the invention relates to a device for automatic high-precision cutting of a layer of material, for electronics, optics or optoelectronics, joined to a source substrate by means of an embrittled area, the source substrate and the layer to be cut forming an assembly to be cut, the device comprising cutting means and means for maintaining the position of the assembly to be cut, characterised in that the cutting means comprise a blade to attack the assembly to be cut and the maintaining means are adaptable so as to maintain the position of the assembly to be cut only in the cutting plane of the blade once the blade has started to attack the assembly to be cut, leaving the said assembly to be cut free in the direction perpendicular to the said cutting plane.

Note that "cutting" in this text refers to the operation consisting of dividing a single element or an assembly into two separate parts, and guaranteeing that the said parts do not combine again.

As will be seen, this type of cut is included within the framework of the invention at an embrittled area.

And the invention also relates to an automatic high-precision cutting process for a layer of material joined to a source substrate by means of an embrittled area, the source substrate and the layer to be cut forming an assembly to be cut, the process comprising:

- positioning of the assembly to be cut with respect to the maintaining means,
- cutting of the layer by cutting means,

characterised in that the cut is made using at least one blade of the cutting means associated with displacement means while the maintaining means maintain the position of the assembly to be cut in the cutting plane, the process including insertion of the blade in a cavity of the assembly to be cut, the said cavity being located close to the embrittled area and the process including self-adjustment along the direction perpendicular to the cutting plane, of the relative positions of the assembly to be cut and the blade as the blade and the assembly to be cut are inserted by cooperation between the cutting edge of the blade and the concave section of the cavity.

Note that the invention is particularly adapted to cutting of layers less than about a hundred microns thick,

and particularly to cutting so-called "thin" layers of the order of 1 micron thick.

Devices and processes like those mentioned above are used to build up layers (thin or not) that might be transferred to the source substrate from which they were pulled off to a "target support".

Substrates are usually in the form of disks called "wafers". Wafers may be made from a semi-conducting material such as silicon.

It is known that an embrittled area can be formed inside a wafer along a plan parallel to the principal faces of the wafer.

The embrittled area may be made by implantation of ions bombarded on the wafer surface, these ions creating an embrittled layer within the thickness of the wafer to delimit an upper region (in this text corresponding to the source substrate) and a lower region adjacent to the ion source (in this text corresponding to the layer that will be cut).

Document FR 2 681 472 describes an example of such a process to make thin layers.

The embrittled area can also be made by any means known in itself, for example by building up an intermediate region made of porous materials between two regions of dense material, by forming an oxide layer buried in a substrate (for example an SOI (Silicon On Insulator) type substrate), or by bonding two layers, the bonding area corresponding to the embrittled area.

A manual operator can make the cut at the embrittled area and form two separate elements with the source substrate and the layer to be cut.

But calling in a manual operator sets a limit on the layer production rate.

Furthermore, in this case, reproducibility of operations is uncertain.

Automatic cutting devices and processes are also known to overcome the above-mentioned disadvantages.

Document EP 925 888 describes one example of such a device and process.

The device in this document uses the impact of a water jet on the edge of a wafer that is held in place on its two principal faces, to attack an embrittled area and divide the wafer into two parts.

But the design and operation of such a device are relatively complex. In particular, specific means are necessary so that the maintaining means associated with each of the two faces of the wafer enable a given separation of the two parts of the wafer.

Furthermore, the maintaining means must also rotate the wafer so that its entire periphery is attacked by the

water jet, which further increases the complexity of the design and operation of the device.

Document EP 989 593 also divulges a layer cutting device and process.

But once again, a complex arrangement is necessary, particularly to maintain the position of the two parts of the wafer that are to be separated.

One purpose of the invention is to overcome the disadvantages mentioned above by cutting layers, particularly thin layers, in a particularly reliable and simple manner.

Another purpose of the invention is to make such a cut without damaging the corresponding surfaces of the cut layer and the substrate to which the layer is joined through the embrittled area.

Another purpose of the invention is to have accurate control over cutting operation parameters to prevent damage to wafers and to adapt the kinetics of this operation to different wafer types.

According to a first aspect of the invention, this purpose is achieved by using a device for automatic high-precision cutting of a layer of material for electronics, optics or optoelectronics, joined to a source substrate by means of an embrittled area, the source substrate and the layer to be cut forming an assembly to be cut, the device comprising cutting means and means for maintaining the position of the assembly to be cut, characterised in that the cutting means comprise a blade to attack the assembly to be cut, characterised in that the cutting means comprise a blade to attack the assembly to be cut and the maintaining

means are adaptable so as to maintain the position of the assembly to be cut only in the cutting plane of the blade once the blade has started to attack the assembly to be cut, leaving the said assembly to be cut free in the direction perpendicular to the said cutting plane.

The following are some preferred but non-limitative embodiments of the device according to the invention:

- the maintaining means comprise a shim,
- the shim is fitted,
- the blade is mobile,
- the maintaining means are arranged so that one side of the assembly to be cut stops in contact with them, usually the side opposite the assembly to be cut attacked by the blade,
- the maintaining means consist of an assembly of shims,
- the maintaining means consist of a single shim,
- the maintaining means are adaptable so as to maintain the position of the assembly to be cut only in the cutting plane of the blade once the blade has started to attack the assembly to be cut, leaving the said assembly to be cut free in the direction perpendicular to the said cutting plane,
- the blade is used with blade position adjustment means along the direction perpendicular to the cutting plane so that the blade can be placed close to the embrittled area of the assembly to be cut,
- the blade is installed on automatic displacement means,
- the said automatic displacement means control translation of the blade in the cutting plane,
- the said controlled translation is a uniform translation,

- the leading edge of the blade has a circular contour corresponding to the contour of the assembly to be cut,
- the blade leading edge covers a quarter of the periphery of the assembly to be cut,
- the cutting means comprise a first cutting means and a second cutting means,
- the device also comprises a sensor capable of acquiring a parameter representing progress with the cut by the first cutting means, and means of triggering use of the second cutting means when the said parameter reaches a predetermined value,
- the said parameter is related to a measurement of the spacing between the parts of the wafer to be cut,
- the first cutting means comprises a blade and the second cutting means comprises two blades arranged symmetrically with respect to the assembly to be cut,
- each blade in the second cutting means is mounted free to displace on the displacement means and the leading edge of each blade is oriented so as to attack the assembly to be cut tangentially on a portion of its periphery.

According to a second aspect, the invention also proposes a process for automatic high-precision cutting of a layer of material joined to a source substrate by means of an embrittled area, the source substrate and the layer to be cut forming an assembly to be cut, the process comprising:

✓ positioning of the assembly to be cut with respect to the maintaining means,

✓ cutting of the layer by cutting means,

characterised in that the cut is made using at least one blade of the cutting means associated with displacement means while the maintaining means maintain the position of the assembly to be cut in the cutting plane, the process including insertion of the blade in a cavity of the assembly to be cut, the said cavity being located close to the embrittled area and the process including self-adjustment along the direction perpendicular to the cutting plane, of the relative positions of the assembly to be cut and the blade as the blade and the assembly to be cut are inserted, by cooperation between the cutting edge of the blade and the concave section of the cavity.

The following are some preferred but non-limitative aspects of the process according to the invention:

- the process includes insertion of the blade in a notch in the assembly to be cut, the said notch being located close to the embrittled area,
- the said notch is an approximately annular shaped notch,
- the process includes self-adjustment along the direction perpendicular to the cutting plane, of the relative positions of the assembly to be cut and the blade as the blade and the assembly to be cut are inserted, by cooperation between the leading edge of the blade and the concave section of the notch,
- the separation wave of the layer to be cut is followed by analysing light transmitted through the principal faces of the assembly to be cut,

- movements of the blade displacement means are slaved to observations of separation of the layer to be cut,
- movements of the blade displacement means are slaved to measurements of forces applied to a mobile element that attacks the assembly to be cut,
- at least one parameter representative of progress with the cut is collected during a first cutting phase carried out by a first cutting means, and the second
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cutting phase made by a second cutting means is controlled as a function of the value of this parameter,

- the first cutting means is a blade attacking the assembly to be cut at a first location, and the second cutting means attacks the assembly to be cut at a distance from the part of the said assembly attacked by the first cutting means,
- the second cutting means comprises two blades on each side of the assembly to be cut, and moved symmetrically with respect to this assembly.

Other aspects, purposes and advantages of the invention will become clearer after reading the following embodiment of the invention, given as a non-limitative example with reference to the appended drawings, wherein:

- Figure 1 is a diagrammatic overview in elevation of the top of an assembly of a first embodiment of a cutting device according to the invention, on which the plane of section II-II is defined,
- Figures 2a and 2b are two sectional diagrammatic views along plane II-II of a wafer comprising an embrittled area, placed in a cutting device like that shown in Figure 1,
- Figure 3 is an enlarged diagrammatic elevation view of the side of a blade of a device like that shown in Figure 1 as it attacks a wafer to cut a layer from it,
- Figure 4 is an enlarged diagrammatic elevation top view of the edge of a blade of a device like that shown in Figure 1, close to the wafer attack area,

- Figures 5a and 5b show a top view and a side view respectively corresponding to a second embodiment of a cutting device according to the invention, comprising improved cutting means used in two successive phases,
- Figure 6 is a view similar to the view in Figure 3, that diagrammatically illustrates the interfaces of a wafer on which a cutting operation is carried out,
- Figure 7 is a diagrammatic top view of the means in the device in Figures 5a and 5b, to cut a wafer layer in a first position of the said means that corresponds to a first phase in the cutting operations,
- Figure 8 is a view similar to the view in Figure 7, in which the cutting means have a second position corresponding to a second phase in the cutting operations,
- Figure 9 is a detailed view of some cutting means in the device corresponding to a second embodiment of the invention,
- Figures 10a and 10b show a top view of two possible shapes of the cutting means in Figure 9,
- Figure 11 diagrammatically illustrates the penetration of a blade in a wafer.

Firstly with reference to Figure 1, the figure shows a cutting device 10 according to a first embodiment of the invention, with a wafer 20. The wafer forms an assembly to be cut.

The device 10 is intended to cut a wafer layer along a cutting plane parallel to the faces of the wafer (in other words parallel to the plane of Figure 1, that is defined as

the horizontal plane). The layer will thus be cut from the source substrate that forms the rest of the wafer 20.

Note that by convention, the view in Figure 1 is called the top view, and consequently for this entire description, we will refer to the vertical direction as being the direction perpendicular to the median plane of the wafer.

The shape of the wafer 20 is a conventional circular shape. This wafer comprises a substrate called the source substrate made of a semiconducting material such as silicon, the said substrate itself comprising an embrittled area like that mentioned above.

The embrittled area extends along an intermediate plane of the wafer parallel to the principal faces of this wafer.

And the embrittled area defines a layer in the substrate that will be pulled off from the wafer (for example to transfer this layer onto a target support).

Two concentric circles around the periphery of the wafer represent an annular chamfer 21 surrounding the wafer.

For reasons of clarity, the separation between the two circles that represent the chamfer 21 have been shown at a relatively large scale compared with the scale used for the diameter of the wafer.

This chamfer is located in the sidewall of the wafer, at a distance from the lower and upper faces of the said wafer. We will describe this chamfer and its purpose in more detail later.

The wafer 20 is placed on the central part 102 of a fixed and plane chassis 100, the said chassis also supporting a shim 110 and a displacement support 120 of a blade 130 fixed on this displacement support.

The shim 110 is fixed (for example by screws) on an end part 103 of the chassis 100, the said chassis 100 actually comprising two end parts 101 and 103 surrounding the central part 102 that is movable.

The shim 110 comprises a section 111 that is in contact with the sidewall of the wafer. The geometry of the section 111 is concave and circular, complementary to the section of the portion of the wafer that fits onto it. The section 111 is prismatic along the vertical direction (as can be seen clearly in Figures 2a and 2b).

This section 111 may also have any other geometry for which the cooperation of shapes with the wall of wafer 20 enables movements of the wafer in the vertical direction perpendicular to the cutting plane of the blade.

In particular, this section 111 may have a slight notch or projection, to further facilitate self-adjustment of the position of the wafer relative to the device (this self-adjustment aspect will be described in detail below).

In the illustrative example in Figure 1, the section 111 of the shim thus covers slightly more than a quarter of the periphery of the wafer. In one variant, this section may cover a quarter of the periphery of the wafer. And in any case, this section must cover a sufficiently large part of the periphery of the wafer to maintain the position of the wafer being attacked by a blade (as will be described below).

The wafer 20 was brought into contact stopping against the prismatic section 111 of the shim, either by hand or by appropriate automatic handling means.

The displacement support 120 is fixed onto the part 101 of the fixed chassis 100. This support also supports the blade 130, to move the said blade towards the wafer in translation (along the direction of arrow F).

The blade 130 comprises a section 131 that will attack the wafer - this section 131 will be called the leading edge of the blade.

Like the section 111 of the shim, the geometry of the leading edge 131 is concave and circular. This circular geometry is then generally complementary to the geometry of the portion of the wafer that the blade will cut. Typically, the blade attacks the wafer over approximately a quarter of the periphery of the wafer.

However, note that the leading edge 131 is not necessarily circular, and its geometry could be any other shape.

The wafer 20 is inserted between the shim 110 and the blade 130 installed on the displacement support 120. These elements are aligned, the shim and the blade being diametrically opposite the centre of the wafer and the blade is displaced along the F direction of this alignment.

The blade will attack the sidewall of the wafer at a required height (the position of the blade also being adjustable in height to attack the said wall at the required height - for example this adjustment can be made by means to adjust the position of the blade along the direction perpendicular to the cutting plane).

The displacement means 120 are capable of moving the blade to bring its leading edge 131 into contact with the sidewall of the wafer, and to penetrate into the wafer beyond the said wall to a given depth.

For example, this penetration depth may be of the order of one centimetre. However, it will be defined as a function of parameters such as the shape of the blade section and the characteristics of the wafer (materials from which the wafer is made, shape of the annular chamfer, etc.).

Note that although the penetration depth may be as much as about one centimetre, the width of the physical contact area between the wafer and the blade must not be more than a few millimetres (corresponding to the width of the exclusion area).

In this respect, the shape of the blade may be adapted for example to comprise:

- a tip defined by two sloping faces that will penetrate into the wafer when the blade and the wafer are first brought into contact, the sloping faces acting as a wedge separating the two parts of the wafer from each other,
- and a portion with a determined constant thickness behind the tip, as shown in Figure 11. This portion with constant thickness is the only part of the blade that is in contact with the wafer after the tip has penetrated into the said wafer. It holds the parts of the wafer at a controlled spacing from each other corresponding to the predetermined thickness of this part of the blade, thus

facilitating controlled cutting of the wafer. In this respect, note that it is important that the size of the physical contact area between the blade and the wafer should be limited, since the blade must not come into contact with the central part of the wafer that is surrounded by the exclusion area (top view of the wafer) that corresponds to the active part of the wafer that will actually be used. Figure 11 thus shows that the tip of the blade that penetrated between the parts of the wafer is no longer in physical contact with the wafer, the contact between the blade and the wafer being limited to the portion with width d1 of the blade with constant thickness. This constant thickness of the back portion of the blade will be defined as a function of the type of wafer to be cut; for example, it may be of the order of 5 millimetres.

The purpose of the blade is to cut the wafer, in other words as defined above to divide it into two separate parts (actually the two parts are the source substrate and the layer to be pulled off), and to guarantee that the said parts do not combine together again after this division.

Consequently, the section of the blade is bevelled, as shown in Figures 2a, 2b and 3.

More precisely, a preferred use of the device according to the invention is illustrated with reference to these figures.

Note that these diagrammatic figures are shown for illustrative purposes only, and that the scales used for the different elements shown (wafer layers, blade, other elements of the device according to the invention, etc.) are in no way representative of reality.

These diagrammatic figures show that the sidewall 22 of the wafer 20 that is shown is not absolutely prismatic, but comprises an annular notch corresponding to the chamfer 21.

This annular notch is produced by bringing together the rounded edges of two parts 20a and 20b of the wafer that were bonded by any process known in itself (bonding or other) to form the said wafer 20. The annular notch 21 corresponds to the bonding interface 203 between the two parts 20a and 20b.

According to standards in force, the edges of the semiconductor wafers must not be sharp, to limit damage to them during an accidental shock; parts 20a and 20b (that themselves form "wafers" when considered independently) therefore respect these standards and their edges are rounded or chamfered.

And the wafer shown corresponds to a preferred use of the invention, in which a thin layer 201 is cut by attacking the wafer with the blade 130 close to an embrittled area 202.

More precisely, the wafer 20 illustrated in these figures was made such that the bonding interface 203 between the two parts 20a and 20b from which the wafer was made is in the immediate vicinity of the embrittled area 202.

And in this case, the tip of the blade 130 preferably attacks the wafer 20 at this bonding interface associated with an annular notch 21 with a concave section forming a chamfer.

According to one advantageous aspect of the invention, as the blade 130 moves in translation along the horizontal direction F, cooperation between the shape of the tip of the blade (usually convex, for example bevelled) and the shape of the chamfered annular notch (usually concave) enables self-adjustment of the height of the wafer with respect to the blade.

During the cut, the wafer is free to move along the vertical direction.

It can be seen in Figure 2a that there is nothing to limit upwards wafer movements.

The same is true for downwards wafer movements; as soon as the blade has started to attack the wall of the wafer, the movable part of the horizontal chassis 102 will be pulled back to leave the wafer completely free in the vertical direction.

Consequently, as soon as the blade has started to engage the sidewall of the wafer in the immediate vicinity of the bonding interface 203, cooperation of the shapes mentioned above causes self-adjustment of the position of the tip of the blade facing the centre of the said interface.

Note that the initial attack height of the blade was adjusted in advance, so that it is approximately facing this interface.

Therefore, more precisely, and with reference to figure 3, the blade 103 initially attacks the sidewall of the wafer in the immediate vicinity of the bonding interface 203, in order to cause cooperation of shapes

between the slopes of the bevel of the blade and the slopes of the annular notch of the chamfer 21.

Note that the thickness of the leading edge of the blade (in other words the thickness of the terminal section of the said blade by the radius of curvature of the tip of the blade) is of the order of ten microns, or even more.

The blade itself may be of the order of a few millimetres thick.

Furthermore, the distance between the bonding interface 203 and the embrittled area 202 is very much less than the dimensions of the blade.

Thus, as the blade attacks the sidewall of the wafer, the geometry of the bevel of the leading edge of the blade produces a wedge effect that separates the parts of the wafer on each side of it along the vertical direction perpendicular to the cutting plane.

And the path of the vertical stresses that separate the two parts of the wafer from each other naturally lie in the embrittled area 202 in the immediate vicinity.

This transfer of vertical stresses from the embrittled area 202 in the region facing the bonding interface 203 towards the embrittled area 202, is illustrated in Figure 3 by the constraint line C that very diagrammatically represents the cut line between the two parts of the wafer in the vicinity of the edge of the said wafer.

When this line C reaches the embrittled area 202, and continuing towards the inside of the wafer (in other words towards the left in Figure 3), the cut line becomes coincident with the embrittled area 202.

This embrittled area 202 represents a "well" for the stresses, and since the wafer is free along the vertical direction, the self-adjustment mentioned above continues to allow the blade to continue its penetration into the wafer at the chamfer 21.

We have already mentioned that in any case the blade was not in contact with the wafer except for a limited depth within the wafer. This depth is of the order of a few millimetres and corresponds to the inactive portion of the wafer ("exclusion area").

In this respect, the geometry of the blade is such that the blade does not act as a "cutting" tool that would "cut" the wafer (the "cut" was defined above, and does not correspond to a slicing effect).

In reality, the internal angle of the bevel of the blade needs to be small enough so that the blade actually penetrates into the wafer, but it must also be large enough so that the blade actually performs its function as a wedge that penetrates between the layer 201 to be transferred and the rest of the wafer. Once the blade has began to penetrate into the wafer, the sloping edges of its leading edge separate the layer 201 from the rest of the wafer along the vertical direction. This vertex angle could be of the order of 60°.

This enables propagation of the separation wave of the layer 201 over a large part or possibly the entire surface of the wafer (although the blade only penetrates a limited depth into the wafer).

It will be noted that the fact that there is no element that limits movements of the wafer either upwards

or downwards in the vertical direction, means that the wafer can not only automatically adjust its position along the vertical direction in which the blade is brought into action, but can also deform freely and symmetrically during this separation.

This facilitates smooth execution of the cut, and reduces risks of deterioration of the layer 201 and the substrate - particularly when the substrate 20b is made of a brittle material such as quartz.

The blade is made from a smooth material, fairly hard to penetrate into the wafer but not too hard to avoid damaging the surfaces of the layer 201 and the substrate.

For example, the blade could be made from a material such as polyvinyl chloride (PVC) or polyetheretherketone (PEEK), or Teflon (registered trademark).

And the blade must be thick enough to keep the layer 201 sufficiently separated from the rest of the wafer and to guarantee that the separation wave of the layer 201 propagates effectively over most of the surface of the wafer.

The Applicant has determined that a thickness of the order of 5 millimetres is suitable for this purpose.

Figure 4 shows the separation wave D of the layer 201, observed close to the edge of the blade, for the device 10 that corresponds to a first embodiment of the invention, as described above.

The separation wave can be defined as being the front observed when the wafer is divided into two parts, and that materializes the line along which the layer 201 divides from the rest of the wafer.

In this respect, figure 2b shows an advantageous variant of the invention, in which progress of the separation wave of layer 201 is continuously displayed by means of a light source 30 (for example an infrared lamp) placed under the wafer and aimed at it, and a camera 40 located on the other side of the wafer to collect light transmitted through the wafer.

The light source can be brought to face the wafer only after the central part 102 of the fixed chassis has been retracted.

A part 102 transparent to radiation output from source 30 can also be used.

It will be seen that the fact that there is no support element facing the principal faces of the wafer makes it possible to observe this separation wave under excellent conditions; this is not the case in automatic devices according to the state of the art that comprise means of holding the principal faces of the wafer in position.

It is also possible to slave movement of the blade displacement support 120 to observations made by the camera 40, by providing a displacement regulation loop to obtain controlled progress of the separation wave.

This aspect of controlling the displacement of cutting means of the device will be described in more detail later in the remainder of the text with reference to a second embodiment of the invention.

The displacement support can also be programmed to enable continuous translation of the blade. This is particularly useful when the structure of the wafer is simple.

However, in the case of a wafer made from a large number of layers bonded together, it may be preferable to move the blade forward intermittently (the regulation means mentioned above will advantageously be used in this case as well).

In the case of a wafer made on a transparent lower substrate 20b (for example quartz), the camera 40 may be placed directly under the wafer (at the location of the source 30 in Figure 2b), to observe the separation by transparency through the lower substrate.

The single shim 110 may be replaced by an assembly of shims comprising several fixed shims, blocking the wafer in the horizontal cutting plane but allowing it free to move in the vertical direction.

If the invention is used on a wafer without an annular chamfer, it will be possible to form a concave-shaped notch in the wall of the wafer facing the location at which the leading edge of the blade will attack the wafer, so that cooperation between shapes and the self-adjustment described above can be achieved.

It is also possible to provide several blades mounted on the same displacement support, or mounted on corresponding displacement means independent of each other.

This aspect will also be described with regard to a second embodiment of the invention.

And in a simplified version of the invention, means of displacing the blade or blades may be activated by manual devices such as a crank handle.

Remember that in any case, it is preferable to generate a single separation wave when the blade(s) is (are) attacking the wafer.

Problems can arise at the junction of two different waves initiated at different locations around the periphery of the wafer and propagating in different directions.

Thus, if several blades are provided, a suitable configuration is the configuration in which one blade moves forward in advance as the tip, the others taking over the attack of the first blade behind it and at its sides, contributing to propagating the same separation wave initiated by the first blade.

However, it is not essential that the wafer should initially be attacked at its mid-point (on the longitudinal axis of the device that joins the centre of the blade and the centre of the shim); the blade may have an asymmetric contour with a tip that moves forwards on one side only, and that attacks one side of the wafer before the other side.

It is also possible that the blade is fixed and that the shim is mobile - in any case, only one of the two elements must be mobile. And in all cases, the provisions for self-adjustment of the position of the wafer mentioned above will be advantageously used.

It is possible to use a pressure sensor or a force sensor with the blade, in order to monitor forces applied to the blade during the cut.

The advance of the blade (or of the mobile element) can also be regulated as a function of these forces. This regulation may be used in combination with the regulation

as a function of the separation wave described above, or as alternative regulation.

Figures 5a and 5b, 7, 8 and 10 show a device 50 to implement a second embodiment of the invention.

Like the device 10 described above, this device 50 is designed to cut an edge of a wafer 20.

Figure 5a shows a diagrammatic top view on which a shim 510 and a first blade 530 supported by displacement means 520 to make it mobile with respect to the shim, are shown around the wafer 20, in a manner similar to the configuration of the device 10 described above.

The shim 510 shown in the left part of Figure 5b is fixed, and blade 530 can be brought towards the wafer to attack the wafer.

The wafer itself is preferably arranged between the shim 510 and the blade 530 so that these three elements are in line along an axis also corresponding to the direction of displacement of the blade 530.

It can be seen in Figure 5a that the shape of the blade 530, unlike the device 10 described above, is such that a large part of the periphery of the wafer cannot be attacked.

On the other hand, the geometry of this blade 530 as seen in a top view has a delta shape, one vertex of which is facing the wafer to attack it (the "vertex" of the delta being truncated so as to attack a small part of the periphery of the wafer).

With reference to Figures 7 and 8, it can be seen that the geometry of the leading edge of this first blade 530

can also be circular, as in the case of the blade 130 of the device 10.

According to one particular aspect of this second embodiment of the invention, the cutting means of the device 50 comprise a second cutting means, in addition to the first blade 530 forming the first cutting means.

This second cutting means is illustrated by two blades 531 and 532 placed on each side of the median axis of the wafer that is parallel to the displacement direction of the blade 530 (axis A shown on Figure 5a).

Each of these blades 531 and 532 is designed to engage the wafer 20 in a second phase of the cutting operation, after engagement of this wafer by the first blade 530 corresponding to a first phase.

Consequently, the blade 531 is carried by displacement means 521 to displace the said blade along a trajectory enabling it to:

- attack wafer 20 at a distance from the part at which the first blade 530 attacks it, on a first side of the wafer relative to the direction A of attack of the first blade,
- and possibly to continue this attack around the wafer periphery.

And symmetrically, the second blade 532 is supported by displacement means 522 on the other side of the axis A.

In the view shown in Figures 5a, 5b, 7 and 8, the two displacement means 521 and 522 are arranged so as to displace the blades 531 and 532 along two symmetric

straight line sections convergent towards the median longitudinal axis A of the wafer.

In this second embodiment of the invention, the first cutting means (blade 530, or any blade assembly comprising at least one blade) attacks the wafer 20 during a first cutting phase.

A sensor monitors progress of a parameter representing the cutting operation performed by the first blade 530.

The second cutting phase will be automatically triggered by appropriate control means, as a function of signals output from this sensor.

The second phase corresponds to use of the second cutting means (the two blades 531 and 532 in the example illustrated here - however, the second cutting means could be in the form of an assembly comprising an arbitrary number of blades).

The second cutting means is only started after reaching a predetermined value of the said parameter representing the cutting operation performed by the first blade 530, as memorised in the second cutting phase trigger means.

In particular, this parameter representing the cutting operation carried out by the first blade 530 may be related to the observed spacing between the two parts of the wafer (or it may be the value of the spacing itself).

In this case, the second cutting means is used starting from a given spacing between the two parts of the wafer.

It is also possible to use another additional or alternative parameter representing the cutting operation

performed by the first blade 530 (for example progress of the separation wave).

Thus, in particular, any type of optical, mechanical or other sensor can be used to characterize progress of the separation caused by the attack of the first cutting means, or the spacing between the layer to be cut and the rest of the wafer.

In all cases, the second phase will only be triggered when the parameter(s) representing progress with the cut during the first phase will have reached one or more predetermined values.

If a camera is used as a sensor, it may be an infrared camera, for example located under a quartz window under the wafer 20. This type of window is shown on Figure 5b as reference 502.

The camera could also be an optical camera operating at a different wavelength. This adaptation of the camera characteristics will be made particularly as a function of the nature of the source substrate of the wafer from which the layer to be cut is taken off.

It would also be possible to use a force sensor associated with the first blade 530 in combination with the sensor mentioned above.

In all cases, the sensor of the parameter(s) representing progress of the cut during the first phase will be sufficient to trigger the second phase.

And the signal(s) from this or these sensors may also be used to regulate progress of the second cutting means during the second phase.

Note that the first cutting means may be fixed in place during this second phase, so that a wedge effect continues to occur between the parts of the wafer that it attacked.

- In one variant, it is also possible that the first cutting means will continue its attack on the wafer during the second cutting phase - therefore the first and second cutting means will work in cooperation during this phase.

Thus in one preferred embodiment of the invention, it is possible to control displacement of the first blade 530 in an initial step, such that it attacks the wall of the wafer all by itself.

Note that the displacement velocity of the blade is precisely controlled during the first cutting phase. Typically, this velocity will be between 0.5 and 5 mm/second.

It is also possible to superpose additional means on the sensor that triggers the second phase, to check that each cutting phase takes place smoothly.

Thus, a force measurement system or a blade displacement velocity measurement system can thus be used while the first blade is attacking the wafer corresponding to the first phase.

In this case, the force applied by the first blade as it attacks the wafer, and/or its advance velocity, can be continually varied during the first phase, so that this first phase can be carried out under optimum conditions.

It would also be possible to use measurements from the sensor that triggers the transition between the first and

second phases, to precisely control displacement of each blade during the phase associated with the said blade.

The fact that two cutting means are implemented sequentially, with the passage from the first means to the second means being controlled by a measurement representing progress of the cut during the first phase, means that the separation wave can be made to advance from one end of the wafer to the other under optimum conditions.

This also provides a means of preventing the formation of several separation waves.

Figure 6 illustrates the position of the blade 530 with respect to the bonding interface of a wafer to be cut.

Once again, the blades of the two cutting means will be prepositioned approximately facing this bonding interface. And once again, after the attack by the first blade, the support placed under the wafer will be retracted so as to leave the wafer free along the vertical direction and thus to enable the self-adjustment mentioned above.

Figures 7 and 8 diagrammatically illustrate a top view of the two cutting means during the two cutting phases.

Thus, in Figure 7, the displacement means associated with the first blade 530 bring the blade into contact with the wafer 20 to attack its wall and to generate a separation wave D (for which several successive positions are shown in this figure and in Figure 8).

As can be seen in the figure, the blade 530 may have a "crescent" shape with a curved leading edge to attack the wafer over a continuous part of its periphery.

An appropriate sensor follows the progress of this separation wave D, and/or any other parameter representing the progress of this first cutting phase.

The second cutting means (and therefore the second cutting phase) is activated when the signals output from this sensor reach a predetermined threshold value (see Figure 8).

As mentioned above, the second phase can also be triggered under the control of signals output by different sensors representing different aspects of progress with the first phase. In this case, one or several composite signals generated from elementary signals from the different sensors can be used.

As illustrated in Figure 8, during the second phase the first blade 530 can be immobilised and remain in position at its maximum advance point reached during the first phase, while the second cutting means is activated.

In the case described here, this second cutting means comprises the two blades 531 and 532 that are moved by the corresponding means 521 and 522 to attack the wafer in turn along a controlled trajectory.

Progress of the blades can be controlled during each phase by signals output from a force sensor, in order to avoid applying excessive force to make the blades penetrate into the wafer, causing a risk of damaging the wafer.

The separation wave D continues to progress under optimum conditions as a result of the attack made during the second phase.

Figure 9 provides additional information about the configuration of the blades in the second cutting means,

these two blades being identical. Note also that the two blades are moved symmetrically with respect to the longitudinal A axis of the wafer, by their corresponding displacement means that are slaved together.

In this figure, the blade 532 slides in two rails 5321 and 5322 that guide the trajectory of the blade.

In the configuration in Figure 9 in which the rails are vertical (in other words are in the direction perpendicular to the cutting plane of the wafer), this blade also forms a right angle such that its leading edge is oriented parallel to the horizontal cutting plane in which the blade is guided by the rails.

It is also possible that the rails should be placed one above the other, so as to support the blade 532 in its horizontal cutting plane. In this case, the rails are turned towards the wafer and the blade 532 does not contain a right angle elbow.

Thus, the blade 532 can attack the wafer tangentially, following it continuously around a portion P2 of its periphery (the blade 531 still being able to attack the wafer at a symmetrical portion P1 of its periphery).

Figure 9 shows a preferred embodiment of the blade 532, shown as a cross-section.

In this figure, the shape of the cross-section of the leading edge 5320 of the blade is rounded (the said cross section corresponding to the cross-hatched part of the blade in Figure 9), so that this blade can penetrate into the wafer without any risk of causing damage to it.

Note that this blade 532 does not penetrate into the wafer until the two parts of the wafer have been separated

by the first blade 530. Thus, the blade 532 does not perform a function to initiate separation, it simply propagates separation initiated by the first blade.

Furthermore, the shape of the blade 532 as seen from above may also be circular (corresponding to a vertical downwards view of the blade 532 along the direction of the arrow V in Figure 9).

Thus, Figure 10a shows a top view of a blade 532 for which the shape of the leading edge is circular in this view.

If a blade 532 with a rectangular-shaped top view (or any other shaped top view with sharp edges) is used, there would be a risk of attacking the wafer with the side edge 53210 of this blade that is at the front of the blade displacement, or with the side wedge 53211 between the said lateral edge and the part of the blade that actually forms the leading edge (see Figure 10b).

The description about the first embodiment, particularly related to the wafers to be cut, their chamfers, the geometry of the leading edge of the blades and the self-adjustment of each blade and the wafer itself during the attack by each blade, and the assembly of shims - therefore in this case shim 510 - are equally applicable to this second embodiment.

And also in this second embodiment, the shim 510 may be made mobile during the first cutting phase and/or the second phase, when some blades are fixed.

With reference to Figure 11 that diagrammatically shows a perspective view similar to the view in Figures 3 and 6, and on which a blade 530 has been diagrammatically

shown, note that if the blade can penetrate to a depth (d1 + d2) during the cut equal to approximately 7 mm, this depth does not correspond to the length d1 of the contact area between the blade and the "internal" walls of the wafer.

This contact length is typically only about 2 mm, while the bevelled part of the tip of the leading edge can penetrate by a length d2 equal to approximately 5 mm, without causing any contact between the blade and the wafer.

After initial penetration of the blade into the wafer (during which the pointed tip of the leading edge is actually in contact with the wafer), thus only the constant thickness part of the blade is in contact with the wafer over a contact length of about 2 mm. This contact maintains a controlled spacing between the parts of the wafer that is to be cut.

And the length d1 of this part is equal to approximately the depth of the wafer exclusion zone that is the peripheral superficial area of the wafer that can include some small defects; thus during the cut, and after the initial penetration, the blade only cooperates with the wafer in its exclusion area (in which there is no risk of damaging useful regions deeper in the wafer).

Thus, high precision cutting assemblies operating fully automatically can be formed in each of the two embodiments.

Obviously, the devices described above may be used to cut wafer layers for any purpose. Layers could be cut to be transferred onto a target support like that mentioned

above, or layers that had been bonded together can be cut (for example to recondition layers to which access is required again, so that these layers can be bonded again after reconditioning).

CLAIMS

1. Device for automatic high-precision cutting of a layer of material, for electronics, optics or optoelectronics, joined to a source substrate by means of an embrittled area, the source substrate and the layer to be cut forming an assembly to be cut, the device comprising cutting means and means for maintaining the position of the assembly to be cut, characterised in that the cutting means comprise a blade to attack the assembly to be cut and the maintaining means are adaptable so as to maintain the position of the assembly to be cut only in the cutting plane of the blade once the blade has started to attack the assembly to be cut, leaving the said assembly to be cut free in the direction perpendicular to the said cutting plane.

2. Device according to claim 1, characterised in that the maintaining means comprise a shim.

3. Device according to claim 2, characterised in that the shim is fitted.

4. Device according to one of claims 1 to 3, characterised in that the blade(s) is (are) mobile.

5. Device according to one of claims 1 to 4, characterised in that the maintaining means are arranged so that one side of the assembly to be cut stops in contact with them, usually the side opposite the assembly to be cut first attacked by the blade.

6. Device according to one of the above claims, characterised in that the maintaining means consist of an assembly of shims.

7. Device according to the above claim, characterised in that the maintaining means consist of a single shim.

8. Device according to one of the above claims, characterised in that the blade is used with blade position adjustment means along the direction perpendicular to the cutting plane so that the blade can be placed close to the embrittled area of the assembly to be cut.

9. Device according to one of the above claims, characterised in that the blade has a vertex angle of the order of 60°.

10. Device according to one of the above claims, characterised in that the blade is mounted on automatic displacement means.

11. Device according to the above claim, characterised in that the said automatic displacement means control translation of the blade in the cutting plane.

12. Device according to the above claim, characterised in that the said controlled translation is a uniform translation.

13. Device according to one of the above claims, characterised in that the leading edge of the blade has a

circular contour corresponding to the contour of the assembly to be cut.

14. Device according to the above claim, characterised in that the blade leading edge covers a quarter of the periphery of the assembly to be cut.

15. Device according to one of the above claims, characterised in that the cutting means comprise a first cutting means and a second cutting means.

16. Device according to the above claim, characterised in that it also comprises a sensor capable of acquiring a parameter representing progress with the cutting operation by the first cutting means, and means of triggering use of the second cutting means when the said parameter reaches a predetermined value.

17. Device according to the above claim, characterised in that the said parameter is related to a measurement of the spacing between the parts of the wafer to be cut.

18. Device according to one of the above three claims, characterised in that the first cutting means comprises a blade, and the second cutting means comprises two blades arranged summetrically with respect to the assembly to be cut.

19. Device according to the above claim, characterised in that each blade in the second cutting means is mounted

free to displace on the displacement means and the leading edge of each blade is oriented so as to attack the assembly to be cut tangentially on a portion of its periphery.

20. Process for automatic high-precision cutting of a layer of material joined to a source substrate by means of an embrittled area, the source substrate and the layer to be cut forming an assembly to be cut, the process comprising:

- ✓ positioning of the assembly to be cut with present to the maintaining means,
- ✓ cutting of the layer by cutting means,

characterised in that the cut is made using at least one blade of the cutting means associated with displacement means while the maintaining means maintain the position of the assembly to be cut in the cutting plane, the process including insertion of the blade in a cavity of the assembly to be cut, the said cavity being located close to the embrittled area and the process including self-adjustment along the direction perpendicular to the cutting plane, of the relative positions of the assembly to be cut and the blade as the blade and the assembly to be cut are inserted, by cooperation between the cutting edge of the blade and the concave section of the cavity.

21. Process according to the above claim, characterised in that the said cavity is an approximately annular-shaped cavity.

22. Process according to the above four claims, characterised in that the separation wave of the layer to be cut is followed by analyzing light transmitted through the principal faces of the assembly to be cut.

23. Process according to the above claim, characterised in that movements of the blade displacement means are slaved to observation of separation of the layer to be cut.

24. Process according to one of the above six claims, characterised in that at least one parameter representative of progress with the cutting operation is collected during a first cutting phase carried out by a first cutting means, and the second cutting phase made by a second cutting means is controlled as a function of the value of this parameter.

25. Process according to one of the above claims, characterised in that the first cutting means is a blade attacking the assembly to be cut at a first location, and the second cutting means attack the assembly to be cut at a distance from the part of the said assembly attacked by the first cutting means.

26. Process according to the above claim, characterised in that the second cutting means comprises two blades on each side of the assembly to be cut, and moved symmetrically with respect to this assembly.