Description

Title of Invention

CUTTING APPARATUS AND METHOD FOR PRODUCING CUT PRODUCT

Technical Field

[0001]

This disclosure relates to a cutting apparatus and a method for producing a cut product.

Background Art

[0002]

Lead frames with semiconductor chips or the like mounted thereon are typically sealed up in resin and then cut by a cutting apparatus to be singulated for production of two or more electronic parts. Electronic parts are each electrically connected to external wiring through a lead frame connected to a semiconductor chip. A cutting apparatus may, depending on the kind of electronic parts, first use a wide blade to cut a lead frame to a depth approximately half the thickness of the lead frame and avoid completely cutting the lead frame along its thickness to form a groove and then use a narrow blade to completely cut the lead frame (see, for example, Patent Literature 1). Cutting a lead frame as such forms a step at the edge of the lead frame.

[0003]

Patent Literature 1 discloses a quad flat non-leaded (QFN) package including a lead frame ("electrode" in Patent Literature 1) with a step formed by the above method.

Citation List

Patent Literature

[0004]

Patent Literature 1: JP 2019-036660 A

Summary of Invention

Technical Problem

[0005]

Patent Literature 1 discloses a wettable-flank QFN package including a lead frame with a step. Producing the package requires avoiding completely cutting the lead frame in cutting the lead frame to a depth approximately half the thickness of the lead

frame to form a groove. This in turn requires measuring the heightwise position of the lead frame and determining on the basis of the measurement result the amount by which to cut the lead frame before forming a groove. Patent Literature 1 fails to disclose a method for measuring the heightwise position of a lead frame, leaving room for improvement.

[0006]

The above circumstances have led to a demand for a cutting apparatus and a method for producing a cut product each of which is capable of measuring the heightwise position of a lead frame.

Solution to Problem

[0007]

A cutting apparatus as an embodiment of this disclosure is a cutting apparatus configured to, for an object to be cut which includes a plate-shaped lead frame having a first face provided with a resin layer and a second face opposite to the first face, form a groove in the second face, the cutting apparatus including: a cutting table on which the object to be cut is placeable; a light source configured to emit light to the second face of the object to be cut while the object to be cut is on the cutting table; a blocking member disposed partway along a path along which the light from the light source propagates to the object to be cut, the blocking member being configured to block a portion of the light emitted from the light source; an imaging mechanism configured to obtain a captured image of the second face of the object to be cut; a height adjusting mechanism configured to adjust a height of the imaging mechanism; and a calculator configured to analyze the captured image, the imaging mechanism including: a lens disposed on the path and between the blocking member and the object to be cut, the lens being configured to collect the light from the light source onto the second face; and an imager disposed opposite to the cutting table across the object to be cut, the imager being configured to receive the light having been reflected by the object to be cut to obtain the captured image, the imager being configured to obtain captured images at a plurality of heights as adjusted by the height adjusting mechanism, the calculator being configured to calculate a heightwise position of the second face on a basis of a state of focus of the blocking member in the captured images.

[0008]

A method as an embodiment of this disclosure for producing a cut product is forming a groove in an object to be cut with use of the cutting apparatus; and cutting the object to be cut, in which the groove has been formed, for singulation into a plurality of cut products.

Advantageous Effects

[0009]

This disclosure may be embodied as a cutting apparatus and a method for producing a cut product each of which is capable of measuring the heightwise position of a lead frame.

Brief Description of Drawings

[0010]

Fig. 1 is a plan view of a package substrate.

Fig. 2 is a cross-sectional view taken along line II-II in Fig. 1.

Fig. 3 is a plan view of a cutting apparatus.

Fig. 4 is a front view of a cutting apparatus.

Fig. 5A is a cross-sectional view indicative of a groove forming step for a package substrate with use of a cutting apparatus.

Fig. 5B is a cross-sectional view indicative of a singulating step for a package substrate with use of a cutting apparatus.

Fig. 5C is a perspective view of an electronic part as singulated by a cutting apparatus.

Fig. 6 is a diagram schematically illustrating the configuration of a measurement unit with a blocking member not in focus.

Fig. 7 is a partial plan view of a substrate provided with cross marks.

Fig. 8 is a diagram indicative of a process of calculating a peak contrast value with use of a measurement unit.

Fig. 9 is a graph that shows a peak contrast value relative to the distance between a holder pillar and a second face.

Fig. 10 is a flowchart indicative of a process of calculating the distance between a holder pillar and a second face.

Fig. 11 is a diagram schematically illustrating the configuration of a measurement unit with a blocking member in focus.

Description of Embodiments

[0011]

The description below deals with a cutting apparatus and a method for producing a cut product as embodiments of this disclosure with reference to drawings. The embodiments below are mere examples for describing a cutting apparatus and a method for producing a cut product. The cutting apparatus and the method for producing a cut

product are not limited to the embodiments below. The cutting apparatus according to this disclosure and the method according to this disclosure for producing a cut product may be embodied variously without departing from the scope of this disclosure.

[0012]

Substrates with elements such as semiconductor chips mounted thereon are sealed up in resin into package substrates and then cut to be singulated for production of two or more electronic parts. Package substrates sealed up in resin are cut with use of a dedicated cutting apparatus.

[0013]

Substrates are sealed up in resin as a result of placing substrates on a molding die of a resin molding apparatus and supplying liquid, molten resin into the molding die. The molten resin may be a thermoplastic resin or a thermosetting resin. A thermosetting resin has a viscosity that decreases when heated. Continuing to heat a thermosetting resin polymerizes and cures the thermosetting resin into a cured resin. A thermosetting resin is desirable in resin-sealing substrates with elements such as semiconductor chips mounted thereon. The resin in which the substrates are sealed up protects the elements mounted on the substrates.

[0014]

The cutting apparatus cuts a package substrate to produce two or more electronic parts. The term "cut" as used herein conceptually covers dividing an object to be cut into two or more singulated cut products and removing a portion of an object to be cut to form a thickness-wise groove. The description below may use the expression "fully cut" to refer to the cutting operation of dividing an object to be cut into two or more singulated cut products and the expression "half-cut" to refer not to the cutting operation of dividing an object to be cut but to the cutting operation of removing a portion of an object to be cut to form a thickness-wise groove. The description below deals first with a package substrate and then with the cutting apparatus for cutting a package substrate.

[0015]

[Configuration of Package Substrate]

Fig. 1 is a plan view of a package substrate 4 (which is an example of the object to be cut) for the present embodiment. Fig. 2 is a cross-sectional view of the package substrate 4 taken along line II-II in Fig. 1. The package substrate 4 for the present embodiment is not limited to any particular kind and is, for example, a wettable-flank quad flat non-leaded (QFN) package substrate. As illustrated in Figs. 1 and 2, the package substrate 4 includes a substrate 41 (which is an example of the lead frame) in the form of a rectangular plate made of a metal such as copper and a rectangular resin layer 42 on a

face of the substrate 41. The description below uses the term "first face 41a" to refer to that face of the substrate 41 on which the resin layer 42 is disposed and the term "second face 41b" to refer to that face of the substrate 41 which is opposite to the first face 41a. The substrate 41 may be a lead frame.

[0016]

The lead frame (that is, the substrate 41) for the present embodiment has a first face 41a provided with two or more semiconductor chip mounting sections (that is, die pads [not illustrated in the drawings]) arranged in a matrix. The semiconductor chip mounting sections are provided with electronic elements 43 mounted thereon such as semiconductor chips, resistors, and capacitors. The substrate 41 for the present embodiment is provided with a total of twelve electronic elements 43 in two columns arranged widthwise and six rows arranged lengthwise. The substrate 41 is made of a metal such as copper (Cu) or Alloy 42 (Fe-Ni) and is electrically conductive. The substrate 41 typically has a face provided with a lead-free metal plating layer or a lead-free solder plating layer (not illustrated in the drawings) formed in advance. The substrate 41 is provided with a large number of leads disposed around each die pad and serving as terminals for external connection. The large number of leads are connected to tie bars arranged in a grid pattern on the substrate 41 to form a metal frame. The electronic elements 43 each include two or more electrodes (not illustrated in the drawings) electrically connected to the leads, which are disposed around the die pad, through bonding wires in the form of gold or copper wires.

[0017]

The substrate 41 for the present embodiment has a rectangular use area 411 and a no-use area 412 around the usable area 411. The no-use area 412 covers the outer edge of the substrate 41. The no-use area 412 is not for use in final products: It is cut off for removal. The use area 411 is, on the other hand, for use in final products and covers the die pads, leads, and tie bars on the lead frame described above. The resin layer 42 is so rectangular as to cover the use area 411 of the substrate 41 and a portion of the no-use area 412, which is outside the use area 411. This means that the resin layer 42 seals up the electronic elements 43 and the bonding wires in the use area 411. Forming such a resin layer 42 forms between the first face 41a of the substrate 41 and the end face of the resin layer 42 (that is, its upper face in Fig. 2) a step corresponding to the thickness of the resin layer 42. The substrate 41, which is included in the package substrate 4, is not limited to a lead frame.

[0018]

[Configuration of Cutting Apparatus]

Figs. 3 and 4 each illustrate a cutting apparatus 1 as the present embodiment. The cutting apparatus 1 includes a cutter unit 10 (which is an example of the first cutting mechanism and the second cutting mechanism), a holder unit 20, a measurement unit 30, and a control unit 50 as main components. The cutting apparatus 1 is configured as follows: The holder unit 20 holds a package substrate 4. The cutter unit 10 cuts the package substrate 4. Before the cutting operation, the measurement unit 30 measures the heightwise position of the second face 41b of the substrate 41 for cutting the package substrate 4. The control unit 50 controls the entire series of cutting steps.

[0019]

The cutting apparatus 1 may include a unit(s) other than the above. The cutting apparatus 1 may include, for example, a substrate supply unit configured to supply package substrates 4, an inspection unit configured to inspect package substrates 4 and/or electronic parts 40 (which is an example of the cut product), a washer unit configured to wash and/or dry electronic parts 40 resulting from the cutting operation, and/or a conveyer unit configured to convey electronic parts 40 resulting from the cutting operation to a container. The description below deals in detail with the respective configurations of the cutter unit 10, the holder unit 20, the measurement unit 30, and the control unit 50. Figs. 3 and 4 each show for the present embodiment an X axis perpendicular to the opposite faces of each blade 11 (described later), a Y axis perpendicular to the X axis and parallel to the placement face 22a of a table 22 (which is an example of the cutting table), and a Z axis perpendicular to the placement face 22a, that is, to the X and Y axes.

[0020]

As illustrated in Figs. 3 and 4, the cutter unit 10 is disposed above the holder unit 20 and configured to cut a package substrate 4. The cutter unit 10 includes blades 11, a spindle 13, and a spindle moving mechanism (not illustrated in the drawings) configured to move the spindle 13 to a desired position in the cutting apparatus 1. The spindle 13 includes a shaft 13a configured to rotate a blade 11 (described later). The shaft 13a of the spindle 13 extends along the X axis. This means that the shaft 13a and the blade 11 rotate about the X axis. The spindle 13 is movable by the spindle moving mechanism (not illustrated in the drawings) along the X and Z axes in Figs. 3 and 4. The control unit 50 (described later) controls how the spindle moving mechanism operates, that is, the movement of the spindle 13 and its positions along the X and Z axes. The description below may use the term "heightwise axis" for the spindle 13 or the blade 11 to refer to the Z axis in Figs. 3 and 4. The control unit 50 is configured to obtain information on the positions of the spindle 13 along the X and Z axes on the basis of information from the spindle moving mechanism.

[0021]

The blades 11 are each in the form of a disc with a blade section along its outer edge. The blades 11 are detachably attached to the shaft 13a of the spindle 13. The blades 11 are each movable along the X and Z axes in Figs. 3 and 4 together with the spindle 13 to which the blade 11 is attached.

[0022]

The blade 11 attached to the shaft 13a of the spindle 13 receives rotation from the spindle 13 through the shaft 13a to rotate at high speed and half-cut or fully cut a package substrate 4 with its blade section along the outer edge. The description below uses the term "first blade 11a" (which is an example of the blade) to refer to a blade 11 for a half-cutting operation, the term "second blade 11b" to refer to a blade 11 for a full-cutting operation, and the term "blade(s) 11" to collectively refer to either or both of the first and second blades 11a and 11b. The first blade 11a has a first thickness, whereas the second blade 11b has a second thickness smaller than the first thickness. This means that the second blade 11b is thinner than the first blade 11a (see Figs. 5A and 5B). The present embodiment is configured such that either of the first and second blades 11a and 11b is attached to the spindle 13 for a cutting operation. The first and second blades 11a and 11b are attachable to and detachable from the spindle 13 and are interchangeable with each other.

[0023]

The holder unit 20 includes a table 22 and a table moving mechanism 24. The table 22 has a placement face 22a on which a package substrate 4 is placeable with the resin layer 42 in contact with the placement face 22a. The holder unit 20 holds the package substrate 4 by air suction or the like. The table moving mechanism 24 is configured to move the table 22 along the Y axis and rotate the table 22 about the Z axis by 90 degrees. While the holder unit 20 is holding a package substrate 4, the table 22 moves along the Y axis relative to the blade 11 and rotates about the Z axis for the blade 11 to cut the package substrate 4 lengthwise and widthwise.

[0024]

It is only relative to the table 22 that the spindle 13 is movable. The table 22, instead of the spindle 13, may be movable along the X axis; the table 22, instead of the spindle 13, may be movable along the Z axis; and the spindle 13, instead of the table 22, may be movable along the Y axis.

[0025]

As illustrated in Figs. 5A to 5C, the cutting apparatus 1 first half-cuts a package substrate 4 and then fully cuts the package substrate 4 to produce electronic parts 40.

Specifically, the method for producing electronic parts 40 includes a groove forming step for the cutting apparatus 1 half-cutting the substrate 41 of a package substrate 4 to form half-cut grooves 44 (which is an example of the groove) with a desired depth and a singulating step for the cutting apparatus 1 fully cutting the grooved package substrate 4 to singulate the package substrate 4 into two or more electronic parts 40. Figs. 5A to 5C each show a lengthwise cross section of a package substrate 4.

[0026]

Fig. 5A illustrates the groove forming step, which first attaches the first blade 11a to the shaft 13a of the spindle 13. The groove forming step then places a package substrate 4 on the table 22 such that the package substrate 4 has a length parallel to the opposite faces of the first blade 11a. The groove forming step positions the first blade 11a between mutually adjacent ones among the two or more electronic elements 43 (see Fig. 1) fixed to the package substrate 4 while the table 22 is holding the package substrate 4. The groove forming step then rotates the first blade 11a at its current position and simultaneously moves the table 22 along the Y axis for the first blade 11a to half-cut the package substrate 4 lengthwise, that is, along the Y axis, and thereby form a half-cut groove 44 in the substrate 41 of the package substrate 4. Specifically, the groove forming step removes a portion of the substrate 41 along the thickness of the package substrate 4 (for example, a portion with a depth approximately equal to half the thickness of the substrate 41 [that is, the lead frame]). After forming a half-cut groove 44, the groove forming step moves the first blade 11a along the X axis to position the first blade 11a between other mutually adjacent electronic elements 43. The groove forming step then moves the table 22 along the Y axis again to form another half-cut groove 44 in the package substrate 4. The groove forming step repeats the above operations to form two or more (for example, three along the length of the package substrate 4) half-cut grooves 44.

[0027]

Next, the groove forming step rotates the table 22 about the Z axis by 90 degrees while the table 22 is holding the package substrate 4 so that the package substrate 4 has a width parallel to the opposite faces of the first blade 11a. The groove forming step then rotates the first blade 11a at its current position and simultaneously moves the table 22 along the Y axis similarly to the above for the first blade 11a to form a half-cut groove 44 along the width of the package substrate 4. The groove forming step repeats the above operations to form two or more (for example, seven along the width of the package substrate 4) half-cut grooves 44. The groove forming step thereby forms half-cut grooves 44 extending in a grid pattern along the length and width of the package substrate 4 and

is completed.

[0028]

Fig. 5B illustrates the singulating step, which first detaches the first blade 11a from the spindle 13 and attaches the second blade 11b to the spindle 13. The singulating step then fully cuts the package substrate 4 with use of the second blade 11b. Specifically, the singulating step cuts the remaining portion of the substrate 41 and the resin layer 42 along each half-cut groove 44 with use of the second blade 11b substantially at the center along the axis along which the half-cut groove 44 extends. This cutting operation follows a procedure identical to that of the half-cutting operation and is not detailed here. The above operations thereby cut the package substrate 4 along the half-cut grooves 44 in a grid pattern for singulation into two or more (twelve for the present embodiment) electronic parts 40 (see Fig. 5C).

[0029]

The measurement unit 30 is configured to measure the heightwise position of the second face 41b of the substrate 41 of a package substrate 4. The measurement unit 30 measures the heightwise position of the second face 41b accurately for the first blade 11a to form a half-cut groove 44 with a desired depth in the substrate 41. The measurement unit 30, as illustrated in Fig. 6, includes an imaging mechanism 31, a height adjusting mechanism 32, a light source 33, a blocking member 34, a calculator 35, a half mirror 36 (which is an example of the mirror), and a contact cutter setup (CCS) block 37 (which is an example of the reference block).

[0030]

The imaging mechanism 31 functions to image the second face 41b of the substrate 41 of a package substrate 4, and includes a camera 31a (which is an example of the imager), a lens 31b, and a first tube 31c in the form of a square tube connecting the camera 31a to the lens 31b. The camera 31a contains an imaging element such as a CCD or a CMOS (not illustrated in the drawings) configured to form an image of the second face 41b as a captured image 31d (see (a) in Fig. 8). For this purpose, the imaging element of the camera 31a has a light-receiving face configured to face the second face 41b. The lens 31b is configured to collect light having been reflected by the second face 41b and let the light pass (or propagate) through the tube of the first tube 31c for the imaging element of the camera 31a to form an image. For this purpose, the lens 31b is between the camera 31a and the second face 41b. The camera 31a is attached to a first end of the first tube 31c, whereas the lens 31b is attached to a second end of the first tube 31c. This means that the imaging mechanism 31 is an integral whole.

[0031]

The height adjusting mechanism 32 includes a main pillar 32a extending along the Z axis and a holder pillar 32b extending from the main pillar 32a along the X axis. The holder pillar 32b is movable along the Z axis relative to the main pillar 32a. The holder pillar 32b holds the first tube 31c and is moved along the Z axis to move the imaging mechanism 31 along the Z axis. The holder pillar 32b is moved by, for example, a motor (not illustrated in the drawings). The control unit 50 obtains information on the number of revolutions of the motor while the holder pillar 32b is being moved vertically to obtain information on the heightwise position of the holder pillar 32b, that is, the heightwise position of the camera 31a.

[0032]

The light source 33 is configured to emit light to the second face 41b of the substrate 41 of a package substrate 4, and is in the form of, for example, an LED. The light source 33 is attached to a first end of a second tube 33a in the form of a square tube. The light emitted from the light source 33 travels inside the second tube 33a. The second tube 33a has a second end connected to the side surface of the first tube 31c. The light from the light source 33 enters the internal space of the first tube 31c. Specifically, the first tube 31c has a side surface with a hole blocked by the second tube 33a. The second tube 33a extends along the X axis.

[0033]

The half mirror 36 is so disposed inside the first tube 31c as to reflect light having passed through the inside of the second tube 33a along the X axis to cause the light to travel toward the second face 41b along the Z axis. The half mirror 36 is configured to let light directly pass therethrough which light has been reflected by the second face 41b and then collected by the lens 31b to cause the light to be incident on the imaging element of the camera 31a. This means that the light emitted from the light source 33 travels through the inside of the second tube 33a, enters the first tube 31c, and is reflected by the half mirror 36 to travel toward the second face 41b. The light reflected by the second face 41b travels through the lens 31b and the half mirror 36 to be incident on the camera 31a. The above configuration allows the imaging element of the camera 31a to obtain a captured image 31d of the second face 41b.

[0034]

The blocking member 34 is disposed inside the second tube 33a. The blocking member 34 is in the form of a frame with a rectangular outer shape. This means that the blocking member 34 is defined by an opening 34a at an inward portion (that is, at the center) and in a shape similar to the outer shape (that is, a rectangular shape). As the light source 33 emits light into the second tube 33a, a portion of the light travels through a

central area of the second tube 33a and enters an area adjacent to the blocking member 34, that is, the opening 34a (which is inward of the blocking member 34). The light passes (or propagates) through the opening 34a and travels through the inside of the second tube 33a toward the first tube 31c. The other portion of the light travels through a peripheral area of the second tube 33a and strikes the blocking member 34. The light does not pass through the blocking member 34 and is reflected or absorbed. This means that the blocking member 34 blocks light having traveled from the light source 33 and through the peripheral area and striking the blocking member 34. The peripheral area refers to an area close to an inner surface of the second tube 33a among its surfaces. The blocking member 34 is attached to a slidable cylinder 34c slidable inside the second tube 33a. This allows the blocking member 34 to be moved along the X axis as a result of the slidable cylinder 34c being moved along the X axis.

[0035]

As described above, the imaging mechanism 31, the light source 33, the second tube 33a, the blocking member 34, and the half mirror 36 are integral with one another. These are all held by the holder pillar 32b of the height adjusting mechanism 32 and configured to be moved along the Z axis as a result of the holder pillar 32b being moved along the Z axis.

[0036]

The calculator 35 is included in the control unit 50. The control unit 50 includes a processor such as a central processing unit (CPU) and a storage device such as a random access memory (RAM) or a read only memory (ROM). The calculator 35 is in the form of a processor. The control unit 50 is configured such that the processor executes control programs stored in the storage device to control the respective operations of the cutter unit 10, the holder unit 20, and the measurement unit 30 of the cutting apparatus 1. The cutting apparatus 1 operates on the basis of operation instructions from the control unit 50 unless otherwise specified. The description below basically omits to deal with operation instructions from the control unit 50 and deals as necessary with such operation instructions. The control unit 50 may be integral with or separate from each unit.

[0037]

The calculator 35 is configured to compute the heightwise position (that is, the absolute position and/or relative position) of the second face 41b of the substrate 41 of a package substrate 4 as measured by the measurement unit 30. For the present embodiment, the heightwise position of the second face 41b of the substrate 41 refers to the height of the second face 41b relative to a reference position (hereinafter referred to as "reference height P") as the heightwise position of something. The reference height P for the present

embodiment is between the upper face 37a of the CCS block 37 and the upper face of the table moving mechanism 24.

[0038]

The CCS block 37 is attached to a side of the table 22 and movable together with the table 22.

[0039]

[Method for Measuring Heightwise Position of Second Face of Substrate]

The description below deals with a method for measuring the heightwise position of the second face 41b of the substrate 41 of a package substrate 4, with reference to Figs. 6 to 11. Before starting the measurement, the method adjusts the respective positions of the blocking member 34, the half mirror 36, and the lens 31b for the camera 31a to obtain a confocal captured image 31d of the second face 41b of the substrate 41 in which captured image 31d both the second face 41b and the blocking member 34 are in focus. Fig. 6 illustrates the blocking member 34 as being out of focus on the second face 41b of the substrate 41. Fig. 11 illustrates the blocking member 34 as being in focus on the second face 41b of the substrate 41.

[0040]

The method first places a package substrate 4 onto the table 22 for the table 22 to hold the package substrate 4 by air suction or the like. The method then moves components such as the imaging mechanism 31, which includes the camera 31a, to a position above the package substrate 4 with use of the height adjusting mechanism 32, and moves the imaging mechanism 31 along the Z axis at that position to a predetermined heightwise position (step S1). The predetermined heightwise position may be, for example, a heightwise position at which the lens 31b is close to but not in contact with the substrate 41 or at which the lens 31b is as far from the substrate 41 as possible while the measurement unit 30 is able to measure the heightwise position with use of an image captured of the second face 41b by the camera 31a.

[0041]

The control unit 50 obtains information on the heightwise position of the camera 31a as a height from the reference height P. The calculator 35 receives information on the heightwise position of the camera 31a. The camera 31a, which is included in the imaging mechanism 31, has a focal length L on which the storage device stores information in advance.

[0042]

The method causes the light source 33 to emit light to the second face 41b of the substrate 41 of the package substrate 4 and the camera 31a to image the second face 41b

(step S2). The camera 31a should desirably image cross marks 41c (which is an example of the cutting mark) disposed on the second face 41b as illustrated in Fig. 7. The cross marks 41c are disposed at edge portions of the second face 41b to indicate portions of the substrate 41 to be half-cut and fully cut, that is, at which portions the blades 11 cut the package substrate 4. The cross marks 41c are printed or otherwise formed at least along two mutually adjacent sides of the second face 41b of the rectangular substrate 41. The camera 31a images any portion of the second face 41b for the measurement unit 30 to measure the heightwise position of the second face 41b of the substrate 41. The camera 31a should preferably image the cross marks 41c, which indicate portions of the substrate 41 to be half-cut and fully cut, to obtain captured images 31d, as such captured images 31d allow the measurement unit 30 to measure the heightwise position of cutting portions of the second face 41b of the substrate 41 and the control unit 50 to obtain information on the cutting portions of the package substrate 4. This in turn allows the cutting apparatus 1 to form half-cut grooves 44 with a desired depth in desired cutting portions of the substrate 41.

[0043]

The imaging element of the camera 31a obtains a captured image 31d as illustrated in (a) of Fig. 8. The present embodiment includes a blocking member 34 disposed between the light source 33 and the second face 41b of the substrate 41 and configured to block light incident on the blocking member 34 to prevent the light from reaching the second face 41b. The camera 31a thus obtains a captured image 31d with a black (or dark) edge portion 31e (which the blocking member 34 blocks) and a bright central portion 31f (which corresponds to the opening 34a, which is adjacent to the blocking member 34 and which allows light to pass therethrough) that shows a cross mark 41c. The captured image 31d has an edge portion 31e as a dark portion and a central portion 31f as a bright portion. The control unit 50 receives data on captured images 31d, which the camera 31a obtains by imaging the second face 41b, and the distance D between the camera 31a and the reference height P (see Fig. 6).

[0044]

At the control unit 50, the calculator 35 adds up the respective pixel values (that is, luminance values) of the individual pixels in each of two or more columns (that is, the vertical arrangements of pixels in Fig. 8) near the boundary between the edge portion 31e and the central portion 31f as illustrated in (b) of Fig. 8 in the data of the captured images 31d that the control unit 50 has received to calculate the combined value of the pixel values for each column. Fig. 8 illustrates in (b) a state where the blocking member 34 is in focus. The combined value of the pixel values is thus one of two values as shown in

(c) of Fig. 8. Next, the calculator 35 generates a curve that approximates the combined values of the pixel values as shown in (d) of Fig. 8 and differentiates the approximate curve to generate a differential curve as shown in (e) of Fig. 8 with a solid line. The differential curve provides a derivative value corresponding to a contrast value as the contrast ratio between the edge portion 31e and central portion 31f of a captured image 31d, as the derivative value indicates the amount of change of a pixel value. Generating a differential curve thus means calculating contrast values. The largest value among all the calculated contrast values (that is, derivative values) corresponds to a portion at which the pixel value has changed by the largest amount. Such portions, at each of which the contrast value is largest, thus correspond to the boundary between the edge portion 31e (that is, dark portion) and central portion 31f (that is, bright portion) of a captured image 31d. The description below may use the term "peak contrast value" to refer to the largest contrast value. Next, the calculator 35 extracts a peak contrast value from among all the contrast values and causes the storage device to store the peak contrast value (step S3). The present embodiment may use a single cross mark 41c or two or more cross marks 41c for the camera 31a to image the second face 41b of the substrate 41 at the predetermined heightwise position and for the calculator 35 to calculate contrast values, extract a peak contrast value, and cause the storage device to store the peak contrast value. If the present embodiment uses two or more cross marks 41c, the calculator 35 causes the storage device to store an average of the peak contrast values.

[0045]

After the camera 31a has imaged the second face 41b of the substrate 41 at the predetermined heightwise position, and the calculator 35 has calculated contrast values, extracted a peak contrast value, and caused the storage device to store the peak contrast value, the method moves the camera 31a (or the holder pillar 32b) by a predetermined distance (No in step S4, step S6); the camera 31a images the second face 41b at a heightwise position after the movement; and the calculator 35 extracts a peak contrast value (step S2, step S3). The method repeats the above operations a predetermined number of times or within a predetermined range of the heightwise position along the Z axis. After the method completes the repeat (Yes in step S4), the measurement ends.

[0046]

Fig. 8 illustrates a state where the blocking member 34 is in focus. Fig. 8 thus shows in (e) a solid line indicative of a differential curve that rises sharply toward a large peak contrast value. This means that the dark portion and the bright portion are clearly separate from each other. In a state where the blocking member 34 is not in focus (not illustrated in the drawings), the camera 31a obtains a captured image 31d with gray near

the boundary between the edge portion 31e and the central portion 31f. The edge portion 31e (that is, the dark portion) and the central portion 31f (that is, the bright portion) are not clearly separate from each other. For each column parallel to the boundary between the edge portion 31e and the central portion 31f, the total of the pixel values thus rises gently from the dark portion to the bright portion. In such a case, the differential curve rises gently toward a small peak contrast value as shown in (e) of Fig. 8 with broken lines, as compared to the solid line (which indicates a state where the blocking member 34 is in focus). Fig. 9 illustrates the relationship between the distance D and the peak contrast value, the distance D being the distance between the camera 31a and the second face 41b of the substrate 41.

[0047]

Fig. 9 indicates that the peak contrast value varies according to the distance D. The largest peak contrast value, that is, the highest contrast ratio, corresponds to a distance D1 with which the blocking member 34 is in focus. The distance D1 refers to the distance D from the reference height P to the camera 31a for a state where the blocking member 34 is in focus on the second face 41b of the substrate 41 as illustrated in Fig. 11 (step S5). In this state, the distance between the camera 31a and the second face 41b of the substrate 41 is equal to the focal length L. Subtracting the value of the focal length L from that of the distance D1 thus calculates the distance D2 from the reference height P to the second face 41b (that is, the heightwise position of the second face 41b) (D2 = D1 - L).

[0048]

Next, the calculator 35 causes the light source 33 to emit light to the upper face 37a of the CCS block 37 and obtains a captured image of the upper face 37a (which is an example of the block captured image) (not illustrated in the drawings). The calculator 35 then calculates the distance D3 from the reference height P to the upper face 37a of the CCS block 37 by a method similar to the above method for calculating the distance D2 (that is, the heightwise position of the second face 41b). The calculator 35 then calculates the distance D4 from the upper face 37a of the CCS block 37 to the second face 41b of the substrate 41 on the basis of the difference between the distances D2 and D3 (D4 = D2 - D3).

[0049]

The cutting apparatus 1 performs the above measurement and calculation of the distance D4 at two or more portions of the package substrate 4, for example, at the four corners of the rectangular substrate (four portions) or at the four corners of the rectangular substrate and two central portions along the respective long sides of the rectangular substrate (six portions in total). If the distance D4 has different values at different portions

due to, for example, a warp in the package substrate 4, the cutting apparatus 1 selects a value for the distance D4 which value allows each cut portion to have a half-cut groove 44 with a depth within tolerance limits. If selecting a single value for the distance D4 results in a cut portion having a half-cut groove 44 with a depth out of tolerance, the cutting apparatus 1 selects two or more values for the distance D4 which values allow each cut portion to have a half-cut groove 44 with a depth within tolerance limits.

[0050]

Next, the spindle moving mechanism (not illustrated in the drawings) moves the spindle 13 to bring the first blade 11a into contact with the upper face 37a of the CCS block 37. The cutting apparatus 1 may be configured to detect the contact between the first blade 11a and the CCS block 37 by a method such as detecting conduction between the first blade 11a and the CCS block 37. The cutting apparatus 1 detects conduction between the first blade 11a and the CCS block 37 specifically as follows: The CCS block 37 and the spindle 13 are each made of an electrically conductive material such as metal. The CCS block 37 and the spindle 13 are, for instance, electrically connected to each other in advance. The spindle 13, the shaft 13a, and the first blade 11a are each made of metal. The spindle 13 and the first blade 11a are thus conductive with each other. The spindle moving mechanism moves the spindle 13 along the Z axis to bring the first blade 11a closer to the upper face 37a of the CCS block 37. While the CCS block 37 and the first blade 11a are not in contact with each other, the CCS block 37, the spindle 13, and the first blade 11a are not conductive with one another. In response to the CCS block 37 and the first blade 11a coming into contact with each other, the CCS block 37, the spindle 13, and the first blade 11a become conductive with one another. The cutting apparatus 1 detects this conduction by a publicly known method. Detecting the conduction means that the first blade 11a has a lowermost point on the upper face 37a of the CCS block 37.

[0051]

With the first blade 11a in contact with the upper face 37a of the CCS block 37, the spindle moving mechanism starts to raise the spindle 13 by the distance D4. This allows the first blade 11a to be at the same heightwise position as the second face 41b of the substrate 41. The heightwise position of the first blade 11a is, to be specific, that of the lowermost point of the first blade 11a, that is, that of the point of contact between the first blade 11a and the upper face 37a of the CCS block 37. Finally, the spindle moving mechanism lowers the spindle 13 by a distance equal to the depth of the half-cut groove 44 to a heightwise position; the spindle 13 rotates the first blade 11a at that heightwise position; and the table moving mechanism 24 moves the table 22 along the Y axis. This allows the cutting apparatus 1 to form half-cut grooves 44 with a desired depth in the

substrate 41. With the first blade 11a in contact with the upper face 37a of the CCS block 37, the spindle moving mechanism may alternatively move the spindle 13 directly to a height at which to form a half-cut groove 44 in the substrate 41.

[0052]

The cutting apparatus 1 images the second face 41b of the substrate 41, calculates contrast values for a differential curve, and extracts a peak contrast value while changing the height of the camera 31a (that is, that of the holder pillar 32b of the height adjusting mechanism 32) as described above. This allows the cutting apparatus 1 to calculate the heightwise position of the second face 41b of the substrate 41 (that is, lead frame) from a reference height P and align the first blade 11a heightwise with the second face 41b of the substrate 41 without use of an expensive device such as a laser sensor. This in turn allows the cutting apparatus 1 to half-cut the substrate 41 of a package substrate 4 to form half-cut grooves 44 with a desired depth.

[0053]

The first blade 11a wears out to an extent as a result of forming a half-cut groove 44. The cutting apparatus 1 should, for each operation of forming a half-cut groove 44, preferably bring the first blade 11a into contact with the upper face 37a of the CCS block 37 to adjust the difference in height between the second face 41b of the substrate 41 and the lowermost point of the first blade 11a to the difference between the distance D4 and the depth of half-cut grooves 44 before half-cutting the substrate 41.

[0054]

The cutting apparatus 1 is not necessarily configured to calculate the heightwise position of the first blade 11a with reference to the upper face 37a of the CCS block 37 as a reference height. The cutting apparatus 1 may, for instance, use as a reference height the height of the axis of the shaft 13a of the spindle 13 after the spindle moving mechanism has moved the first blade 11a to the lowermost point. The first blade 11a may have a reference height not corresponding to the respective reference heightwise positions of the camera 31a and the substrate 41.

[0055]

[Alternative Embodiments]

The description below deals with embodiments alternative to the embodiments described above. For ease of understanding, the description below uses the same terms and reference signs as in the description of the above embodiments for similar elements.

[0056]

(1) The embodiment described above includes a single spindle 13 and first and second blades 11a and 11b interchangeable with each other. The cutter unit 10 may

alternatively include two separate spindles 13 for the respective first and second blades 11a and 11b.

[0057]

(2) The embodiment described above is configured to image the second face 41b and extract a peak contrast value a predetermined number of times or within a predetermined range. The present disclosure is, however, not limited to such a configuration. The cutting apparatus 1 may alternatively be configured to, for instance, end the measurement in response to the peak contrast value starting to decrease after increasing. This also allows the cutting apparatus 1 to obtain information on the distance D1, with which the peak contrast value is largest.

[0058]

(3) The embodiment described above includes a slidable cylinder 34c inside the second tube 33a. The cutting apparatus 1 may alternatively be configured such that the second tube 33a is divided into two sections and that the slidable cylinder 34c is slidably disposed between the two sections.

[0059]

(4) The embodiment described above includes a blocking member 34 in the form of a rectangular frame. The present disclosure is, however, not limited to such a configuration. The blocking member 34 may be in any shape with a linear section in the boundary between a portion configured to block light from the light source 33 and a portion configured to let the light pass therethrough.

[0060]

(5) The embodiment described above is configured to calculate the combined value of the pixel values for each of two or more columns, that is, vertical arrangements, near the boundary between the edge portion 31e and central portion 31f of the blocking member 34. The present disclosure is, however, not limited to such a configuration. The cutting apparatus 1 may alternatively be configured to, for instance, calculate the combined value of the pixel values for each of two or more rows, that is, horizontal arrangements, if the cutting apparatus 1 has selected a portion above the lateral center in (a) of Fig. 8 as being near the boundary between the edge portion 31e and the central portion 31f.

[0061]

(6) The embodiment described above is configured such that the camera 31a images cross marks 41c. The camera 31a may alternatively image something other than cross marks 41c.

[0062]

(7) The embodiment described above uses a cross mark 41c to indicate a portion of the substrate 41 to be half-cut and fully cut. The substrate 41 may alternatively be provided with a mark other than a cross mark 41c.

[0063]

(8) The embodiment described above includes a lens 31b between the half mirror 36 and the substrate 41. The lens 31b may alternatively be between the half mirror 36 and the camera 31a.

[0064]

[Summary of Above Embodiments]

The description below summarizes the cutting method, the method for producing a cut product, and the cutting apparatus each described above as an embodiment.

[0065]

<1> A cutting apparatus (1) is configured to, for an object to be cut (4) which includes a plate-shaped lead frame (41) having a first face (41a) provided with a resin layer (42) and a second face (41b) opposite to the first face (41a), form a groove (44) in the second face (41b), the cutting apparatus (1) including: a cutting table (22) on which the object to be cut (4) is placeable; a light source (33) configured to emit light to the second face (41b) of the object to be cut (4) while the object to be cut (4) is on the cutting table (22); a blocking member (34) disposed partway along a path along which the light from the light source (33) propagates to the object to be cut (4), the blocking member (34) being configured to block a portion of the light emitted from the light source (33); an imaging mechanism (31) configured to obtain a captured image (31d) of the second face (41b) of the object to be cut (4); a height adjusting mechanism (32) configured to adjust a height of the imaging mechanism (31); and a calculator (35) configured to analyze the captured image (31d), the imaging mechanism (31) including: a lens (31b) disposed on the path and between the blocking member (34) and the object to be cut (4), the lens (31b) being configured to collect the light from the light source (33) onto the second face (41b); and an imager (31a) disposed opposite to the cutting table (22) across the object to be cut (4), the imager (31a) being configured to receive the light having been reflected by the object to be cut (4) to obtain the captured image (31d), the imager (31a) being configured to obtain captured images (31d) at a plurality of heights as adjusted by the height adjusting mechanism (32), the calculator (35) being configured to calculate a heightwise position of the second face (41b) on a basis of a state of focus of the blocking member (34) in the captured images (31d).

[0066]

The cutting apparatus (1) calculates the heightwise position of the second face

(41b) on the basis of the state of focus of the blocking member (34) in captured images (31d) to obtain accurate information on the heightwise position of the second face 41b. This allows the cutting apparatus (1) to form grooves (44) with a desired depth in the second face (41b) of the object to be cut (4) on the basis of the heightwise position calculated.

[0067]

<2> The cutting apparatus (1) described in <1> above may be further configured such that the blocking member (34) is in a form of a frame configured to block a portion of the light emitted from the light source (33) which portion corresponds to a peripheral area.

[0068]

The cutting apparatus (1) is configured such that the blocking member (34) blocks a portion of light emitted from the light source (33) for the cutting apparatus (1) to obtain a captured image (31d) with a high contrast ratio. This allows the cutting apparatus (1) to obtain a captured image (31d) with the blocking member (34) accurately in focus.

[0069]

<3> The cutting apparatus (1) described in <1> or <2> above may be further configured such that the calculator (35) is configured to calculate for each of the captured images (31d) a contrast ratio between the blocking member (34) and an area adjacent to the blocking member (34), and the calculator (35) is configured to calculate the heightwise position of the second face (41b) on a basis of a height that the imager (31a) has when the imager (31a) obtains that captured image (31d) among the captured images (31d) which has a highest contrast ratio among the contrast ratios that the calculator (35) has calculated.

[0070]

A higher contrast ratio for a captured image (31d) allows a clearer boundary between the bright portion and the dark portion and thereby allows the blocking member (34) to be closer to the state of focus. The cutting apparatus (1) calculates the heightwise position of the second face (41b) on the basis of the height that the imager (31a) has when the imager (31a) obtains that captured image (31d) which has the highest contrast ratio. This allows the cutting apparatus (1) to obtain a captured image (31d) with the blocking member (34) accurately in focus.

[0071]

<4> The cutting apparatus (1) described in any one of <1> to <3> above may be further configured such that the blocking member (34) is movable between the light

source (33) and the object to be cut (4).

[0072]

The cutting apparatus (1) is capable of easily obtaining a confocal captured image (31d) in which both the second face (41b) and the blocking member (34) are in focus.

[0073]

<5> The cutting apparatus (1) described in any one of <1> to <4> above may be further configured such that the light source (33) and the blocking member (34) each have a height that is adjusted in conjunction with the height adjusting mechanism (32) adjusting a height of the imager (31a).

[0074]

The cutting apparatus (1) is configured such that simply adjusting the height of the imager (31a) allows the cutting apparatus (1) to obtain a captured image (31d) of the second face (41b).

[0075]

<6> The cutting apparatus (1) described in any one of <1> to <5> above may further include: a mirror (36) disposed on the path and between the blocking member (34) and the lens (31b), the mirror (36) being configured to reflect the light toward the second face (41b), wherein the mirror (36) has a height that is adjusted in conjunction with the height adjusting mechanism (32) adjusting a height of the imager (31a).

[0076]

The cutting apparatus (1) is configured such that simply adjusting the height of the imager (31a) allows the cutting apparatus (1) to obtain a captured image (31d) of the second face (41b).

[0077]

<7> The cutting apparatus (1) described in any one of <1> to <6> above may be further configured such that the imager (31a) is configured to obtain captured images (31d) of a cutting mark (41c) that is for use to cut the object to be cut (4) into pieces.

[0078]

The cutting apparatus (1) causes the imager (31a) to image a cutting mark (41c) for use to cut the object to be cut (4) to obtain a captured image (31d). This allows the cutting apparatus (1) to accurately measure the heightwise position of a cutting portion of the second face 41b of the object to be cut (4) and thereby form grooves 44 with a desired depth.

[0079]

<8> The cutting apparatus (1) described in any one of <1> to <7> above may be

further configured such that the imager (31a) is configured to obtain a block captured image of a reference block (37) indicative of a reference height that is for use to calculate the heightwise position of the second face (41b).

[0080]

The cutting apparatus (1) measures the heightwise position of a cutting portion of the second face 41b of the object to be cut (4) as a value relative to a block captured image of a reference block (37).

[0081]

<9> The cutting apparatus (1) described in any one of <1> to <8> above may further include: a blade (11a) configured to form the groove (44) in the second face (41b) of the object to be cut (4); and a spindle (13) configured to rotate the blade (11a), wherein the cutting apparatus (1) is configured to, on a basis of the heightwise position of the second face (41b) which heightwise position the calculator (35) has calculated, adjust a height of the blade (11a) before the blade (11a) forms the groove (44) in the second face (41b).

[0082]

The cutting apparatus (1) is configured to, on the basis of the heightwise position of the second face (41b) which heightwise position the calculator (35) has calculated, adjust the height of the blade (11a) before the blade (11a) forms the groove (44) in the second face (41b). This allows the cutting apparatus (1) to form grooves (44) with a desired depth in the second face (41b) of the object to be cut (4).

[0083]

<10> A method for producing a cut product (40) includes: forming a groove (44) in an object to be cut (4) with use of a cutting apparatus (1) according to any one of <1> to <9> above; and cutting the object to be cut (4), in which the groove (44) has been formed, for singulation into a plurality of cut products (40).

[0084]

The method allows reliable production of a cut product (40) including a wettable-flank substrate (41).

Industrial Applicability

[0085]

This disclosure is applicable to a cutting apparatus and a method for producing a cut product.

Reference Signs List

[0086]

1	Cutting apparatus
4	Package substrate (object to be cut)
11a	First blade (blade)
13	Spindle
22	Table (cutting table)
31	Imaging mechanism
31a	Camera (imager)
31b	Lens
31d	Captured image
32	Height adjusting mechanism
33	Light source
34	Blocking member
35	Calculator
36	Half mirror (mirror)
37	CCS block (reference block)
40	Electronic part (cut product)
41	Substrate (d)
41a	First face
41b	Second face
41c	Cross mark (cutting mark)
42	Resin layer
44	Half-cut groove (groove)

Claims

1. A cutting apparatus configured to, for an object to be cut which includes a plate-shaped lead frame having a first face provided with a resin layer and a second face opposite to the first face, form a groove in the second face,

the cutting apparatus comprising:

a cutting table on which the object to be cut is placeable;

a light source configured to emit light to the second face of the object to be cut while the object to be cut is on the cutting table;

a blocking member disposed partway along a path along which the light from the light source propagates to the object to be cut, the blocking member being configured to block a portion of the light emitted from the light source;

an imaging mechanism configured to obtain a captured image of the second face of the object to be cut;

a height adjusting mechanism configured to adjust a height of the imaging mechanism; and

a calculator configured to analyze the captured image,

the imaging mechanism including:

a lens disposed on the path and between the blocking member and the object to be cut, the lens being configured to collect the light from the light source onto the second face; and

an imager disposed opposite to the cutting table across the object to be cut, the imager being configured to receive the light having been reflected by the object to be cut to obtain the captured image,

the imager being configured to obtain captured images at a plurality of heights as adjusted by the height adjusting mechanism,

the calculator being configured to calculate a heightwise position of the second face on a basis of a state of focus of the blocking member in the captured images.

2. The cutting apparatus according to claim 1, wherein

the blocking member is in a form of a frame configured to block a portion of the light emitted from the light source which portion corresponds to a peripheral area.

3. The cutting apparatus according to claim 1 or 2, wherein

the calculator is configured to calculate for each of the captured images a contrast ratio between the blocking member and an area adjacent to the blocking member, and

the calculator is configured to calculate the heightwise position of the second face on a basis of a height that the imager has when the imager obtains that captured image among the captured images which has a highest contrast ratio among the contrast ratios that the calculator has calculated.

4. The cutting apparatus according to any one of claims 1 to 3, wherein

the blocking member is movable between the light source and the object to be cut.

5. The cutting apparatus according to any one of claims 1 to 4, wherein

the light source and the blocking member each have a height that is adjusted in conjunction with the height adjusting mechanism adjusting a height of the imager.

6. The cutting apparatus according to any one of claims 1 to 5, further comprising:

a mirror disposed on the path and between the blocking member and the lens, the mirror being configured to reflect the light toward the second face,

wherein the mirror has a height that is adjusted in conjunction with the height adjusting mechanism adjusting a height of the imager.

7. The cutting apparatus according to any one of claims 1 to 6, wherein

the imager is configured to obtain captured images of a cutting mark that is for use to cut the object to be cut into pieces.

8. The cutting apparatus according to any one of claims 1 to 7, wherein

the imager is configured to obtain a block captured image of a reference block indicative of a reference height that is for use to calculate the heightwise position of the second face.

9. The cutting apparatus according to any one of claims 1 to 8, further comprising:

a blade configured to form the groove in the second face of the object to be cut; and

a spindle configured to rotate the blade,

wherein the cutting apparatus is configured to, on a basis of the heightwise position of the second face which heightwise position the calculator has calculated, adjust a height of the blade before the blade forms the groove in the second face.

10. A method for producing a cut product,

the method comprising:

forming a groove in an object to be cut with use of a cutting apparatus according to any one of claims 1 to 9; and

cutting the object to be cut, in which the groove has been formed, for singulation into a plurality of cut products.