

DESCRIPTION

Title of Invention: INSPECTION APPARATUS, CUTTING APPARATUS, AND METHOD FOR MANUFACTURING SEMICONDUCTOR COMPONENT

5 Technical Field

[0001] The present invention relates to an inspection apparatus, a cutting apparatus, and a method for manufacturing semiconductor components.

Background Art

10 [0002] In the manufacturing line of products such as semiconductor components, a product may be marked with a bad mark indicating that it is defective. In this case, a bad mark inspection is often performed by a subsequent inspection apparatus to inspect whether the product is marked with a bad mark. Patent literature 1 discloses a method for detecting a bad mark using image processing.

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Citation List

Patent Document

[0003] Patent Document 1: JP 2013-38285A

20 Summary of Invention

Technical Problem

[0004] In order to accurately detect a bad mark, it is desirable to set, in an image capturing a product, a region (bad mark region) where if the product contains a bad mark, the bad mark will be applied, as precisely as possible. However, because the
25 position, shape, and the like of the bad mark vary depending on the product, the position of the bad mark region in such an image is often not uniformly fixed. The position of the bad mark region in such an image also varies depending on the

mounting position, angle, and the like of the camera. Therefore, in many cases, the bad mark region needs to be set manually. As a result, there are problems such as a large variation in settings by the operator, making it difficult to ensure the accuracy of the bad mark inspection.

5 [0005] It is an object of the present invention to provide an inspection apparatus, a cutting apparatus, and a method for manufacturing semiconductor components that can properly set a bad mark region in an image capturing an inspection object, and to improve the accuracy of a bad mark inspection.

10 Solution to Problem

[0006] An inspection apparatus according to an aspect of the present invention includes a control unit. The control unit is configured to set in advance, in a setting image in which an inspection object appears, a bad mark region in which a bad mark appears when the inspection object includes the bad mark, and determine whether or
15 not the inspection object appearing in an inspection image contains the bad mark by inspecting the bad mark region in the inspection image. The setting in advance the bad mark region includes: acquiring the setting image in which a good component, which is an inspection object without the bad mark, appears, and a defective component, which is an inspection object with the bad mark, appears; and defining the
20 bad mark region by comparing a brightness of a good component region, in which the good component appears, in the setting image, with a brightness of a defective component region, in which the defective component appears, in the setting image.

[0007] A cutting apparatus according to another aspect of the present invention includes: a cutting mechanism configured to cut a substrate including a plurality of
25 semiconductor components and divide the substrate into the individual semiconductor components; and the above-described inspection apparatus, the inspection apparatus being configured to inspect the individual semiconductor components serving as

inspection objects.

[0008] A method for manufacturing semiconductor components according to a further aspect of the present invention includes: a step of cutting a substrate including a plurality of semiconductor components using a cutting mechanism, and dividing the substrate into the individual semiconductor components; and a step of inspecting the individual semiconductor components serving as the inspection objects using the above-described inspection apparatus.

Advantageous Effects of Invention

[0009] According to the present invention, it is possible to properly set a bad mark region in an image capturing an inspection object, and to improve the accuracy of a bad mark inspection.

Brief Description of Drawings

[0010] FIG. 1 is a plan view schematically showing a cutting apparatus according to an embodiment.

FIG. 2 is a lateral cross-sectional view schematically showing an image-capturing environment of a second optical inspection camera according to an embodiment.

FIG. 3 is a diagram schematically showing a hardware configuration of a computer according to an embodiment.

FIG. 4 is a diagram showing an example of an image of a semiconductor component captured by the second optical inspection camera according to an embodiment.

FIG. 5 is a flowchart showing a flow of a method for setting parameters for bad mark inspections according to an embodiment.

FIG. 6 is a diagram showing an example of split regions set within one

component region according to an embodiment.

FIG. 7A is a diagram showing results of comparison in brightness between a good component region and a defective component region according to an embodiment.

5 FIG. 7B is a diagram showing results of comparison in brightness between a good component region and another good component region according to an embodiment.

FIG. 7C is a diagram showing results of comparison in brightness between a good component region and yet another good component region according to an
10 embodiment.

FIG. 8 is a table showing calculation results for setting a third threshold according to an embodiment.

FIG. 9 is a graph showing the relationship between the parameter and the area difference according to an embodiment.

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Description of Embodiments

[0011] An embodiment according to an aspect of the present invention (hereinafter also referred to as “the present embodiment”) will be described in detail below with reference to the drawings. Note that like or corresponding elements in
20 the drawings are denoted by like reference numerals, and descriptions will not be repeated for such elements. Also, the illustrations in the drawings are schematic illustrations with elements omitted or exaggerated as appropriate to facilitate understanding.

[0012] [1. Configuration]

25 <1-1. Overall Configuration of Cutting Apparatus>

FIG. 1 is a plan view schematically showing a cutting apparatus 1 according to the present embodiment. The cutting apparatus 1 is configured to cut a package

substrate (cutting target) in order to divide the package substrate into a plurality of semiconductor components (package components). In the package substrate, substrates or lead frames, each of which has a semiconductor chip mounted thereon, are sealed with resin.

5 [0013] Examples of package substrates include a BGA (Ball Grid Array) package substrate, an LGA (Land Grid Array) package substrate, a CSP (Chip Size Package) package substrate, an LED (Light Emitting Diode) package substrate, and a QFN (Quad Flat No-leaded) package substrate.

[0014] The cutting apparatus 1 is also configured to inspect each of the plurality
10 of divided semiconductor components. In the cutting apparatus 1, an image of each semiconductor component is captured, and the semiconductor component is inspected based on the captured image. Inspection data is generated through the inspection, and each semiconductor component is classified as a “good component” or a “defective component”.

15 [0015] In this example, a package substrate P1 is the cutting target, and the cutting apparatus 1 divides the package substrate P1 into a plurality of semiconductor components S1. Hereinafter, out of the two main surfaces of the package substrate P1, the resin-sealed surface is referred to as the mold surface, and the surface opposite to the mold surface is referred to as the ball/lead surface.

20 [0016] As shown in FIG. 1, the cutting apparatus 1 includes a cutting module (cutting mechanism) A1 and an inspection/storage module (inspection apparatus) B1 as constituent elements. The cutting module A1 is configured to manufacture a plurality of semiconductor components S1 by cutting the package substrate P1. The inspection/storage module B1 is configured to inspect each of the manufactured
25 semiconductor components S1 as inspection objects, and then store the semiconductor components S1 in trays. Various constituent elements of the cutting apparatus 1 can be attachable to and detachable from the other constituent elements and exchangeable.

[0017] The cutting module A1 mainly includes a substrate supply part 3, a positioning part 4, cutting tables 5, spindle parts 6, and a conveying part 7.

[0018] The substrate supply part 3 supplies a plurality of package substrates P1 stored in a magazine M1 one by one to the positioning part 4 by pushing out the
5 package substrates P1 one by one from the magazine M1. At this time, the package substrates P1 are each arranged such that the ball/lead surface faces upward.

[0019] The positioning part 4 positions the package substrate P1 pushed out from the substrate supply part 3 by arranging the package substrate P1 on a rail part 4a. After that, the positioning part 4 conveys the positioned package substrate P1 to the
10 cutting tables 5.

[0020] The cutting tables 5 each hold the package substrate P1 that is to be cut. In this example, the illustrated cutting apparatus 1 has a twin cut table configuration including two cutting tables 5. Each of the cutting tables 5 includes a holding member 5a, a rotating mechanism 5b, and a moving mechanism 5c. The holding
15 member 5a holds the package substrate P1 conveyed by the positioning part 4 by suctioning the package substrate P1 from below. The rotating mechanism 5b can rotate the holding member 5a in a $\theta 1$ direction shown in FIG. 1 (that is, in an X-Y horizontal plane in FIG. 1). The moving mechanism 5c can move the holding member 5a along the Y axis shown in the figure.

[0021] The spindle parts 6 each divide the package substrate P1 into a plurality of semiconductor components S1 by cutting the package substrate P1. In this example, the illustrated cutting apparatus 1 has a twin spindle configuration including two spindle parts 6. The spindle parts 6 can be moved along the X axis and the Z axis shown in the figure. Note that the cutting apparatus 1 may have a single spindle
25 configuration including only one spindle part 6.

[0022] The spindle parts 6 each include a blade 6a and a rotary shaft 6c. The blade 6a cuts the package substrate P1 by rotating at high speed, and thus divides the

package substrate P1 into a plurality of semiconductor components S1. The blade 6a is mounted on the rotary shaft 6c in a state of being held between not-shown first and second flanges. The first and second flanges are fixed to the rotary shaft 6c by a not-shown fastening member such as a nut. The first flange is also called an inner flange,
5 and the second flange is also called an outer flange.

[0023] The spindle parts 6 each include a cutting water nozzle, a cooling water nozzle, and a cleaning water nozzle (none of which is shown), for example. The cutting water nozzle sprays cutting water toward the blade 6a rotating at high speed. The cooling water nozzle sprays cooling water. The cleaning water nozzle sprays
10 cleaning water to wash cutting debris or the like away.

[0024] Referring again to FIG. 1, after the cutting table 5 suctions the package substrate P1, an image of the package substrate P1 is captured by a first position checking camera 5d, and the position of the package substrate P1 is checked. The checking performed using the first position checking camera 5d is, for example,
15 checking of the position of a mark provided on the package substrate P1. The mark is a mark for determining a cutting position of the package substrate P1, for example.

[0025] Thereafter, the cutting table 5 moves along the Y axis in the figure toward the corresponding spindle part 6. After the cutting table 5 moves to a position below the spindle part 6, the cutting table 5 is positioned, and then the package substrate P1
20 is cut by moving the cutting table 5 and the spindle part 6 relative to each other. Each time the package substrate P1 is cut by the blade 6a of the spindle part 6, an image of the package substrate P1 is captured by a second position checking camera 6b provided in the spindle part 6, and is checked. The checking performed using the second position checking camera 6b is, for example, the checking of a cut position and a cut
25 width of the package substrate P1.

[0026] After the cutting of the package substrate P1 is complete, the cutting table 5 moves away from the spindle part 6 along the Y axis shown in the figure while

suctioning the plurality of divided semiconductor components S1. During this moving process, a first cleaner 5e cleans and dries the upper surfaces (ball/lead surfaces) of the semiconductor components S1.

[0027] The conveying part 7 suctions the semiconductor components S1 held on the cutting table 5 from above and conveys the semiconductor components S1 to an inspection table 11 of the inspection/storage module B1. During this conveying process, a second cleaner 7a cleans and dries the lower surfaces (mold surfaces) of the semiconductor components S1.

[0028] The inspection/storage module B1 mainly includes the inspection table 11, a first optical inspection camera 12, a second optical inspection camera 13, illumination parts 16 and 17, an arrangement part 14, and an extraction part 15. Note that the first optical inspection camera 12 may be provided in the cutting module A1.

[0029] The inspection table 11 holds the semiconductor components S1 for optical inspection of the semiconductor components S1. The inspection table 11 can be moved along the X axis shown in the figure. Furthermore, the inspection table 11 can be vertically inverted. The inspection table 11 includes a holding member that holds the semiconductor components S1 by suctioning the semiconductor components S1. The surface of the inspection table 11 on which the semiconductor components S1 are held is made of dark rubber such as black rubber, in this example. Note that the rubber does not need to be dark, and may be bright such as white, for example.

[0030] The first optical inspection camera 12 and the second optical inspection camera 13 capture images of the mold surface and ball/lead surface of each semiconductor component S1. Based on the captured images (image data) generated by the first optical inspection camera 12 and the second optical inspection camera 13, various types of inspection are performed on the semiconductor component S1. The first optical inspection camera 12 and the second optical inspection camera 13 are each arranged in the vicinity of the inspection table 11 so as to capture an image in an

upward direction. The images generated by the first optical inspection camera 12 and the second optical inspection camera 13 are gray scale (256 gradation) images in this example, but the present invention is not limited to this and the images may be color images, for example. Note that after cutting the package substrate P1 in the spindle
5 part 6, the plurality of divided semiconductor components S1 maintain the array on the package substrate P1 prior to cutting, until they are imaged by the first optical inspection camera 12 and the second optical inspection camera 13, and are subsequently placed in the arrangement part 14, which will be described later. In other words, during this period, the plurality of divided semiconductor components S1
10 are kept aligned vertically and horizontally. Therefore, in the images captured by the first optical inspection camera 12 and the second optical inspection camera 13, the semiconductor components S1 aligned vertically and horizontally appear.

[0031] The first optical inspection camera 12 captures an image of the mold surface of each semiconductor component S1 that is conveyed to the inspection table
15 11 by the conveying part 7. After that, the conveying part 7 places the semiconductor component S1 on the holding member of the inspection table 11. After having suctioned the semiconductor component S1, the inspection table 11 is vertically inverted. The inspection table 11 moves to a position above the second optical inspection camera 13, and an image of the ball/lead surface of the semiconductor
20 component S1 is captured by the second optical inspection camera 13.

[0032] The illumination part 16 is provided above the first optical inspection camera 12, and the illumination part 17 is provided above the second optical inspection camera 13. The illumination parts 16 and 17 have a so-called coaxial and/or dome-shaped illumination configuration, for example. The illumination part 16 is
25 configured to irradiate the semiconductor component S1 on the conveying part 7 with light during inspection by the first optical inspection camera 12. The illumination part 17 is configured to irradiate the semiconductor component S1 on the inspection

table 11 with light during inspection by the second optical inspection camera 13. Since the set of the first optical inspection camera 12 and the illumination part 16 and the set of the second optical inspection camera 13 and the illumination part 17 have the same configuration, the configuration of the latter set will be described below as a
5 representative, for example.

[0033] FIG. 2 is a lateral cross-sectional view schematically showing an image-capturing environment of the second optical inspection camera 13. As shown in FIG. 2, during inspection by the second optical inspection camera 13, light generated by the illumination part 17 is emitted toward the semiconductor component S1. In this
10 example, the illumination part 17 is constituted by a dome-shaped illumination, and includes a dome 17a and a plurality of LEDs 17b arranged on the inner surface of the dome 17a. While the semiconductor component S1 is irradiated with light, an image of the semiconductor component S1 is generated by the second optical inspection camera 13. Inspection of the semiconductor component S1 is performed based on
15 the image.

[0034] Referring again to FIG. 1, the inspected semiconductor component S1 is then placed on the arrangement part 14. The arrangement part 14 can be moved along the Y axis shown in the figure. The inspection table 11 places the inspected semiconductor component S1 on the arrangement part 14.

20 [0035] The semiconductor components S1 that were placed on the arrangement part 14 are transferred to a tray by the extraction part 15. The semiconductor components S1 are classified as a “good component” or a “defective component” based on the results of the inspections performed using the first optical inspection camera 12 and the second optical inspection camera 13. The extraction part 15
25 transfers each of the semiconductor components S1 to a good component tray 15a or a defective component tray 15b based on the classification results. In other words, good components are stored in the good component tray 15a, and defective

components are stored in the defective component tray 15b. When the good component tray 15a or the defective component tray 15b is completely full of semiconductor components S1, it is replaced with a new tray.

[0036] The cutting apparatus 1 further includes a computer 50 and a monitor 20.

5 The monitor 20 is configured to display images. The monitor 20 is constituted by a display device such as a liquid crystal monitor or an organic EL (Electro Luminescence) monitor. Note that in the example shown in FIG. 1, the computer 50 and the monitor 20 are provided in the inspection/storage module B1, but they may be provided in the cutting module A1.

10 [0037] The computer 50 controls, for example, the operations of various parts of the cutting module A1 and the inspection/storage module B1. For example, the computer 50 controls the operations of the substrate supply part 3, the positioning part 4, the cutting tables 5, the spindle parts 6, the conveying part 7, the inspection table 11, the first position checking camera 5d, the second position checking camera 6b, the first
15 optical inspection camera 12, the second optical inspection camera 13, the illumination parts 16 and 17, the arrangement part 14, the extraction part 15, and the monitor 20.

[0038] Also, the computer 50 performs various types of inspection on the semiconductor components S1 based on image data generated by the first optical inspection camera 12 and the second optical inspection camera 13, for example. Next,
20 the computer 50 will be described in detail.

[0039] <1-2. Hardware Configuration of Computer>

FIG. 3 is a diagram schematically showing a hardware configuration of the computer 50. As shown in FIG. 3, the computer 50 includes a control unit 70, an input/output I/F (interface) 90, a receiving unit 95, and a memory unit 80. These
25 constituent elements are electrically connected to each other via a bus.

[0040] The control unit 70 includes a CPU (Central Processing Unit) 72, a RAM (Random Access Memory) 74, a ROM (Read Only Memory) 76, and the like. The

control unit 70 is configured to control the constituent elements of the computer 50 according to information processing, so as to control the constituent elements of the cutting apparatus 1 other than the computer 50.

[0041] The input/output I/F 90 is configured to communicate with various constituent elements included in the cutting apparatus 1 via signal lines. The input/output I/F 90 is used in the transmission of data from the computer 50 to various constituent elements of the cutting apparatus 1 and in the reception of data transmitted from various constituent elements of the cutting apparatus 1 to the computer 50. The receiving unit 95 is configured to accept instructions from the user. The receiving unit 95 includes some or all of the following: a touch panel, a keyboard, a mouse, and a microphone, for example.

[0042] The memory unit 80 is an auxiliary storage device such as a hard disk drive or a solid state drive, for example. The memory unit 80 is configured to store a control program 81, for example. Various operations in the cutting apparatus 1 are realized by execution of the control program 81 by the control unit 70. When the control unit 70 is to execute the control program 81, the control program 81 is loaded to the RAM 74. The control unit 70 then controls various constituent elements by using the CPU 72 to interpret and execute the control program 81 loaded to the RAM 74.

[0043] [2. Method for Manufacturing Semiconductor Component]

A method for manufacturing the semiconductor components S1 using the above-described cutting apparatus 1 will be described. First, the package substrate P1 is prepared and housed in the magazine M1, which is included in the cutting module A1 of the cutting apparatus 1. In this example, the package substrate P1 is constituted by various elements such as semiconductor elements arranged on a single substrate in a given repeating pattern. As a result, one package substrate P1 has a structure in which a plurality of semiconductor components S1 of the same type are coupled

together while being arranged horizontally and vertically. Each semiconductor component S1 included in one package substrate P1 is marked with a bad mark if necessary before being housed in the magazine M1. A bad mark is a mark to be applied to a semiconductor component S1 if it is determined to have a defect (to be
5 defective) in processes upstream of the cutting apparatus 1 in the production line. A bad mark is applied to the surface of the semiconductor component S1, for example, by laser cutting, printing, engraving, or similar methods, in a manner such that it is visually detectable from the outer appearance of the semiconductor component S1.

[0044] The package substrate P1 supplied to the magazine M1 is conveyed to the
10 spindle part 6 in the above-described manner, and cut in the spindle part 6. Here, the package substrate P1 is cut horizontally and vertically along the boundary lines of the plurality of semiconductor components S1 included in the package substrate P1. As a result, a plurality of divided semiconductor components S1 are obtained. The plurality of divided semiconductor components S1 are conveyed to the
15 inspection/storage module B1, where they undergo various types of inspection, while maintaining their positional relationship before the cutting. The various types of inspection in this context include outer appearance inspection based on the images generated by the first optical inspection camera 12 and the second optical inspection camera 13. The outer appearance inspection based on the images generated by the
20 second optical inspection camera 13 includes a bad mark inspection to inspect whether or not each semiconductor component S1 appearing in the image has a bad mark. Such processing is executed by the control unit 70 of the computer 50.

[0045] The control unit 70 classifies each semiconductor component S1 as a good or defective component through various types of inspection including a bad mark
25 inspection. The control unit 70 controls the operation of the extraction part 15 to convey the semiconductor components S1 classified as good components to the good component tray 15a and the semiconductor components S1 classified as defective

components to the defective component tray 15b. Based thereon, each semiconductor component S1 is sorted to the good component tray 15a or the defective component tray 15b. During this process, the semiconductor component S1 that has been determined as containing a bad mark in the bad mark inspection is classified as a defective component, and sorted to the defective component tray 15b. On the other hand, the semiconductor component S1 that has been determined as not containing a bad mark is sorted to the good component tray 15a unless it is determined as being a defective component. As a result, a plurality of semiconductor components S1 that are separate from each other are obtained from the package substrate P1 and classified as a good or defective component. With this, the semiconductor components S1 are manufactured by the cutting apparatus 1.

[0046] [3. Bad Mark Inspection]

Next, a bad mark inspection is described in detail. The following describes the preparation process that is carried out prior to the bad mark inspection and a flow of the bad mark inspection that is carried out after the preparation process in order. The preparation process is performed when the package substrate P1 to be cut by the cutting apparatus 1 is a substrate of a new type to be cut. The information on the package substrate P1 of a substrate type on which the preparation process is once performed is stored in the memory unit 80, and then can be retrieved from the memory unit 80 when cutting the package substrate P1 of this substrate type, and used.

[0047] <3-1. Flow of Preparation Process>

A preparation process is carried out prior to the start of the above-described process for manufacturing the semiconductor component S1. During the preparation process, various parameters for operation of the cutting apparatus 1 are set. As described above, the process for manufacturing the semiconductor component S1 includes the bad mark inspection. During the preparation process, not only various parameters for use in processes other than the bad mark inspection are set, but also

various parameters for the bad mark inspection are set. The following describes how to set parameters for the bad mark inspection.

[0048] FIG. 4 is a diagram showing an example of an image IM1 of the semiconductor components S1 captured by the second optical inspection camera 13.

- 5 The image IM1 is an image of the ball/lead surface side of the semiconductor components S1 in this example. A plurality of semiconductor components S1 appear in the image IM1, and in this example, the entirety of four semiconductor components S1 arranged in a 2×2 matrix is shown. The region corresponding to each semiconductor component S1 in the image IM1 is referred to as a component region.
- 10 Four component regions T1 to T4 appear in the image IM1. A plurality of cutting lines formed when the package substrate P1 is divided into a plurality of semiconductor components S1 also appear in the image IM1. In the image IM1, the cutting lines appear as an image of the surface of the inspection table 11 that holds the semiconductor components S1. The component regions T1 to T4 are adjacent to each
- 15 other with these cutting lines serving as boundary lines BL.

- [0049] In the example in FIG. 4, out of the four semiconductor components S1 corresponding to the respective component regions T1 to T4, only one semiconductor component S1 corresponding to the component region T3 contains a bad mark BM. In the image IM1, the region where the bad mark BM will appear if the semiconductor
- 20 component S1 contains the bad mark BM is referred to as a bad mark ROI (Region of Interest). The bad mark region ROI in the component region T3 contains an image of the bad mark BM, but the bad mark regions ROI in the component regions T1, T2, and T4 do not contain such an image of the bad mark BM.

- [0050] In order to carry out the bad mark inspection with accuracy, it is desirable
- 25 to set a bad mark region ROI as accurately as possible within the field of view of the image IM1 capturing the semiconductor components S1. However, because the position, shape, and the like of the bad mark BM are different depending on the product,

the position of the bad mark region ROI in the image IM1 is often not uniformly fixed. The position of the bad mark region ROI in the image IM1 slightly varies depending also on a slight variation in the mounting position and angle of the second optical inspection camera 13, and the like. As a result, conventionally, the bad mark region

5 ROI has been set manually, but this has led to the problems such as a large variation in settings by the operator. Also, thresholds for use in determining whether or not there is a bad mark BM in the bad mark region ROI have been conventionally set manually, but this also has led to the problems such as a large variation in settings by the operator. When attempting to manually set the bad mark region ROI around the

10 bad mark BM, the determination as to whether or not the bad mark region ROI appropriately surrounds the bad mark BM is based on the individual's subjective views. Adjusting the thresholds also involves individual's subjective views. For example, some people set the bad mark region ROI too wide, and the image of the bad mark BM in the bad mark region ROI is relatively small. This may change the average

15 brightness within the bad mark region ROI and prevent the bad mark BM from being detected at the set threshold. If the bad mark region ROI and the threshold settings are not appropriate as in this example, the accuracy of the bad mark inspection will be reduced. In addition, there is a problem that manually setting the bad mark region ROI and the thresholds would take a long time.

20 [0051] Based on the above-described problems, in the present embodiment, the bad mark region ROI and the thresholds are automatically set. FIG. 5 shows a flow of a method for setting the bad mark region ROI and a threshold (later-described third threshold Th3), which are parameters for the bad mark inspection. The procedure shown in FIG. 5 is executed by the control unit 70. The following describes the

25 details of the procedure shown in FIG. 5.

[0052] First, in step S100, the control unit 70 cuts the package substrate P1 using the spindle part 6, as in the main process of manufacturing the semiconductor

components S1, and then causes the second optical inspection camera 13 to capture images of the plurality of divided semiconductor components S1. In this example, in one image IM1 captured by the second optical inspection camera 13, only some of the semiconductor components S1 contained in one package substrate P1 appear
5 depending on the angle of view of the second optical inspection camera 13. The control unit 70 performs multiple times of shooting on an array of the plurality of semiconductor components S1 originating from the one package substrate P1, and obtains a plurality of images IM1. An image of each semiconductor component S1 originating from one package substrate P1 is captured in at least one of these plurality
10 of images IM1.

[0053] In the following step S101, the control unit 70 acquires a setting image from among the plurality of images IM1 acquired in step S100. A plurality of setting images may be used, but for simplicity in this description, a single setting image is assumed to be set. Specifically, the control unit 70 displays a plurality of images IM1
15 on the monitor 20 sequentially, in response to operation of the operator on the receiving unit 95. The operator operates the receiving unit 95 while checking the monitor 20, and selects one image IM1 from among the plurality of images IM1. Here, the conditions for selecting an image IM1 (hereinafter, selection conditions) are that at least one semiconductor component S1 (good component) that does not contain the
20 bad mark BM and at least one semiconductor component S1 (defective component) that contains the bad mark BM appear in that image. The control unit 70 acquires an image IM1 that satisfies the selection conditions and is selected by the operator, as a setting image. In the following, the setting image is also marked with a sign IM1.

[0054] In the following step S102, the control unit 70 extracts a plurality of
25 component regions T1 to T4 from the setting image IM1. Note that, due to the above-described selection conditions, at least one of the component regions T1 to T4 extracted here is the good component region, in which a good component appears, and

at least one of the remaining regions is the defective component region, in which a defective component appears. In this description, the image in FIG. 4 is assumed to be selected as the setting image IM1. In the example in FIG. 4, T1, T2, and T4 are the good component regions, and T3 is the defective component region. The component regions T1 to T4 can be detected by image processing using a given method. For example, the control unit 70 can detect the boundary lines BL and cut out the component regions T1 to T4 along the boundary lines BL.

[0055] In the following step S103, the control unit 70 divides each of the plurality of component regions T1 to T4, which includes at least one good component region and at least one defective component region, into n split regions D1 to Dn (n is an integer of 2 or more). FIG. 6 shows the split regions D1 to Dn set within the component region T1. Note that, in the other component regions T2 to T4, the same method is used to set the split regions D1 to Dn. In this example, the split regions D1 to Dn are set in a matrix (10×10 in FIG. 6). In this example, the split regions D1 to Dn are evenly set without gaps or overlaps within the component region. However, the split regions D1 to Dn may be set with gaps interposed between them, may overlap with each other, or may be set unevenly.

[0056] In the following step S104, the control unit 70 calculates the brightness of each of the split regions D1 to Dn in each of the component regions T1 to T4. Each of the split regions D1 to Dn contains a plurality of pixels. Therefore, the brightness of a split region has a representative value representing the brightness of the plurality of pixels contained in that split region. In this example, the average brightness of the plurality of pixels is set as the representative value. However, the representative value can be, for example, the median or the most frequent value of the brightness of the plurality of pixels.

[0057] In the following step S105, the control unit 70 compares the brightness between the plurality of component regions T1 to T4, which include at least one good

component region and at least one defective component region. The comparison of brightness in this example is meant to calculate the difference in brightness (brightness difference). In addition, in this example, one component region serving as a standard is selected from among the plurality of component regions T1 to T4 and the brightness of the selected component region is compared with the brightness of each of the remaining three component regions. One component region serving as a standard may be automatically selected by a given method such as selection based on the brightness of each component region, or random selection, but it may be determined in advance. In this example, the component region T1 is selected as one component region serving as a standard, and therefore brightness is compared for three combinations of the component regions (T1, T2), (T1, T3), and (T1, T4). Alternatively, brightness may be compared for all combinations of the plurality of component regions T1 to T4, without selecting one component region serving as a standard. According to the above-described method, it is ensured that the brightness of the good component region is compared to the brightness of the defective component region for at least one combination.

[0058] In this example, the brightness of each split region D1 to Dn is compared between the component regions T1 to T4. Specifically, between the two component regions to be compared, the difference in brightness (brightness difference) between the split region D1 of one component region and the split region D1 of the other component region is calculated. The same procedure is repeated for the split regions D2 to Dn. Accordingly, for all the split regions D1 to Dn, the difference in brightness (brightness difference) between the split region of one component region and the corresponding split region of another component region is calculated. According to the above-described method, for each of the split regions D1 to Dn, the brightness is compared between the good component region and the defective component region. FIG. 7A shows the results of comparison in brightness between the good component

region T1 and the defective component region T3. In FIG. 7A, the values within each of the split regions D1 to Dn that constitute the component region indicate the calculated brightness difference for the corresponding split region.

[0059] In the following step S106, the control unit 70 selects split regions where
5 the brightness difference (absolute value) between the two component regions compared in step S105 is greater than or equal to a first threshold Th1. In this example, as in step S105, the same process is repeated for the three combinations of the component regions (T1, T2), (T1, T3), and (T1, T4). This ensures that split regions where the brightness difference is greater than or equal to the first threshold
10 Th1 are selected for at least one combination of a good component region and a defective component region. In FIG. 7A, the split regions in dark gray are the split regions where the difference in brightness between the good component region T1 and the defective component region T3 is greater than or equal to the first threshold Th1. FIG. 7B shows results of comparison in brightness between the good component
15 region T1 and the good component region T2, while FIG. 7C shows results of comparison in brightness between the good component region T1 and the good component region T4, although the values for the brightness difference are omitted. In FIGS. 7B and 7C, similar to FIG. 7A, the split regions in dark gray are the split regions where the brightness difference between the corresponding two component
20 regions is greater than or equal to the first threshold Th1.

[0060] The first threshold Th1 can be set as appropriate. For example, the first threshold Th1 may be a fixed value or may be set automatically. In the case where it is automatically set, for example, the first threshold Th1 can be calculated based on the brightness of corresponding two component regions. In this example, the first
25 threshold Th1 is automatically set to (maximum brightness difference)/2.

[0061] In the following step S107, the control unit 70 further selects, in addition to the split regions selected in step S106, split regions where the brightness difference

between the component regions is greater than or equal to a second threshold Th2, from among the split regions adjacent to the split regions selected in step S106. In this example, as in steps S105 and S106, the same process is repeated for the three combinations of the component regions (T1, T2), (T1,T3), and (T1, T4). In FIGS. 5 7A to 7C, the split regions in light gray are the split regions selected in step S107.

[0062] The second threshold Th2 can also be set as appropriate. In this example, the second threshold Th2 is a fixed value. However, the second threshold Th2 may be automatically set. In the case where it is automatically set, for example, the second threshold Th2 can be calculated based on the brightness of corresponding two component regions, or can be calculated based on the first threshold Th1. The second threshold Th2 is preferably less than the first threshold Th1. Therefore, for example, the second threshold Th2 can be a value obtained by multiplying the first threshold Th1 by a factor greater than 0 and less than 1. If the second threshold Th2 is a fixed value and the first threshold Th1 is automatically set, it is desirable to anticipate the value that the first threshold Th1 can take, and set in advance the second threshold Th2 to a value that is less than the anticipated value.

[0063] Here, when reviewing the step S106 with reference to FIG. 7A, it is conceivable that the split regions where the brightness difference (absolute value) between the good component region T1 and the defective component region T3 is greater than or equal to the first threshold Th1 (that is, the brightness difference is larger) are mainly the regions where the bad mark BM is present. It is conceivable that the bad mark BM is likely to be present in the vicinity of the split regions selected in step S106, that is, in the vicinity of the regions where the bad mark BM is likely to be present. Therefore, the above-described step S107 is executed in order to detect a split region that could not be detected in step S106 but is likely to contain a bad mark BM. Setting the second threshold Th2 to a value less than the first threshold Th1 means that, in order to achieve this objective, the detection sensitivity is increased

when performing the selection in step S107 than when performing the selection in step S106. The regions selected in step S107 are also the regions where the brightness difference is relatively greater, and are considered to mainly be the regions where the bad mark BM is present.

- 5 [0064] In the following step S108, the control unit 70 defines the bad mark region ROI so that it contains the split regions selected in steps S106 and S107. In this example, one or more regions (hereinafter, “coupled regions”) C formed by connection of the selected split regions are first detected for the three combinations (T1, T2), (T1, T3), and (T1, T4). Then, among the detected one or more coupled regions C, the
- 10 maximum coupled region Cmax, which is the coupled region C with the maximum area, is detected, and the bad mark region ROI that contains this maximum coupled region Cmax is defined. In the examples in FIGS. 7A to 7C, a total of 10 coupled regions C are detected. The region with the largest area is detected as the maximum coupled region Cmax. The maximum coupled region Cmax is considered to be the
- 15 region where the bad mark BM is present. Therefore, the maximum coupled region Cmax is detected from the comparison results (FIG. 7A) between the good component region T1, which does not include the bad mark BM, and the defective component region T3, which includes the bad mark BM. The coupled regions C other than the maximum coupled region Cmax are detected based on errors.
- 20 [0065] When detecting the coupled regions C, the “connection” of the split regions can mean that, for example, the split regions are connected to each other in up, down, left, or right direction, or connected to each other in up, down, left, right, or diagonal direction. FIGS. 7A to 7C show examples of cases where the split regions are connected to each other in up, down, left, right, or diagonal direction.
- 25 [0066] In this example, as shown in FIG. 7A, the bad mark region ROI is defined as the smallest rectangular region including the maximum coupled region Cmax. However, the bad mark region ROI is not limited to this example, and may be, for

example, the maximum coupled region C_{max} itself, or may be a smaller region that surrounds the maximum coupled region C_{max} . In this example, information identifying the relative position of the bad mark region ROI within the component region is stored in the memory unit 80 as information that identifies the position of the bad mark region ROI.

[0067] With the above-described steps S100 to S108, the bad mark region ROI is set in advance prior to the bad mark inspection. The following steps S109 to S111 indicate a process for setting the third threshold $Th3$ in advance. The third threshold $Th3$ is a parameter for use in the inspection of the bad mark region ROI within an inspection image. The inspection image is an image to be subjected to a bad mark inspection, and is captured by the second optical inspection camera 13 under the same conditions as the setting image IM1. In this example, the third threshold $Th3$ is calculated based on the brightness of the bad mark region ROI in the setting image IM1.

[0068] In step S109, the control unit 70 selects one pair of good component region and defective component region from the plurality of component regions T1 to T4. This selection is not limited to this, but is made by selecting two component regions T1 and T3, which form the maximum coupled region C_{max} , for example.

[0069] In step S110, the control unit 70 specifies, while varying a parameter L , the appropriate parameter L as the third threshold $Th3$. In this example, the variation range of the parameter L is the maximum brightness range (0 to 255) that the pixel can take. However, the variation range of the parameter L is not limited to this. For example, the variation range of the parameter L may be limited to the periphery of the expected value that is appropriate for the third threshold $Th3$, and may be, for example, a range such as 30 to 230 that is narrower than the maximum range. The incremental amount of the variation of the parameter L may be 1, or 2 or more.

[0070] Specifically, the control unit 70 calculates the area of the portion where the

brightness exceeds the parameter L within the bad mark region ROI contained in the one component region (good component region) selected in step S109, while varying the parameter L within the range of variation. Similarly, the control unit 70 calculates the area of the portion where the brightness exceeds the parameter L within the bad mark region ROI contained in the other component region (defective component region) selected in step S109, while varying the parameter L within the range of variation. The areas can be counted, for example, as the number of pixels. In addition, the control unit 70 calculates the difference between the above-described two areas (hereinafter referred to as the area difference), while varying the parameter L within the range of variation. FIG. 8 shows a table indicating the results of the above calculations. FIG. 9 is a graph showing the relationship between the parameter L (horizontal axis) and the area difference (vertical axis) shown in FIG. 8.

[0071] The third threshold Th3 can be said to be the threshold for separating the bad mark BM and the background area. Here, referring to FIG. 4, in this example, the bad mark region ROI mainly includes a bright portion representing the bad mark BM (hereinafter, “bad mark portion”), a dark portion representing the substrate (hereinafter, “substrate portion”), and a portion representing the balls brighter than the bad mark BM (hereinafter, “ball portion”). In the image IM1 of FIG. 4, the ball portions correspond to a white dot pattern. Next, when referring to FIG. 9, while the parameter L varies from 0 to a certain value V1 ($V1 > 0$), the area difference is substantially 0 because the brightness of all pixels usually falls within the range of L to 255. However, when the parameter L exceeds the value V1, the brightness of the pixel of the substrate portion starts to deviate from the range of L to 255, so the graph of the area difference abruptly rises. This is because, due to the presence of the bad mark BM, the substrate portion is hidden in the defective component region (i.e., the conventional substrate portion is not visible due to the bad mark BM), but the substrate portion is not hidden in the good component region (i.e., the conventional substrate

portion is visible). That is, when the parameter L exceeds the value V1, the presence of the bad mark BM starts to appear as the area difference.

[0072] When the parameter L exceeds a peak value V2 ($V2 > V1$), the graph of the area difference abruptly drops, and when the parameter L exceeds a value V3 ($V3 > V2$), the graph of the area difference is gradual or roughly constant. This is because the number of pixels in the substrate portion that is hidden by the bad mark BM is capped. Note that the peak value V2 can be a value close to the average brightness of the substrate portion. Then, when the parameter L exceeds a value V4 ($V4 > V3$), the graph of the area difference starts to further descend. V4 can be a value close to the average brightness of the bad mark BM. Therefore, when the parameter L exceeds the value V4, the brightness of the pixel in the bad mark region begins to deviate from the range of L to 255, so the graph of the area difference approaches 0. This is because the bad mark region ROI in the good component region and the bad mark region ROI in the defective component region have the same area of the ball portions.

[0073] In the following step S111, the control unit 70 sets the third threshold Th3 based on the area difference calculated in step S110. Specifically, the control unit 70 specifies the parameter L (hereinafter, standard parameter Ls) that maximizes the area difference within the range of variation (0 to 255) of the parameter L. Then, the brightness that is separated away from this standard parameter Ls by a predetermined offset value F1 is set as the third threshold Th3, and is stored in the memory unit 80. At this time, the value of the standard parameter Ls may also be stored in the memory unit 80 as a reference value. The offset value F1 may be a fixed value or may be set automatically. In the case where it is automatically set, for example, the offset value F1 may be calculated based on the brightnesses of the pixels of the bad mark regions ROI contained in the two target areas, namely, the good component region and the defective component region.

[0074] In this example, the third threshold Th3 is set to a value greater than the standard parameter Ls by the offset value F1. This is to set the third threshold Th3 to be in the range of V3 to V4. This is because the range of V3 to V4 is the portion where the number of pixels in the substrate portion hidden by the bad mark BM is capped, and the bad mark BM stably appears.

[0075] With this, the bad mark region ROI and the third threshold Th3, which are two parameters for use in the bad mark inspection, are set.

[0076] <3-2. Flow of Bad Mark Inspection>

The following describes the flow of the bad mark inspection. The bad mark inspection is performed on an inspection image captured by the second optical inspection camera 13 during the main process of manufacturing the semiconductor components S1. The inspection images is of the same type as the image in the example in FIG. 4. Accordingly, in the following, the inspection image is also marked with the sign IM1.

[0077] The control unit 70 continuously acquires inspection images IM1, and executes the following procedure on each inspection image IM1. First, as in step S102, the control unit 70 extracts a plurality of component regions T1 to T4 from the inspection image IM1. Then, the control unit 70 sets the bad mark region ROI within each component region, based on information that specifies the position of the bad mark region ROI stored in step S108, with reference to the memory unit 80. Then, the control unit 70 reads the third threshold Th3 with reference to the memory unit 80. For each bad mark region ROI, the control unit 70 determines whether the number of pixels that exceed the third threshold Th3 and are contained in this bad mark region ROI is greater than or equal to a fourth threshold Th4. If it is determined that the number of pixels is at least the fourth threshold Th4, the bad mark BM is included in the bad mark region ROI, and the semiconductor component S1 corresponding to the component region that includes the bad mark region ROI is determined to be defective.

Otherwise, it is determined that the bad mark BM is not included in the bad mark region ROI, and the semiconductor component S1 corresponding to the component region that includes the bad mark region ROI is determined to be good.

[0078] With this, the bad mark inspection ends. Note that the fourth threshold Th4 may be a fixed value or may be set manually or automatically prior to the bad mark inspection. In the case where it is automatically set prior to the bad mark inspection, for example, the fourth threshold Th4 may be calculated based on the brightnesses of the pixels of the bad mark region ROI contained in the two target areas, namely, the good component region and the defective component region.

10 [0079] [4. Features]

As described above, in the cutting apparatus 1 according to the present embodiment, the bad mark region ROI is automatically set in advance. This eliminates variation in settings by the operator, resulting in an improvement in accuracy of the bad mark inspection. In addition, the setting time required to prepare for the bad mark inspection can be reduced.

[0080] The third threshold Th3 is also automatically set in advance. This also eliminates variation in settings by the operator for the third threshold Th3, resulting in a further improvement in accuracy of the bad mark inspection. In addition, the setting time required to prepare for the bad mark inspection can be further reduced.

20 [0081] [5. Modifications]

The above-described embodiment is merely illustrative of the present invention in all respects. Various improvements and changes can be made to the above-described embodiment within the scope of the present invention. For example, the following modifications are possible. When implementing the present invention, specific configurations can be adopted as appropriate depending on the embodiment.

[0082] <5-1>

In the above-described embodiment, step S107 may be omitted.

[0083] <5-2>

In the above-described embodiment, an example is shown in which the bad mark region ROI mainly includes the bad mark portion, the substrate portion, and the ball portion. In addition, the ball portion, the bad mark portion, and the substrate portion are arranged in order of brightness. However, even if the bad mark portion is the darkest region, the third threshold Th3 can be calculated using a similar algorithm because the bad mark portion is separated from the substrate portion near the peak value V2. Thus, the above-described algorithm for calculating the third threshold Th3 can be applied to various types of semiconductor components S1.

10 [0084] <5-3>

In the above-described embodiment, the bad mark region ROI and the third threshold Th3 are automatically set in advance. However, of the bad mark region ROI and the third threshold Th3, only the bad mark region ROI may be automatically set, or only the third threshold Th3 may be automatically set.

15 [0085] <5-4>

In the above-described embodiment, in step S100 of the preparation process, the same package substrate P1 as that in the main process of manufacturing the semiconductor component S1 is used, but it is also possible to use a dummy substrate of this package substrate P1.

20 [0086] The embodiments of the present invention described above are illustrative. In other words, the detailed description and accompanying drawings have been disclosed for the purpose of illustration. Therefore, some of the constituent elements described in the detailed description and the accompanying drawings may not be essential for solving the problem. Accordingly, simply because non-essential constituent elements are described in the detailed description and accompanying drawings, such non-essential constituent elements are not intended to be immediately identified as essential.

List of Reference Numerals

[0087]

- 1: Cutting apparatus, 3: Substrate supply part, 4: Positioning part, 4a: Rail part,
- 5 5: Cutting table, 5a: Holding member, 5b: Rotating mechanism, 5c: Moving mechanism,
- 5d: First position checking camera, 5e: First cleaner, 6: Spindle part, 6a: Blade, 6b: Second position checking camera, 6c: Rotary shaft, 7: conveying part, 7a: Second cleaner, 11: Inspection table, 12: First optical inspection camera,
- 10 13: Second optical inspection camera, 14: Arrangement part, 15: Extraction part, 15a: Good component tray, 15b: Defective component tray, 16, 17: illumination part, 17a: Dome, 17b: LED, 20: Monitor, 50: Computer, 70: Control unit, 72: CPU, 74: RAM,
- 76: ROM, 80: Memory unit, 81: Control program, 90: Input/output I/F,
- 15 95: Receiving unit, A1: Cutting module: B1: Inspection/storage module, BL: Boundary line, BM: Bad mark, C: Coupled region, Cmax: Maximum coupled region,
- D1: Split region, D1 to Dn: Split region, F1: Offset value, IM1: Image (Setting image, Inspection image), L: Parameter, Ls: Standard parameter,
- 20 M1: Magazine, P1: Package substrate, ROI: Bad mark region, S1: Semiconductor component, T1 to T4: Component region, T1, T2, T4: Good component region, T3: Defective component region, Th1: First threshold, Th2: Second threshold, Th3: Third threshold, Th4: Fourth threshold,
- 25 V1 to V4: Value, V2: Peak value

CLAIMS

[Claim 1] An inspection apparatus, comprising:

a control unit configured to set in advance, in a setting image in which an
5 inspection object appears, a bad mark region in which a bad mark will appear if the
inspection object includes the bad mark, and determine whether or not the inspection
object appearing in an inspection image contains the bad mark by inspecting the bad
mark region in the inspection image,

wherein the setting in advance the bad mark region includes:

10 acquiring the setting image in which a good component, which is an
inspection object without the bad mark, appears, and a defective component, which is
an inspection object with the bad mark, appears; and

defining the bad mark region by comparing a brightness of a good
component region, in which the good component appears, in the setting image, with a
15 brightness of a defective component region, in which the defective component appears,
in the setting image.

[Claim 2] The inspection apparatus according to claim 1,

wherein the control unit defines the bad mark region by dividing each of the
20 good component region and the defective component region into a plurality of split
regions, and comparing the brightness of the good component region with the
brightness of the defective component region for each of the split regions.

[Claim 3] The inspection apparatus according to claim 2,

25 wherein the control unit selects a split region in which a brightness difference
between the good component region and the defective component region is greater
than or equal to a first threshold, and defines the bad mark region so that it contains

the selected split region.

[Claim 4] The inspection apparatus according to claim 3,

wherein the control unit further selects, in addition to the split region in which
5 the brightness difference is greater than or equal to the first threshold, a split region in
which the brightness difference is greater than or equal to a second threshold, from
among split regions adjacent to the split region in which the brightness difference is
greater than or equal to the first threshold, and defines the bad mark region so that it
contains the selected split region.

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[Claim 5] The inspection apparatus according to claim 3 or 4,

wherein the control unit defines the bad mark region so that it contains a
region of the largest area, from among one or more regions formed by connection of
the selected split regions.

15

[Claim 6] The inspection apparatus according to any one of claims 1 to 5,

wherein the control unit sets in advance a third threshold for use in an
inspection of the bad mark region in the inspection image, based on a brightness of the
bad mark region in the setting image.

20

[Claim 7] The inspection apparatus according to claim 6,

wherein the setting in advance the third threshold includes:

calculating a difference between an area of a portion in which the
brightness of the bad mark region included in the good component region exceeds the
25 third threshold and an area of a portion in which the brightness of the bad mark region
included in the defective component region exceeds the third threshold, while varying
the third threshold; and

setting in advance the third threshold based on the difference.

[Claim 8] The inspection apparatus according to claim 7,

 wherein the control unit sets in advance a brightness deviated by an offset
5 value from the third threshold that maximizes the difference within a variation range
 of the third threshold, as the third threshold.

[Claim 9] A cutting apparatus, comprising:

 a cutting mechanism configured to cut a substrate including a plurality of
10 semiconductor components and divide the substrate into the individual semiconductor
 components; and

 the inspection apparatus according to any one of claims 1 to 8, the inspection
 apparatus being configured to inspect the individual semiconductor components
 serving as inspection objects.

15

[Claim 10] A method for manufacturing semiconductor components,
 comprising:

 cutting a substrate including a plurality of semiconductor components using
 a cutting mechanism, and dividing the substrate into the individual semiconductor
20 components; and

 inspecting the individual semiconductor components serving as the inspection
 objects using the inspection apparatus according to any one of claims 1 to 8.