

Method for forming saw-cuts into a semiconductor product

The present invention relates to a method for forming saw-cuts into a semiconductor product. The invention also relates to a sawing device.

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A wafer or substrate is a thin slice of semiconducting material, such as crystalline silicon. A substrate is also simply referred to as semiconductor material. If integrated circuits, or other objects are present on a substrate, the substrate is referred to as semiconductor product. During semiconductor product
10 manufacturing, a wafer or substrate is typically cut into separate smaller units. This process is referred to as singulation and units are small blocks of semiconductor whereon an integrated circuit is fabricated. Singulation is also referred to as separation or individualisation, and can be accomplished in various ways, for example by scratching and breaking the substrate, by cutting via a laser, or by
15 sawing. Singulation is often an automated process, as this enables accurate and precise separation of the smaller units. However, regardless of singulation being an automated process, the accuracy and precision thereof still leaves to be desired. A reason therefor is the high demands placed on accuracy and precision of singulation. The smaller units need to be very precisely dimensioned to be able to
20 incorporate them in electronic equipment.

Apart from demands on precision and accuracy, demands on cost reduction are also present. In order to reduce costs, lower quality substrates are used. The lower quality of substrates typically is attributed to increased curvature of the substrate.
25 Typically, a substrate has a very limited thickness as compared to its length and width. As described herein the direction wherein the thickness of a substrate extends, is referred to as the Z direction, and the upper surface and the lower surface of the substrate extend in both the X direction and Y direction, wherein the X, Y, and Z directions are all perpendicular to each other. A substrate can be
30 curved in any combination of these different X, Y, and Z directions.

In the case of singulation via sawing, variation in a depth of a saw-cut is influenced by curvature of the substrate in the Z-direction. In practice, curvature of the substrate in the Z direction is not particular relevant during singulation, as a saw
35 blade cuts through the entire thickness of the substrate. As such, precision and

accuracy of the position of the saw blade with respect to the substrate with regard to the Z direction is of less relevance during singulation. Curvature in the X and/or Y directions is very relevant during singulation, in contrast to curvature in the Z direction. Such a curvature within the X, Y oriented plane of the substrate is referred to as camber. As saw-blades are generally configured to cut in a straight line, any camber in the substrate could result in poorly cut and uneven units.

If the substrate is not curved in either the X or the Y direction, the smaller units obtained after singulation will be cut exactly at the intended position. If the substrate is curved in the X direction, an approach to limit the deviations in the dimension of the units is to first cut the substrate in either the X or the Y direction, such that two substrate halves are obtained. The two substrate halves are thereafter individually subjected to a singulation process. A sawblade cuts in a straight line such that a total difference between the intended cutting trajectory (which is curved, due to the substrate's curvature) and a straight cutting line is minimized. By first cutting the substrate in half, the position where the sawblade cuts in a straight line, can be optimized for each half.

However, the efficiency of production, measured in unit per hour (UPH), decreases due to cutting the substrate in half and by measuring the curvature of each half individually prior to singulation. UPH measurements describe the average processing rates of equipment, in this case sawing equipment.

Regardless of the UPH loss, the average deviation of saw cuts from intended sawing trajectories on a substrate still remains unacceptably large. In particular, when lower quality substrates are used which typically display curvature in one or multiple directions. As a result, the outer dimensions of the singulated unit deviates from the intended outer dimensions. When the unit contains an integrated circuit, the distance from one or more outer edges of the unit to the integrated circuit can become unacceptably small. As such, the unit will have to be discarded, representing an undesirable loss.

There is thus a need for a singulation process wherein, for a unit, a difference between the actual outer dimensions of the unit and the intended outer dimensions

of the unit is further minimized. In general, there is a need to more accurately singulate substrates.

In a first aspect, the invention hereto provides a method for forming saw-cuts into a semiconductor product, comprising the steps of:

- gripping a semiconductor product with a carrier having a X, Y oriented holding surface,
- determining the position in X, Y orientation of a semiconductor product held by the carrier,
- 10 - controlling a relative movement of the carrier and a saw blade, in particular a circular saw blade, for cutting the semiconductor product based on the position of the semiconductor product held by the carrier,

wherein besides the position also the shape in X, Y orientation of the semiconductor product held by the carrier is detected, and

- 15 wherein during the cutting of the semiconductor product the saw blade and the carrier are moved with respect to each other in X and Y orientations to saw non-linear cuts in the semiconductor product, in particular non-linear cuts in X, Y orientation. Optionally, the saw blade and the carrier are moved simultaneously with respect to each other in X and Y orientations.

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By moving the saw blade and the carrier with respect to each other, in X and Y orientations, non-linear cuts can be made in the semiconductor product. Non-linear is for instance curved. This allows to compensate for non-linearities or cambers in the semiconductor product during sawing. In addition, the average processing rate, measured in UPH, does not decrease when making non-linear cuts according to the method according to the invention.

An X, Y oriented surface is a surface that extends in both the X and Y directions. The shape in X, Y orientation of the semiconductor product is a two dimensional shape of a surface of the semiconductor product. Typically, the surface of the semiconductor product is furthest from the carrier and closest to the saw-blade.

The compensation for non-linearities or cambers in the semiconductor product in both X and Y directions is different from compensation for non-linearities in the Z-direction, i.e. the thickness direction, of the semiconductor product. Compensation

for non-linearities in the Z-direction is of less relevance for the present invention, as it is preferred that the sawn non-linear cuts extend through the entire thickness of the semiconductor product.

- 5 Preferably, the carrier is moved in an X direction and the sawing blade is moved in a Y direction. Any compensation for a camber in the semiconductor product in the X or Y direction is effected by at least one (small) movement of the saw blade in the perpendicular direction in the X, Y oriented plane during sawing. This ensures that the saw blade only has to move over a very small range in as compared to the
- 10 range wherein the carrier moves. As the carrier typically does not comprise parts that move or rotate with respect to the carrier itself during sawing, it is advantageous to move the carrier over a relatively large distance during sawing, while the saw blade is moved over a relatively small distance. Moving the saw blade over a relatively large distance would result in a more complex construction
- 15 of the sawing device, as the saw blade would have to simultaneously rotate and move over a relatively large distance.

During detection of the orientation and the shape in X, Y orientation of the semiconductor product at least two references on the semiconductor product held

20 by the carrier may be detected. Preferably, more than two references on the semiconductor product held by the carrier are detected. These references are also referred to as fiducials or fiducial markers and can take any form or shape. The fiducials aid in detecting a camber or curvatures of the semiconductor product in primarily the X and Y directions.

- 25 The relative movement of the carrier and the saw blade may also be controlled in a Z direction, which Z direction is perpendicular to the X, Y oriented holding surface of the carrier. This allows to correct for curvature or a camber of the semiconductor product during sawing. In particular, this is advantageous when saw cuts of a
- 30 specific depth have to be made in the semiconductor product. Movement of the carrier may for instance be controlled in an X direction, while the movement of the saw blade may be controlled in the Y direction. Both the carrier and the saw blade may be controlled in the Z direction.

Relative movement of the carrier and saw blade in X, Y orientation is possible while the saw blade makes a saw cut. If, for example a saw cut has to be made in the X direction, the saw blade will rotate within an X, Z oriented plane. As the saw blade cuts in the semiconductor product, the saw blade is moved in the X direction
5 relative to the carrier. As such, a part of the outer cutting edge of the saw blade is 'trapped' within the saw cut, particularly when the saw blade is circular, and relative movement of the saw blade and the carrier in the Y direction (i.e. the direction perpendicular to the X direction in an X, Y oriented plane) is limited.

10 Curvature of semiconductor product is most very limited. Saw cuts made using the saw blade are a little bit wider than the average thickness of the saw blade at the position of the cutting edge of the saw blade. As such, there is room for moving the saw blade relative to the carrier in the Y direction at small increments. These small movements in the Y direction are sufficient to compensate for curvature of the
15 semiconductor product.

Nevertheless, it is preferred that the carrier and the saw blade are also relatively rotated in an X, Y oriented plane. In particular, the carrier and the saw blade are relatively rotated in an X, Y oriented plane around an imaginary axis extending in
20 the Z direction. This means that the outer edge of the saw blade that contacts the semiconductor product while making a saw cut, is directed both in the X and (slightly) in the Y direction. This allows the saw blade to more easily follow any curvature of the semiconductor product. In turn, this results in more accurately singulated units.

25 In particular, the ability of the saw blade to be rotated in an X, Y oriented plane relatively to the carrier, i.e. rotational freedom, is most conveniently provided by rotating the carrier in the X, Y oriented plane, in particular around an imaginary axis extending in the Z direction.

30 In line with the above, at least one non-linear cut is made in the semiconductor product and the X direction or Y direction mutually enclose an angle R that is larger than 0°. Depending on the relative movement of the saw blade and the carrier in the X, Y oriented surface of the substrate when a saw cut is formed, the angle R

can vary and be adjusted as desired, based on curvature of the semiconductor product.

Preferably, the positions and orientations of saw-cuts are registered.

- 5 Advantageously, the registered positions and orientations of saw-cuts aid increasing the accuracy and precision of the saw-cuts that have yet to be made. As such, the trajectory of the saw blade relative to the semiconductor product can be adjusted during sawing. In addition, registered positions and orientations of saw-cuts aid in increasing accuracy and precision of subsequent saw cuts and serve to
- 10 calibrate the saw blade and the carrier.

In a second aspect, the invention provides a sawing device for forming saw-cuts into a semiconductor product, comprising:

- 15 - a moveable carrier comprising a X, Y oriented holding surface for holding a semiconductor product,
- a saw blade comprising a cutting edge, moveable relative to the carrier,
- a drive system for relative movement of the carrier and the saw blade;
- at least one sensor for determining the position and shape in X, Y
- 20 orientation of the semiconductor product held by the carrier, and
- a control unit for controlling the drive system,

wherein the control unit and the drive system enable to perform the method for forming saw-cuts into a semiconductor product as disclosed hereinabove such that

25 during the cutting of the semiconductor product the saw blade and the carrier are relatively moved in X and Y directions to saw non-linear cuts in the semiconductor product. In particular, wherein during the cutting of the semiconductor product the saw blade and the carrier are relatively moved simultaneously in X and Y directions. The saw blade can for instance be movable only in the X direction, while

30 the carrier is movable only in the Y direction. It is also possible that the saw blade is only movable in the Y direction, while the carrier is only movable in the X direction. Another option is that the saw blade is stationary within the sawing device, i.e. the saw blade is not movable in neither the X direction and the Y direction. The carrier should as such be movable in both the X direction and the Y direction, to allow

35 sawing of non-linear cuts.

Preferably the saw blade and the carrier are also relative moveable in a Z direction, which Z direction is perpendicular to the X, Y oriented holding surface of the carrier. As described herein, this allows to correct for curvature or a camber of the semiconductor product during sawing. In particular, this is advantageous when saw cuts of a specific depth have to be made in the semiconductor product. Movement of the carrier may for instance be controlled in a Z direction and an X direction, while movement of the saw blade may be controlled in the Y direction. In addition, the saw blade may be controlled in the Z direction as well.

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In an embodiment, the saw blade and the carrier are also relative rotationally moveable in an X, Y oriented plane. In particular, the carrier and the saw blade are relatively rotationally movable in an X, Y oriented plane around an imaginary axis extending in the Z direction. This means that the outer edge of the saw blade that contacts the semiconductor product while making a saw cut, may be directed both in the X and (slightly) in the Y direction. This allows the saw blade to more easily follow any curvature of the semiconductor product. In turn, this results in more accurately singulated units. It is advantageous that the rotational moveability is provided by the carrier.

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In another embodiment, the at least one sensor is sensitive for fiducials on a semiconductor product held by the carrier. The fiducials aid in detecting a camber or curvatures of the semiconductor product in primarily the X and Y directions.

25 Preferably, the at least one sensor is an optical sensor. An optical sensor is a device capable of converting light rays into electronic signals. A camera is an example of an optical sensor. Optical sensors are capable of reliably establishing the position of fiducials. As such, they are suited for establishing the exact location of the semiconductor product with respect to the saw blade. In line therewith, the sawing device may also include a distance sensor, in particular a confocal sensor, for detecting the relative distance of the saw blade to the surface of the semiconductor product held by the carrier.

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Preferably, the control unit is connectable to a subsequent processing station for transferring the positions and orientations of realised saw-cuts. As such,

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information about the exact shape of singulated semiconductor product is used for subsequent processing of the smaller units.

Preferably, the saw blade is a circular saw blade. Circular saw blades are efficient
5 to saw blades for singulating semiconductor products.

The present invention will be further elucidated on the basis of the non-limitative exemplary embodiments shown in the following figures. Herein shows:

Figure 1 A schematic view of a substrate without a camber; and
10 Figure 2 A schematic view of a substrate with a camber.

Figure 1 shows a high quality substrate 1, without any curvature. A sawing trajectory 2 is depicted going straight through the substrate in a linear fashion. Because of the high quality substrate, the saw cut is straight and parallel to the
15 longitudinal sides 3, 4 of the substrate.

Figure 2 shows a curved substrate 1 of lesser quality. The curve is exaggerated, as an example. The substrate 1 can be gripped by a carrier and the position of the substrate 1 held by the carrier (not shown) is determined. The carrier and a saw
20 blade for cutting the substrate 1 are moved relatively, resulting in a curved sawing trajectory 2. The curved sawing trajectory 2 adjusts for the curvature in the substrate 1 and is more or less parallel to the curved sides 3, 4 of the substrate 1. By following the curvature of the substrate, smaller units can eventually be obtained that are more accurately singulated.

25 It will be clear that the invention is not limited to the exemplary embodiments which are described here, but that countless variants are possible within the framework of the attached claims, which will be obvious to the person skilled in the art. In this case, it is conceivable for different inventive concepts and/or technical measures of
30 the above-described variant embodiments to be completely or partly combined without departing from the inventive idea described in the attached claims.

The verb 'comprise' and its conjugations as used in this patent document are understood to mean not only 'comprise', but to also include the expressions
35 'contain', 'substantially contain', 'formed by' and conjugations thereof.

Claims

1. Method for forming saw-cuts into a semiconductor product, comprising the steps of:
- 5
- gripping a semiconductor product with a carrier having a X, Y oriented holding surface,
 - determining the position in X, Y orientation of a semiconductor product held by the carrier,
 - 10 – detecting the shape in X, Y orientation of the semiconductor product held by the carrier,
 - controlling a relative movement of the carrier and a saw blade for cutting the semiconductor product based on the position of the semiconductor product held by the carrier,
 - 15 wherein during the cutting of the semiconductor product the saw blade and the carrier are moved with respect to each other in both X and Y orientations during the cutting of the semiconductor product to saw non-linear cuts in the semiconductor product.
- 20 2. Method according to claim 1, **characterised in that** the carrier is moved in an X direction and the saw blade is moved in a Y direction.
3. Method according to claims 1 or 2, **characterised in that** during detection of the orientation and the shape in X, Y orientation of the semiconductor product at
- 25 least two references on the semiconductor product held by the carrier are detected.
4. Method according to any of the preceding claims, **characterised in that** the relative movement of the carrier and the saw blade is also controlled in a Z direction, which Z direction is perpendicular to the X, Y oriented holding surface of
- 30 the carrier.
5. Method according to any of the preceding claims, **characterised in that** the carrier and the saw blade are also relatively rotated in an X, Y oriented plane.

6. Method according to claim 5, **characterised in that** at least one non-linear cut sawn in the semiconductor product and the X direction or Y direction mutually enclose an angle R that is larger than 0°.

5 7. Method according to any of the claims 1 – 6, **characterised in that** the positions and orientations of saw-cuts are registered.

8. Sawing device for forming saw-cuts into a semiconductor product, comprising:

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- a moveable carrier comprising a X, Y oriented holding surface for holding a semiconductor product,
- a saw blade comprising a cutting edge, moveable relative to the carrier,
- a drive system for relative movement of the carrier and the saw blade, in
- 15 particular for relative movement of the carrier and the saw blade in both X and Y orientations during the cutting of a semiconductor product;
- at least one sensor for determining the position and shape in X, Y orientation of the semiconductor product held by the carrier, and
- a control unit for controlling the drive system,

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wherein the control unit and the drive system enable to perform the method for forming saw-cuts into a semiconductor product according any of the preceding claims such that during the cutting of the semiconductor product the saw blade and the carrier are relatively moved simultaneously in X and Y directions to saw non-

25 linear cuts in the semiconductor product.

9. Sawing device according to claim 8, **characterised in that** the saw blade and the carrier are also relative moveable in a Z direction, which Z direction is perpendicular to the X, Y oriented holding surface of the carrier.

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10. Sawing device according to claim 8 or 9, **characterised in that** the saw blade and the carrier are also relative rotationally moveable in an X, Y oriented plane.

11. Sawing device according to any of the claims 8 – 10, **characterised in that** the at least one sensor is sensitive for fiducials on a semiconductor product held by the carrier.
- 5 12. Sawing device according to any of the claims 8 – 11, **characterised in that** the at least one sensor is an optical sensor.
13. Sawing device according to any of the claims 8 – 12, **characterised in that** the sawing device also includes a distance sensor, in particular a confocal sensor,
10 for detecting the relative distance of the saw blade to the surface of the semiconductor product held by the carrier.
14. Sawing device according to any of the claims 8 – 13, **characterised in that** the control unit is connectable to a subsequent processing station for transferring
15 the positions and orientations of realised saw-cuts.
15. Sawing device according to any of the claims 8 – 14, wherein the saw blade is a circular saw blade.