

DESCRIPTION

Title of Invention: INSPECTION SYSTEM, SEMICONDUCTOR MANUFACTURING APPARATUS, AND INSPECTION METHOD

5 Technical Field

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

Background Art

- 10 [0002] JP 2023-076250A (Patent Document 1) discloses an inspection system that inspects an object to be inspected based on a captured image of the object. In this inspection system, for example, one captured image includes four objects to be inspected (see Patent Document 1).

15 Citation List

Patent Document

[0003] Patent Document 1: JP 2023-076250A

Summary of Invention

20 Technical Problem

[0004] If an electronic component to be inspected is large, the electronic component may not fit into the field of view of a camera. The above-mentioned Patent Document 1 does not disclose a method for inspecting an electronic component that does not fit into the field of view of a camera.

- 25 [0005] The present invention was made to solve this problem, and an object of the present invention is to provide an inspection system, a semiconductor manufacturing apparatus, and an inspection method that enable relatively high accuracy inspection of

an electronic component of a size that does not fit into the field of view of a camera.

Solution to Problem

[0006] An inspection system according to an aspect of the present invention
5 includes a table, a camera, a first movement mechanism, a second movement
mechanism, and a control unit. The table holds an electronic component. The
camera captures an image of a part of the electronic component and generates first
partial image data. The first movement mechanism moves at least one of the table
and the camera such that a relative positional relationship between the electronic
10 component and the camera in a direction along a first axis is changed. The second
movement mechanism moves at least one of the table and the camera such that a
relative positional relationship between the electronic component and the camera in a
direction along a second axis is changed. The control unit controls each of the camera,
the first movement mechanism, and the second movement mechanism such that a
15 plurality of first partial image data respectively indicating different parts of the
electronic component are generated. The control unit executes: first processing for
subjecting each of the plurality of first partial image data to correction performed with
consideration given to an inclination of the camera with respect to the first axis and
correction with consideration given to a difference between an angle formed by the
20 first axis and the second axis and a reference angle; second processing for generating
composite image data by compositing the plurality of first partial image data after
correction; and third processing for inspecting the electronic component based on the
composite image data.

[0007] A semiconductor manufacturing apparatus according to another aspect of
25 the present invention includes the inspection system and a manufacturing system.
The manufacturing system manufactures an electronic component. The electronic
component is a semiconductor device. The inspection system inspects the electronic

component manufactured by the manufacturing system.

[0008] An inspection method according to another aspect of the present invention is an inspection method using an inspection system. The inspection system includes a table, a camera, a first movement mechanism, and a second movement mechanism.

5 The table holds an electronic component. The camera captures an image of a part of the electronic component and generates first partial image data. The first movement mechanism moves at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a first axis is changed. The second movement mechanism moves at least one of the
10 table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a second axis is changed. The inspection method includes generating a plurality of partial image data respectively indicating different parts of the electronic component, subjecting each of the plurality of partial image data to correction with consideration given to an inclination of the
15 camera with respect to the first axis and correction with consideration given to a difference between an angle formed by the first axis and the second axis and a reference angle; generating composite image data by compositing the plurality of partial image data after correction; and inspecting the electronic component based on the composite image data.

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Advantageous Effects of Invention

[0009] According to the present invention, it is possible to provide an inspection system, a semiconductor manufacturing apparatus, and an inspection method that enable relatively high accuracy inspection of an electronic component of a size that
25 does not fit into the field of view of a camera.

Brief Description of Drawings

[0010] FIG. 1 is a plan view schematically showing a cutting apparatus.

FIG. 2 is a diagram including a schematic cross section of an illumination part.

FIG. 3 is a diagram schematically showing a hardware configuration of a computer.

5 FIG. 4 is a diagram for describing a problem that occurs when unprocessed partial image data are composited in a case where a second optical inspection camera is inclined about a Z axis with respect to an inspection table.

FIG. 5 is a diagram for describing a problem that occurs when unprocessed partial image data are composited in a case where a rectangular object to be imaged is
10 imaged in a trapezoid shape.

FIG. 6 is a diagram for describing a problem that occurs when unprocessed partial image data are composited in a case where a direction of movement of the second optical inspection camera deviates from a Y axis.

FIG. 7 is a flowchart showing a calibration procedure in the cutting apparatus.

15 FIG. 8 is a diagram for describing an inclination about an X axis.

FIG. 9 is a diagram schematically showing a plane of a calibration plate.

FIG. 10 is a diagram for describing an outline of adjustment of the inclination about the X axis.

FIG. 11 is a flowchart showing processing executed in step S100 of FIG. 7.

20 FIG. 12 is a diagram for describing distances between dots in a captured image of the calibration plate.

FIG. 13 is a diagram including a table that shows an example of distances between dots in five captured images.

FIG. 14 is a diagram for describing an outline of a virtual plane.

25 FIG. 15 is a diagram for describing a procedure for generating the virtual plane.

FIG. 16 is a flowchart showing processing executed in step S110 of FIG. 7.

FIG. 17 is a flowchart showing processing executed in step S120 of FIG. 7.

FIG. 18 is a diagram for describing an outline of correction of distortion aberration.

FIG. 19 is a flowchart showing processing executed in step S400 of FIG. 17.

5 FIG. 20 is a diagram for describing an outline of rotation correction in a case where partial images are inclined with respect to the X axis.

FIG. 21 is a diagram for describing a procedure for calculating an inclination of the second optical inspection camera about the Z axis with respect to the X axis.

FIG. 22 is a flowchart showing processing executed in step S410 of FIG. 17.

10 FIG. 23 is a diagram for describing an outline of trapezoid correction in a case where a rectangular object to be imaged is imaged in a trapezoid shape.

FIG. 24 is a flowchart showing processing executed in step S420 of FIG. 17.

15 FIG. 25 is a diagram for describing an outline of axial angle correction in a case where there is a deviation between the direction of movement of the second optical inspection camera and the Y axis.

FIG. 26 is a diagram for describing a procedure for calculating an inclination of the direction of movement of the second optical inspection camera with respect to the Y axis.

FIG. 27 is a flowchart showing processing executed in step S430 of FIG. 17.

20 FIG. 28 is a flowchart showing a procedure for inspecting an electronic component that does not fit into the field of view of the second optical inspection camera.

Description of Embodiments

25 [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 identical elements or corresponding

elements are denoted by the same reference signs in the drawings, and descriptions thereof will not be repeated. Also, the illustrations in the drawings are schematic illustrations with elements omitted or exaggerated as appropriate to facilitate understanding. In the drawings, an X axis and a Y axis are orthogonal to each other,
5 the X axis and a Z axis are orthogonal to each other, and the Y axis and the Z axis are orthogonal to each other.

[0012] [1. Configuration]

<1-1. Overall configuration of cutting apparatus>

FIG. 1 is a plan view schematically showing a cutting apparatus 1 according
10 to the present embodiment. The cutting apparatus 1 is configured to cut a package substrate (an object to be cut) to divide the package substrate into a plurality of electronic components (package components). In the package substrate, a substrate or a lead frame on which semiconductor chips are mounted is sealed with resin. It should be noted that the object to be cut does not necessarily have to be a package
15 substrate, and may be, for example, a substrate (including a wafer) that has not been sealed with resin. Cut pieces of a substrate that has not been sealed with resin are also included in the “electronic components”.

[0013] Examples of the package substrate include a BGA (Ball Grid Array) package substrate, an LGA (Land Grid Array) package substrate, a CSP (Chip Size
20 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 separated electronic components. In the cutting apparatus 1, an image of each electronic component is captured, and the electronic components are inspected based on the
25 captured images. Inspection data is generated through the inspection, and each electronic component is classified as a “good component” or a “defective component”. In particular, electronic components each having a size that does not fit into a single

captured image are inspected in the cutting apparatus 1. A specific inspection procedure will be described later.

[0015] In this example, a package substrate P1 is the object to be cut, and the cutting apparatus 1 divides the package substrate P1 into a plurality of electronic components S1. Hereinafter, out of two main surfaces of the package substrate P1, a surface sealed with resin will be referred to as a “mold surface”, and the surface opposite to the mold surface will be referred to as a “ball/lead surface”. In the case where the object to be cut is a substrate that has not been sealed with resin, a surface facing upward at the time of cutting (cutting surface) corresponds to the ball/lead surface in the present embodiment, and the surface opposite to the cutting surface corresponds to the mold surface in the present embodiment.

[0016] As shown in FIG. 1, the cutting apparatus 1 includes a cutting module A1 and an inspection/storage module B1 as constituent elements. The cutting module A1 is configured to manufacture a plurality of electronic components S1 by cutting the package substrate P1. The inspection/storage module B1 is configured to inspect each of the manufactured electronic components S1, and then store the electronic components S1 in trays. Various constituent elements of the cutting apparatus 1 are detachable from the other constituent elements and attachable to the other constituent elements, and are replaceable.

[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 package substrates P1 one by one to the positioning part 4 by pushing out the package substrates P1 one by one from a magazine M1 storing the plurality of package substrates P1. At this time, the package substrates P1 are each oriented 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.

Thereafter, the positioning part 4 conveys the positioned package substrate P1 to the cutting tables 5.

[0020] The cutting tables 5 each hold a package substrate P 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 movement mechanism 5c. The holding 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 the figure (i.e., in an X-Y horizontal plane in FIG. 1). The movement mechanism 5c can move the holding member 5a along the Y axis shown in the figure.

[0021] The spindle parts 6 each divide a package substrate P1 into a plurality of electronic 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 move along the X axis and the Z axis shown in the figure. It should be noted that the cutting apparatus 1 may have a single spindle configuration including only one spindle part 6.

[0022] Each spindle part 6 includes a blade 6a and a rotation 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 electronic components S1. The blade 6a is mounted on the rotation shaft 6c in a state of being held between a first flange and a second flange (not shown). The first flange and the second flange are fixed to the rotation shaft 6c by a fastening member (not shown) such as a nut or the like. The first flange is also called an inner flange, and the second flange is also called an outer flange.

[0023] The spindle part 6 includes a cutting water nozzle, a cooling water nozzle, and a cleaning water nozzle, for example (none of which is shown). 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 cleaning water to wash cutting debris or the like away.

[0024] 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
5 position of the package substrate P1 is checked. The check performed using the first position checking camera 5d is, for example, the check of the position of a mark provided on the package substrate P1. The mark is used to determine a cutting position on the package substrate P1, for example.

[0025] Thereafter, the cutting table 5 moves along the Y axis in the figure toward
10 a corresponding one of the spindle parts 6. After the cutting table 5 comes to a position below the spindle part 6, positioning is performed, and then the package substrate P1 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 with the blade 6a of the spindle part 6, an image of the package substrate P1 is captured by a second position checking
15 camera 6b provided in the spindle part 6 to perform check. The check performed using the second position checking camera 6b is, for example, the check of the cut position and the cut width of the package substrate P1.

[0026] After cutting of the package substrate P1 is complete, the cutting table 5 moves away from the spindle part 6 along the Y axis in the figure while suctioning the
20 plurality of separated electronic components S1. During this movement, a first cleaner 5e cleans and dries the upper surfaces (ball/lead surfaces) of the electronic components S1.

[0027] The conveying part 7 suctions the electronic components S1 held on the cutting table 5 from above and conveys the electronic components S1 to an inspection
25 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 electronic 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. It should be noted that the first optical inspection camera 12 may be provided in the cutting module A1.

[0029] The inspection table 11 holds an electronic component S1 for optical inspection of the electronic component S1. The inspection table 11 can move along the X axis in the figure. Furthermore, the inspection table 11 can be vertically inverted. The inspection table 11 includes a holding member that holds the electronic component S1 by suctioning the electronic component S1. The surface of the inspection table 11 on which the electronic component S1 is held is made of black rubber, for example. It should be noted that the rubber does not need to be black, and may be white, for example.

[0030] The first optical inspection camera 12 and the second optical inspection camera 13 capture images of the mold surface and the ball/lead surface of the electronic component S1, respectively. 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 electronic 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 of an upper region. The first optical inspection camera 12 and the second optical inspection camera 13 can each move along the Y axis in the figure. Although a detailed description will be given later, the directions of movement of the first optical inspection camera 12 and the second optical inspection camera 13 may not be completely parallel with the Y axis. The captured images generated by the first optical inspection camera 12 and the second optical inspection camera 13 are gray scale (256 gradation) images, for example.

[0031] The first optical inspection camera 12 captures an image of the mold surface of the electronic component S1 that is being conveyed to the inspection table 11 by the conveying part 7. After that, the conveying part 7 places the electronic component S1 on the holding member of the inspection table 11. After the electronic component S1 is suctioned, 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 electronic 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 each have a so-called coaxial illumination configuration and/or a dome-shaped illumination configuration, for example. The illumination part 16 is configured to irradiate the electronic component S1 on the inspection table 11 with light during inspection by the first optical inspection camera 12. The illumination part 17 is configured to irradiate the electronic component S1 on the inspection table 11 with light during inspection by the second optical inspection camera 13. Since the illumination parts 16 and 17 have the same configuration, for example, the configuration of the illumination part 17 will be described below as a representative.

[0033] FIG. 2 is a diagram including a schematic cross section of the illumination part 17. 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 electronic component S1. While the electronic component S1 is irradiated with light, a captured image of the electronic component S1 is generated by the second optical inspection camera 13. The electronic component S1 is inspected based on the captured image.

[0034] The illumination part 17 is constituted by a dome-shaped light, and includes a dome 17a and a plurality of LEDs 17b. It should be noted that the dome-

shaped light may be constituted by a so-called dome light, but does not necessarily have to be constituted by a dome light, and is only required to include a dome-shaped (umbrella-shaped) member and a plurality of light emitting members (e.g., LEDs) arranged inside the dome-shaped member. The dome 17a is dome-shaped and has a circular shape in a plan view. The plurality of LEDs 17b are arranged on the inner surface of the dome 17a. In the illumination part 17, a plurality of segments (Ch01 to Ch08) are formed from the inside to the outside in the radial direction of the dome 17a. The illumination part 17 is a so-called multi-channel light in which the light intensity of each segment can be adjusted individually. In each of the plurality of segments, a plurality of LEDs 17b are arranged at predetermined intervals in the circumferential direction of the dome 17a.

[0035] Referring again to FIG. 1, inspected electronic components S1 are disposed on the arrangement part 14. The arrangement part 14 can move along the Y axis in the figure. The inspection table 11 disposes the inspected electronic components S1 on the arrangement part 14.

[0036] The extraction part 15 transfers the electronic components S1 disposed on the arrangement part 14 to trays. The electronic 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 transfers each of the electronic 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 filled with electronic components S1, it is replaced with a new tray.

[0037] The cutting apparatus 1 further includes a computer 50 and a monitor 20. The monitor 20 is configured to display images. The monitor 20 is constituted by,

for example, a display device such as a liquid crystal monitor or an organic EL (Electro Luminescence) monitor.

[0038] The computer 50 controls the operations of various parts of the cutting module A1 and the inspection/storage module B1, for example. 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 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.

[0039] Also, the computer 50 performs various types of inspection on the electronic components S1 based on image data generated by the first optical inspection camera 12 and the second optical inspection camera 13, for example. Next, the computer 50 will be described in detail.

[0040] <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, an acceptance unit 95, and a storage unit 80, and these elements are electrically connected to each other via a bus.

[0041] 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 and the constituent elements of the cutting apparatus 1 according to information processing.

[0042] The input/output I/F 90 is configured to communicate with the 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 the constituent elements of the cutting apparatus 1 and in the reception of data transmitted from the constituent

elements of the cutting apparatus 1 to the computer 50. The acceptance unit 95 is configured to accept instructions from a user. The acceptance unit 95 is constituted by some or all of the following: a touch panel, a keyboard, a mouse, and a microphone, for example.

5 [0043] The storage unit 80 is an auxiliary storage device such as a hard disk drive or a solid state drive, for example. The storage 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 a RAM
10 74. The control unit 70 then controls the constituent elements by using the CPU 72 to interpret and execute the control program 81 loaded to the RAM 74.

[0044] [2. Inspection of electronic component of size that does not fit into the field of view of camera]

As described above, electronic components are inspected in the cutting
15 apparatus 1. Specifically, various types of inspection are performed on each electronic component S1 based on captured images (image data) generated by the first optical inspection camera 12 and the second optical inspection camera 13. Hereinafter, the inspection performed using the second optical inspection camera 13 will be described representatively. Similar processing is performed in the inspection
20 performed using the first optical inspection camera 12.

[0045] A case is conceivable in which the size of each electronic component S1 held on the inspection table 11 is large, so that the electronic component S1 does not fit into the field of view (angle of view) of the second optical inspection camera 13. In such a case, in the cutting apparatus 1, a plurality of partial image data respectively
25 indicating different parts of the electronic component S1 are generated by the second optical inspection camera 13, and the partial image data are composited. Composite image data is generated by compositing the partial image data. The composite image

data indicates an image of the entire electronic component S1. In the cutting apparatus 1, the electronic component S1 is inspected based on the composite image data.

[0046] If unprocessed partial image data are composited, large displacement of
5 partial images may occur at boundary portions (joint portions) between the partial images. Examples of factors that cause the displacement include distortion aberration of a lens included in the second optical inspection camera 13, an inclination of the second optical inspection camera 13 about the Z axis with respect to the inspection table 11 (with respect to the X axis), a phenomenon in which a rectangular
10 electronic component S1 is imaged in a trapezoid shape even if displacement due to the distortion aberration of the lens and the inclination of the second optical inspection camera 13 has been corrected, and deviation of the direction of movement of the second optical inspection camera 13 from the Y axis.

[0047] FIG. 4 is a diagram for describing a problem that occurs when unprocessed
15 partial image data are composited in a case where the second optical inspection camera 13 is inclined about the Z axis with respect to the inspection table 11. As shown in FIG. 4, if the second optical inspection camera 13 is inclined about the Z axis with respect to the inspection table 11, partial images inclined with respect to the X axis are captured. Partial images PI1, PI2, and PI3 respectively show different parts of an
20 object to be imaged, for example. When the partial images PI1, PI2, and PI3 are composited, a composite image IM1 is generated. In the composite image IM1, for example, a line that should linearly extend in parallel with the X axis is discontinuous at the boundaries between the partial images.

[0048] FIG. 5 is a diagram for describing a problem that occurs when unprocessed
25 partial image data are composited in a case where a rectangular object to be imaged is imaged in a trapezoid shape. As shown in FIG. 5, for example, there is a case in which a rectangular object to be imaged is imaged in a trapezoid shape even if

distortion or the like resulting from the distortion aberration of the lens of the second optical inspection camera 13 has been corrected. In a partial image PI4, a range with a length of 100 mm is imaged on the left side and a range with a length of 105 mm is imaged on the right side, for example. As a result, a rectangular object to be imaged is imaged in a trapezoid shape. In such a case, for example, if a partial image showing the left half of the object and a partial image showing the right half of the object are composited, a composite image IM2 is generated. In the composite image IM2, for example, lines that should linearly extend are discontinuous at the boundaries between the partial images.

[0049] FIG. 6 is a diagram for describing a problem that occurs when unprocessed partial image data are composited in a case where the direction of movement of the second optical inspection camera 13 deviates from the Y axis. As described above, there is a case in which the direction of movement of the second optical inspection camera 13 is not completely parallel with the Y axis as shown in FIG. 6. In such a case, for example, it is assumed that partial images PI5, PI6, PI7, PI8, and PI9 are successively captured. The partial images PI5, PI6, PI7, PI8, and PI9 respectively show different parts of an object to be imaged, for example. When the partial images PI5, PI6, PI7, PI8, and PI9 are composited, a composite image IM3 is generated. In the composite image IM3, for example, a line that should linearly extend obliquely upward is discontinuous at the boundaries between the partial images.

[0050] As described above, if unprocessed partial image data are composited, displacement of the partial images at the boundary portions between the partial images may become large. In the cutting apparatus 1, each piece of partial image data is corrected before partial image data are composited. More specifically, a plurality of partial image data are composited after each of the plurality of partial image data is corrected with consideration given to the inclination of the second optical inspection camera 13 with respect to the X axis and consideration given to a difference between

a reference angle (e.g., 90°) and an angle formed by the X axis and an axis corresponding to the direction of movement of the second optical inspection camera 13. Since the plurality of partial image data are composited after the various types of correction are performed, displacement that may occur at the boundary portions between the partial image data is suppressed in the composite image data. Therefore, the cutting apparatus 1 can inspect each electronic component S1 with relatively high accuracy based on the composite image data.

[0051] In the cutting apparatus 1, partial images are corrected using various types of correction data. The various types of correction data are generated in advance through calibration of the cutting apparatus 1. In the cutting apparatus 1, each electronic component S1 is inspected using the various types of correction data generated in advance. The following describes a calibration operation and an inspection operation in order.

[0052] [3. Operation]

<3-1. Calibration operation>

FIG. 7 is a flowchart showing a calibration procedure in the cutting apparatus 1. As shown in FIG. 7, an operator adjusts the inclination of the second optical inspection camera 13 (step S100). For example, the inclination of the second optical inspection camera 13 is adjusted such that the inclination of the second optical inspection camera 13 about the X axis with respect to the inspection table 11 (hereinafter also referred to as “the inclination about the X axis”) and the inclination of the second optical inspection camera 13 about the Y axis with respect to the inspection table 11 (hereinafter also referred to as “the inclination about the Y axis”) each approach 0° .

[0053] FIG. 8 is a diagram for describing the inclination about the X axis. As shown in FIG. 8, in this example, the second optical inspection camera 13 is inclined by an angle θ_1 about the X axis with respect to the inspection table 11. A calibration

plate is set on the inspection table 11 when the inclination of the second optical inspection camera 13 is adjusted.

[0054] FIG. 9 is a diagram schematically showing a plane of a calibration plate PL1. As shown in FIG. 9, the calibration plate PL1 includes a plurality of dots of the same size arranged vertically and horizontally at equal intervals. In the cutting apparatus 1, calibration is performed based on, for example, the shapes of the dots in a captured image.

[0055] Referring again to FIG. 8, in this example, the inspection table 11 is not completely flat but is slightly warped. In such a case, the inclination about the X axis changes as the second optical inspection camera 13 moves in the X and Y directions.

[0056] FIG. 10 is a diagram for describing an outline of the adjustment of the inclination about the X axis. In FIG. 10, the left figure shows inclination information AN1 for each imaging position before the adjustment of the inclination about the X axis, and the right figure shows inclination information AN1 for each imaging position after the adjustment of the inclination about the X axis. Each inclination information AN1 indicates an inclination about the X axis at the corresponding imaging position. Each inclination information AN1 is calculated, for example, by using various known methods based on a captured image. By manually adjusting the inclination of the second optical inspection camera 13 about the X axis, the inclination about the X axis is adjusted. For example, the inclination information AN1 for each imaging position is displayed on the monitor 20, and the operator adjusts the inclination of the second optical inspection camera 13 while checking the monitor 20. When it is determined that the inclination about the X axis at each imaging position falls within a desired range, the operator ends the adjustment of the inclination about the X axis. The operator may adjust the inclination about the Y axis in a procedure similar to the procedure for adjusting the inclination about the X axis after completion of the adjustment of the inclination about the X axis, or may adjust the inclination about the

Y axis in a procedure similar to the procedure for adjusting the inclination about the X axis in parallel with the adjustment of the inclination about the X axis.

[0057] FIG. 11 is a flowchart showing processing executed in step S100 of FIG. 7. In the cutting apparatus 1, a plurality of imaging positions at the time of calibration are determined in advance. The term “imaging position” refers to the location of the second optical inspection camera 13 on the X-Y plane. In this example, the inclination about the X axis is adjusted first, and then the inclination about the Y axis is adjusted. Since the procedure for adjusting the inclination about the X axis and the procedure for adjusting the inclination about the Y axis are substantially the same, only the procedure for adjusting the inclination about the X axis will be described here.

[0058] As shown in FIG. 11, the control unit 70 controls the second optical inspection camera 13 to start imaging the calibration plate PL1 held on the inspection table 11 (step S200). The control unit 70 performs control to move at least one of the inspection table 11 and the second optical inspection camera 13 to an imaging position at which imaging has not yet been performed out of the plurality of imaging positions determined in advance (step S210). The control unit 70 controls the second optical inspection camera 13 to perform automatic focusing (AF) (step S220). Automatic focusing is performed by adjusting the position of the second optical inspection camera 13 on the Z axis. In the state where focus of the second optical inspection camera 13 is achieved, the control unit 70 obtains coordinate information of the second optical inspection camera 13 on the Z axis (step S230).

[0059] The control unit 70 determines whether or not imaging has been performed at all the imaging positions determined in advance (step S240). If it is determined that imaging has not been performed at all the imaging positions determined in advance (NO in step S240), the control unit 70 again executes the processing in step S210.

[0060] On the other hand, if it is determined that imaging has been performed at

all the imaging positions determined in advance (YES in step S240), the control unit 70 determines whether or not imaging has been performed a predetermined number of times at all the imaging positions (step S250). If it is determined that imaging has not been performed the predetermined number of times at all the imaging positions
5 (NO in step S250), the control unit 70 again executes the processing in step S200.

[0061] On the other hand, if it is determined that imaging has been performed the predetermined number of times at all the imaging positions (YES in step S250), the control unit 70 extracts an average captured image for each of the imaging positions and calculates inclinations about the X axis at the respective imaging positions based
10 on the average captured images (step S260). The result of the calculation is displayed on the monitor 20, for example.

[0062] Even if images of the calibration plate PL1 are captured at the same imaging position, positions of dots in the captured images slightly shift due to mechanical accuracy of the inspection table 11 and the second optical inspection
15 camera 13 and image processing accuracy. In view of such circumstances, imaging is performed the predetermined number of times at all the imaging positions, and the inclination about the X axis is calculated based on average captured images. The average captured images are determined based on distances between dots in the captured images.

20 [0063] FIG. 12 is a diagram for describing distances between dots in a captured image of the calibration plate PL1. As shown in FIG. 12, the distances between dots include a distance AD1 between dots DO1 in the X axis direction and a distance BD1 between dots DO1 in the Y axis direction. For example, a captured image in which the distance AD1 and the distance BD1 are the closest to average values is extracted
25 as an average captured image.

[0064] FIG. 13 is a diagram including a table that shows an example of the distances between dots in five captured images. As shown in FIG. 13, in this example,

the distance AD1 and the distance BD1 in a captured image of $n=3$ are the closest to the average values. Therefore, the captured image of $n=3$ is extracted as an average captured image.

[0065] Referring again to FIG. 11, when the processing in step S260 is executed,
5 the operator checks the inclination about the X axis at each imaging position displayed on the monitor 20, and determines whether or not the inclination about the X axis at each imaging position satisfies a predetermined standard (step S270). If it is determined that the inclination about the X axis at each imaging position satisfies the predetermined standard (YES in step S270), the adjustment of the inclination of the
10 second optical inspection camera 13 ends.

[0066] On the other hand, if it is determined that the inclination about the X axis at each imaging position does not satisfy the predetermined standard (NO in step S270), the operator gives an instruction to readjust the inclination of the second optical inspection camera 13, for example, via the acceptance unit 95 of the computer 50.
15 When the readjustment instruction is given, the control unit 70 performs control to move the second optical inspection camera 13 to a position at which the inclination about the X axis is average among the plurality of imaging positions (step S280). Thereafter, the operator manually adjusts the inclination of the second optical inspection camera 13 about the X axis (step S290). Upon completion of the manual
20 adjustment, the processing in step S200 is executed again.

[0067] Referring back to FIG. 7, when the adjustment of the inclination of the second optical inspection camera 13 is complete, the control unit 70 of the computer 50 generates a virtual plane based on a plurality of partial image data generated by the second optical inspection camera 13 (step S110). The term “virtual plane” refers to
25 a plane for estimating a focus position (z) for each imaging position (x, y). The term “focus position” refers to the position of the second optical inspection camera 13 on the Z axis in the state where focus is achieved.

[0068] FIG. 14 is a diagram for describing an outline of the virtual plane. As shown in FIG. 14, for example, if the inspection table 11 is slightly inclined, the focus position of the second optical inspection camera 13 varies according to the imaging position. For example, focus positions of the second optical inspection camera 13 at both end positions are actually detected, and the focus position of the second optical inspection camera 13 at the central position is estimated based on a virtual plane VP1.

[0069] FIG. 15 is a diagram for describing a procedure for generating the virtual plane. In FIG. 15, the upper left figure shows points D1, D2, D3, and D4 in the X-Y plane. The points D1, D2, D3, and D4 correspond to imaging positions of the second optical inspection camera 13, respectively. The calibration plate PL1 is set on the inspection table 11 when the virtual plane is generated. For example, if the inspection table 11 is warped even slightly, it is assumed that the focus positions (positions on the Z axis) at the points D1, D2, D3, and D4 are different from each other. First, the focus positions at the points D1, D2, D3, and D4 are detected.

[0070] The upper right figure shows the points D1, D2, D3, and D4 in the XYZ space as viewed from diagonally above. For each of the points D1, D2, D3, and D4, (x, y) indicate coordinate positions in the XY plane, and (z) indicates the focus position. By connecting the points D1, D2, D3, and D4 with each other, a tetrahedron is formed. A virtual plane for estimating the focus position at a point DX1 (x, y) in this case is considered. When viewed from directly above, the point DX1 intersects two faces of the tetrahedron.

[0071] That is to say, the point DX1 intersects a face FA1 as shown in the lower left figure, and also intersects a face FA3 as shown in the lower center figure. Accordingly, the focus position at the point DX1 is highly likely to be on an intermediate plane between the face FA1 and the face FA3.

[0072] The lower right figure is a figure for describing a method for deriving the intermediate plane between the face FA1 and the face FA3. The intermediate plane

between the face FA1 and the face FA3 is a plane connecting the points D1, D2, and D5. The coordinates of the point D5 are mean values of the coordinates of the points D1, D2, D3, and D4. An expression representing the intermediate plane between the face FA1 and the face FA3 is derived, for example, based on the coordinates of the points D1, D2, and D5 by using various known techniques. The focus position at the point DX1 is estimated by substituting (x, y) of the point DX1 into the expression representing the intermediate plane. That is to say, this intermediate plane is used as the virtual plane. The method for deriving the virtual plane is not limited to this method. For example, the virtual plane may be derived based on (x, y, z) of four or more points surrounding the imaging position.

[0073] FIG. 16 is a flowchart showing processing executed in step S110 of FIG. 7. In FIG. 16, processing in steps S300 to S340 is the same as the processing in steps S200 to S240 in FIG. 11, respectively, and therefore, descriptions of these steps will not be repeated.

[0074] When it is determined in step S340 that imaging has been performed at all the imaging positions determined in advance (YES in step S340), the control unit 70 generates a virtual plane based on the imaging positions and the focus positions (step S350). It should be noted that the virtual plane does not necessarily have to be generated in advance, and it is sufficient that (x, y, z) of each imaging position are stored in the storage unit 80. Each time an electronic component S1 is inspected, the virtual plane may be generated based on (x, y, z) of each of at least three points surrounding the imaging position of the second optical inspection camera 13.

[0075] Referring again to FIG. 7, when the virtual plane is generated, the control unit 70 obtains various types of correction data by using the generated virtual plane (step S120). Examples of the correction data to be obtained include distortion correction data, rotation correction data, trapezoid correction data, and axial angle correction data.

[0076] FIG. 17 is a flowchart showing processing executed in step S120 of FIG. 7. As shown in FIG. 17, the control unit 70 executes processing for obtaining distortion correction data (step S400).

[0077] FIG. 18 is a diagram for describing an outline of correction of distortion aberration. As shown in FIG. 18, in this example, pincushion distortion aberration is corrected. The distortion aberration to be corrected may be barrel distortion aberration. The distortion correction data is data for correcting distortion aberration. The distortion correction data is obtained, for example, based on images captured by the second optical inspection camera 13 by using various known methods.

[0078] FIG. 19 is a flowchart showing processing executed in step S400 of FIG. 17. In FIG. 19, processing in steps S500, S510, S540, and S550 is the same as the processing in steps S200, S210, S240, and S250 in FIG. 11, respectively, and therefore, descriptions of these steps will not be repeated.

[0079] When the movement to one of the plurality of predetermined imaging positions at which imaging has not yet been performed is complete in step S510, the control unit 70 controls the second optical inspection camera 13 to adjust the Z axis coordinate position based on the virtual plane (step S520). When adjustment of the Z axis coordinate position is complete, the control unit 70 controls the second optical inspection camera 13 to capture a partial image of the calibration plate PL1 (step S530).

[0080] When it is determined that imaging has been performed a predetermined number of times at all the imaging positions (YES in step S550), the control unit 70 extracts an average captured image for each of the imaging positions (step S560). The control unit 70 generates distortion correction data based on the extracted average captured images (step S570).

[0081] Referring again to FIG. 17, when the distortion correction data is obtained, the control unit 70 executes processing for obtaining rotation correction data (step S410).

[0082] FIG. 20 is a diagram for describing an outline of rotation correction in a case where partial images are inclined with respect to the X axis. As shown in FIG. 20, in this example, each of partial images PI10 and PI11 is inclined at an angle θ_2 with respect to the X axis. In the cutting apparatus 1, the rotation of each partial image is corrected by cutting out a region that is parallel with the X axis from the partial image. Since such rotation correction is performed, the partial images PI10 and PI11 adjacent to each other partially overlap with each other. By compositing the partial images PI10 and PI11 after the rotation correction, a composite image IM4 is generated. In order to perform such rotation correction, it is necessary to calculate the inclination (angle θ_2 : rotation correction data) of the second optical inspection camera 13 about the Z axis with respect to the X axis.

[0083] FIG. 21 is a diagram for describing a procedure for calculating the inclination of the second optical inspection camera 13 about the Z axis with respect to the X axis. In FIG. 21, an axis AX1 indicates, for example, a row of dots DO1 on the calibration plate PL1. X coordinates of imaging positions corresponding to partial images PI12 and PI13 are different from each other, but Y coordinates of these imaging positions are the same. Factors that cause the row of dots DO1 to be imaged obliquely in each of the partial images PI12 and PI13 include (1) the inclination of the second optical inspection camera 13 about the Z axis with respect to the X axis and (2) an inclination of the calibration plate PL1 on the inspection table 11. That is to say, the angle of the axis AX1 in each of the partial images PI12 and PI13 is the sum of the above factors (1) and (2).

[0084] On the other hand, in this example, when attention is paid to a specific dot DO1, the position of the dot DO1 on the Y axis moves a distance Y1 as the imaging position moves a distance X1 on the X axis. An inclination (angle θ_3) occurring due to this movement is caused by the above factor (2). Therefore, it is possible to calculate the above factor (1) by subtracting the angle θ_3 from the angle of the axis

AX1 in each of the partial images PI12 and PI13.

[0085] FIG. 22 is a flowchart showing processing executed in step S410 of FIG. 17. In FIG. 22, processing in steps S600, S610, S620, S630, S650, S660, and S670 is the same as the processing in steps S500, S510, S520, S530, S540, S550, and S560 in FIG. 19, respectively, and therefore, descriptions of these steps will not be repeated.

[0086] When a partial image is captured in step S630, the control unit 70 performs distortion correction on the partial image data by using the distortion correction data (step S640). When an average captured image is extracted for each imaging position in step S670, the control unit 70 generates rotation correction data based on the extracted average captured images (step S680).

[0087] Referring again to FIG. 17, when the rotation correction data is obtained, the control unit 70 executes processing for obtaining trapezoid correction data (step S420).

[0088] FIG. 23 is a diagram for describing an outline of the trapezoid correction in a case where a rectangular object to be imaged is imaged in a trapezoid shape. As described above, there is a case in which a rectangular object is imaged in a trapezoid shape as shown in FIG. 23 even if distortion or the like resulting from distortion aberration of the lens of the second optical inspection camera 13 has been corrected, for example. In a partial image PI14, an area with a length of 100 mm is imaged on the left side and an area with a length of 105 mm is imaged on the right side, for example. As a result, a rectangular object is imaged in a trapezoid shape. In the trapezoid correction, the partial image PI14 is corrected such that, for example, the imaging range on the left side and the imaging range on the right side become the same and the imaging range on the upper side and the imaging range on the lower side become the same. As a result, the rectangular object to be imaged has an accurate shape in a corrected partial image PI15. Trapezoid correction data necessary for such correction is obtained by using various known methods such as affine transformation,

for example.

[0089] FIG. 24 is a flowchart showing processing executed in step S420 of FIG. 17. As shown in FIG. 24, the control unit 70 performs the rotation correction on the average captured images extracted for the respective imaging positions in step S670 of FIG. 22 (step S700). The control unit 70 generates trapezoid correction data such that, in the captured images after the rotation correction, the imaging range on the left side and the imaging range on the right side become the same and the imaging range on the upper side and the imaging range on the lower side become the same (step S710).

[0090] Referring again to FIG. 17, when the trapezoid correction data is obtained, the control unit 70 executes processing for obtaining axial angle correction data (step S430).

[0091] FIG. 25 is a diagram for describing an outline of axial angle correction in a case where there is a deviation between the direction of movement of the second optical inspection camera 13 and the Y axis. As shown in FIG. 25, if there is a deviation between the direction of movement of the second optical inspection camera 13 and the Y axis, partial images PI16 and PI17 are corrected by adjusting (offsetting) image cutting positions in each of the partial images. By compositing the corrected partial images, a composite image IM5 is generated.

[0092] FIG. 26 is a diagram for describing a procedure for calculating the inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis. Offset amounts of the cutting positions are determined based on the inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis.

[0093] In FIG. 26, an axis AX2 indicates, for example, a row of dots DO1 on the calibration plate PL1. X coordinates of imaging positions corresponding to partial images PI18 and PI19 are the same, but Y coordinates of these imaging positions are different from each other. Factors that cause the row of dots DO1 to be imaged

obliquely in each of the partial images PI18 and PI19 include (A) the inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis (axial angle correction data) and (B) an inclination of the calibration plate PL1 on the inspection table 11. That is to say, the angle of the axis AX2 in each of the partial images PI18 and PI19 is the sum of the above factors (A) and (B).

[0094] On the other hand, in this example, when attention is paid to a specific dot DO1, the position of the dot DO1 on the X axis moves a distance X2 as the imaging position moves a distance Y2 on the Y axis. An inclination (angle θ_4) occurring due to this movement is caused by the above factor (B). Therefore, it is possible to calculate the above factor (A) by subtracting the angle θ_4 from the angle of the axis AX2 in each of the partial images PI18 and PI19.

[0095] FIG. 27 is a flowchart showing processing executed in step S430 of FIG. 17. In FIG. 27, processing in steps S800, S810, S820, S830, S850, S860, and S870 is the same as the processing in steps S600, S610, S620, S630, S650, S660, and S670 in FIG. 22, respectively, and therefore, descriptions of these steps will not be repeated.

[0096] When a partial image is captured in step S830, the control unit 70 performs distortion correction using the distortion correction data, rotation correction using the rotation correction data, and trapezoid correction using the trapezoid correction data in this order on the partial image data (step S840). When an average captured image is extracted for each imaging position in step S870, the control unit 70 generates axial angle correction data based on the extracted average captured images (step S880). Thus, the virtual plane and the various types of correction data are generated through calibration.

[0097] <3-2. Inspection operation>

FIG. 28 is a flowchart showing a procedure for inspecting an electronic component S1 that does not fit into the field of view of the second optical inspection camera 13. Processing shown in this flowchart is executed by the control unit 70 of

the computer 50 in predetermined cycles.

[0098] As shown in FIG. 28, the control unit 70 determines a plurality of imaging positions based on arrangement information of an electronic component S1 to be inspected (step S900). The control unit 70 controls the second optical inspection camera 13 to start imaging the electronic component S1 held on the inspection table 11 (step S910). The control unit 70 performs control to move at least one of the inspection table 11 and the second optical inspection camera 13 to an imaging position at which imaging has not yet been performed out of the plurality of imaging positions determined in advance (step S920).

10 [0099] The control unit 70 calculates a Z axis coordinate position based on the virtual plane, and performs control to move the second optical inspection camera 13 to the calculated Z axis coordinate position (step S930). When adjustment of the Z axis coordinate position is complete, the control unit 70 controls the second optical inspection camera 13 to capture a partial image of the electronic component S1 (step
15 S940). Thus, in the cutting apparatus 1, the focus position of the second optical inspection camera 13 along the Z axis is individually adjusted when partial image data is generated. The control unit 70 performs the distortion correction using the distortion correction data, the rotation correction using the rotation correction data, and the trapezoid correction using the trapezoid correction data in this order on the partial
20 image data (step S950).

[0100] The control unit 70 determines whether or not imaging has been completed at all the imaging positions determined in advance (step S960). If it is determined that imaging has not been completed at all the imaging positions determined in advance (NO in step S960), the control unit 70 again executes the processing in step
25 S920.

[0101] On the other hand, if it is determined that imaging has been completed at all the imaging positions determined in advance (YES in step S960), the control unit

70 performs offset (axis correction) of partial image data by using axis correction data (step S970). The control unit 70 generates composite image data by compositing partial image data subjected to the various types of correction (step S980). The control unit 70 inspects and measures the electronic component S1 based on the composite image data (step S990). The inspection of the electronic component S1 includes visual inspection of the electronic component S1, and the measurement of the electronic component S1 includes measurement of the length of each part of the electronic component S1.

[0102] [4. Features]

As described above, in the cutting apparatus 1, a plurality of partial image data are composited after each of the plurality of partial image data is corrected with consideration given to the inclination of the camera with respect to the X axis and consideration given to a difference between a reference angle (e.g., 90°) and an angle formed by the X axis and an axis extending along the direction of movement of the second optical inspection camera 13. Since the plurality of partial image data are composited after the various types of correction are performed, displacement that may occur at the boundary portions between the partial image data is suppressed in the composite image data. Therefore, the cutting apparatus 1 can inspect the electronic component S1 with relatively high accuracy based on the composite image data.

[0103] In the cutting apparatus 1, the focus position is individually adjusted when each of the plurality of partial image data is generated. Therefore, the cutting apparatus 1 can generate each of the plurality of partial image data by using the second optical inspection camera 13 that is set at an appropriate focus position. As a result, the cutting apparatus 1 can inspect the electronic component S1 with relatively high accuracy.

[0104] In the cutting apparatus 1, the correction performed with consideration given to the inclination of the second optical inspection camera 13 with respect to the

X axis and the correction performed with consideration given to a difference between the reference angle (e.g., 90°) and an angle formed by the X axis and the direction of movement of the second optical inspection camera 13 (inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis) are performed in this order on each of the plurality of partial image data. These types of correction are performed in this order for the following reason. As described above, the inclination of the second optical inspection camera 13 with respect to the X axis can be calculated based on images captured by the second optical inspection camera 13 even if correction has not been performed with consideration given to the inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis. On the other hand, the inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis cannot be calculated based on images captured by the second optical inspection camera 13 when correction has not been performed with consideration given to the inclination of the second optical inspection camera 13 with respect to the X axis. This is because the captured images that have not been corrected with consideration given to the inclination of the second optical inspection camera 13 with respect to the X axis are affected by both the inclination of the second optical inspection camera 13 with respect to the X axis and the inclination of the direction of movement of the second optical inspection camera 13 with respect to the Y axis. Therefore, in the cutting apparatus 1, the correction performed with consideration given to the inclination of the camera with respect to the X axis is performed earlier. Since the plurality of partial image data are composited after these types of correction are performed in the appropriate order, displacement that may occur at the boundary portions between the partial image data is suppressed in the composite image data. Therefore, the cutting apparatus 1 can inspect the electronic component S1 with relatively high accuracy based on the composite image data.

[0105] In the cutting apparatus 1, imaging of the calibration plate PL1 is performed a plurality of times at the same imaging position, and the correction data is obtained based on an average captured image, so that compositing of images can be performed based on the correction data having higher accuracy. It should be noted
5 that, depending on an object to be imaged, the correction data may be obtained based on a captured image that is the closest to a median of variations of a plurality of captured images rather than an average of the plurality of captured images.

[0106] The cutting apparatus 1 can generate a single composite image from a plurality of corrected captured images. Therefore, even in a case where it is
10 necessary to install a camera that can capture an image in a wider field of view to inspect an electronic component of a size that does not fit into the field of view of a camera included in a conventional apparatus, it is possible to inspect such an electronic component with the camera included in the conventional apparatus.

[0107] It should be noted that the inspection table 11 is an example of a “table” in
15 the present invention, and the first optical inspection camera 12 and the second optical inspection camera 13 are each an example of a “camera” in the present invention. The mechanism for moving the inspection table 11 along the X axis is an example of a “first movement mechanism” in the present invention, and the mechanism for moving each of the first optical inspection camera 12 and the second optical inspection
20 camera 13 along the Y axis is an example of a “second movement mechanism” in the present invention. The control unit 70 is an example of a “control unit” in the present invention, and the mechanism for moving each of the first optical inspection camera 12 and the second optical inspection camera 13 along the Z axis is an example of a “third movement mechanism” in the present invention.

25 [0108] [5. Other embodiments]

The idea of the above embodiment is not limited to the embodiment described above. Hereinafter, examples of other embodiments to which the idea of the above

embodiment is applicable will be described.

[0109] In the above embodiment, the technique for inspecting an object to be inspected that does not fit into the field of view of a camera is applied to a cutting apparatus. However, the applicable range of the technique is not limited to a cutting apparatus. For example, the technique may be applied to a resin molding apparatus that manufactures resin molded products. For example, the technique may be applied to inspection of resin molded products that do not fit into the field of view of a camera. The technique is applicable to, for example, a semiconductor manufacturing apparatus such as a cutting apparatus and a resin molding apparatus.

[0110] In the above embodiment, the imaging position of each camera is adjusted by moving the inspection table 11 along the X axis and moving each of the first optical inspection camera 12 and the second optical inspection camera 13 along the Y axis. However, the method for adjusting the imaging position of each camera is not limited to this method. For example, the imaging position of each camera may be adjusted by moving each camera along both the X axis and the Y axis, or by moving the inspection table 11 along both the X axis and the Y axis.

[0111] The embodiments of the present invention described above are illustrative. In other words, the detailed description and accompanying drawings are disclosed for the purpose of illustration. Therefore, some of the components described in the detailed description and the accompanying drawings may not be essential for solving the problem. Accordingly, simply because non-essential components are described in the detailed description and the accompanying drawings, such non-essential components are not intended to be immediately identified as essential.

[0112] Furthermore, the above embodiments are merely illustrative of the present invention in all respects. Various improvements and changes can be made to the above embodiments within the scope of the present invention. For example, the configuration of at least a portion of any of the embodiments and the configuration of

at least a portion of any of the other embodiments may be combined. In other words, when implementing the present invention, specific configurations can be adopted as appropriate depending on the embodiment.

[0113] [6. Appendix]

5 <Technique 1>

(Configuration)

An inspection system including:

a table for holding an electronic component;

a camera configured to capture an image of a part of the electronic component

10 and generate first partial image data;

a first movement mechanism configured to move at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a first axis is changed;

15 a second movement mechanism configured to move at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a second axis is changed; and

a control unit configured to control each of the camera, the first movement mechanism, and the second movement mechanism such that a plurality of first partial image data respectively indicating different parts of the electronic component are
20 generated,

wherein the control unit executes: first processing for subjecting each of the plurality of first partial image data to correction with consideration given to an inclination of the camera with respect to the first axis and correction with consideration given to a difference between an angle formed by the first axis and the second axis and
25 a reference angle; second processing for generating composite image data by compositing the plurality of first partial image data after correction; and third processing for inspecting the electronic component based on the composite image data.

[0114] (Effects etc.)

In this inspection system, the plurality of first partial image data are composited after each of the plurality of first partial image data is subjected to the correction performed with consideration given to the inclination of the camera with
5 respect to the first axis and the correction performed with consideration given to the difference between the angle formed by the first axis and the second axis and the reference angle. Since the plurality of first partial image data are composited after the various types of correction are performed, displacement that may occur at boundary portions between the first partial image data is suppressed in the composite
10 image data. Thus, this inspection system can inspect the electronic component with relatively high accuracy based on the composite image data.

[0115] <Technique 2>

(Configuration)

The inspection system according to technique 1, wherein the reference angle
15 is 90°.

[0116] (Effects etc.)

In this inspection system, when the angle formed by the first axis and the second axis deviates from the right angle, each of the plurality of first partial image data is corrected. Since the plurality of first partial image data are composited after
20 being corrected, displacement that may occur at the boundary portions between the first partial image data is suppressed in the composite image data. Thus, this inspection system can inspect the electronic component with relatively high accuracy based on the composite image data.

[0117] <Technique 3>

25 (Configuration)

The inspection system according to technique 1 or 2,
wherein the camera includes a lens, and

in the first processing, each of the plurality of first partial image data is further subjected to correction with consideration given to distortion of the lens.

[0118] (Effects etc.)

In this inspection system, the plurality of first partial image data are
5 composited after each of the plurality of first partial image data is further corrected with consideration given to the distortion of the lens. Since the plurality of first partial image data are composited after the various types of correction are performed, displacement that may occur at the boundary portions between the first partial image data is suppressed in the composite image data. Thus, this inspection system can
10 inspect the electronic component with relatively high accuracy based on the composite image data.

[0119] <Technique 4>

(Configuration)

The inspection system according to any one of techniques 1 to 3, further
15 including a third movement mechanism configured to move the camera along a third axis that is orthogonal to the first axis and the second axis,

wherein the control unit controls the third movement mechanism such that a focus position of the camera along the third axis is individually adjusted when each of the plurality of first partial image data is generated.

20 [0120] (Effects etc.)

For example, if the table is not completely flat, the focus position may vary according to an imaging position of the electronic component. In this inspection system, the focus position is individually adjusted when each of the plurality of first partial image data is generated. Therefore, this inspection system can generate each
25 of the plurality of first partial image data by using the camera set at an appropriate focus position. As a result, this inspection system can inspect the electronic component with relatively high accuracy.

[0121] <Technique 5>

(Configuration)

The inspection system according to technique 4,
wherein the control unit controls the third movement mechanism such that the
5 focus position is adjusted by referring to a virtual plane, and
the virtual plane is generated based on the focus position at each of at least
three points surrounding an imaging position of the camera.

[0122] (Effects etc.)

In this inspection system, the focus position of the camera is adjusted with
10 relatively high accuracy by referring to the virtual plane. Therefore, this inspection
system can generate each of the plurality of first partial image data by using the camera
set at an appropriate focus position. As a result, this inspection system can inspect
the electronic component with relatively high accuracy.

[0123] <Technique 6>

15 (Configuration)

The inspection system according to any one of techniques 1 to 5, wherein, in
the first processing, the control unit subjects each of the plurality of first partial image
data to the correction performed with consideration given to the inclination of the
camera with respect to the first axis and the correction performed with consideration
20 given to the difference between the angle formed by the first axis and the second axis
and the reference angle in this order.

[0124] (Effects etc.)

In this inspection system, each of the plurality of first partial image data is
subjected to the correction performed with consideration given to the inclination of the
25 camera with respect to the first axis and the correction performed with consideration
given to the difference between the angle formed by the first axis and the second axis
and the reference angle in this order. That is, in this inspection system, the correction

that is performed earlier is the correction performed with consideration given to the inclination of the camera with respect to the first axis, which is not affected by the difference between the angle formed by the first axis and the second axis and the reference angle. Since the plurality of first partial image data are composited after
5 the correction is performed in the appropriate order, displacement that may occur at the boundary portions between the first partial image data is suppressed in the composite image data. Thus, this inspection system can inspect the electronic component with relatively high accuracy based on the composite image data.

[0125] <Technique 7>

10 (Configuration)

The inspection system according to any one of techniques 1 to 6,
wherein first correction data is used for the correction performed with consideration given to the inclination of the camera with respect to the first axis, and second correction data is used for the correction performed with consideration given
15 to the difference between the angle formed by the first axis and the second axis and the reference angle,

each of the first correction data and the second correction data is generated in advance,

the camera captures an image of a calibration plate and generates second
20 partial image data, and

the second correction data is generated based on the second partial image data that has been corrected using the first correction data.

[0126] (Effects etc.)

In this inspection system, the second correction data is generated based on the
25 second partial image data in which the inclination of the camera with respect to the first axis has been corrected. Therefore, second correction data having relatively high accuracy is generated in advance in this inspection system. As a result, in this

inspection system, the plurality of first partial image data are composited after each of the plurality of first partial image data is corrected using the second correction data having relatively high accuracy, so that displacement that may occur at the boundary portions between the first partial image data is suppressed in the composite image data.

5 Thus, this inspection system can inspect the electronic component with relatively high accuracy based on the composite image data.

[0127] <Technique 8>

(Configuration)

A semiconductor manufacturing apparatus including:

10 the inspection system according to any one of techniques 1 to 7; and
a manufacturing system for manufacturing the electronic component,
wherein the electronic component is a semiconductor device, and
the inspection system inspects the electronic component manufactured by the
manufacturing system.

15 [0128] (Effects etc.)

In this semiconductor manufacturing apparatus, a plurality of first partial image data are composited after each of the plurality of first partial image data is subjected to correction performed with consideration given to an inclination of the camera with respect to the first axis and correction performed with consideration given
20 to a difference between an angle formed by the first axis and the second axis and a reference angle. Since the plurality of first partial image data are composited after the various types of correction are performed, displacement that may occur at boundary portions between the first partial image data is suppressed in the composite image data. Thus, the semiconductor manufacturing apparatus can inspect the
25 electronic component with relatively high accuracy based on the composite image data.

[0129] <Technique 9>

(Configuration)

An inspection method using an inspection system,
wherein the inspection system including:
a table for holding an electronic component;
a camera configured to capture an image of a part of the electronic component
5 and generate partial image data;
a first movement mechanism configured to move at least one of the table and
the camera such that a relative positional relationship between the electronic
component and the camera in a direction along a first axis is changed; and
a second movement mechanism configured to move at least one of the table
10 and the camera such that a relative positional relationship between the electronic
component and the camera in a direction along a second axis is changed; and
the inspection method including:
a step of generating a plurality of partial image data respectively indicating
different parts of the electronic component;
15 a step of subjecting each of the plurality of partial image data to correction
performed with consideration given to an inclination of the camera with respect to the
first axis and correction performed with consideration given to a difference between
an angle formed by the first axis and the second axis and a reference angle;
a step of generating composite image data by compositing the plurality of
20 partial image data after correction; and
a step of inspecting the electronic component based on the composite image
data.

[0130] (Effects etc.)

In this inspection method, a plurality of first partial image data are composited
25 after each of the plurality of first partial image data is subjected to the correction
performed with consideration given to the inclination of the camera with respect to the
first axis and the correction performed with consideration given to the difference

between the angle formed by the first axis and the second axis and the reference angle. Since the plurality of first partial image data are composited after the various types of correction are performed, displacement that may occur at boundary portions between the first partial image data is suppressed in the composite image data. Therefore, according to this inspection method, the electronic component can be inspected with relatively high accuracy based on the composite image data.

List of Reference Numerals

	[0131]	1	Cutting apparatus
10		3	Substrate supply part
		4	Positioning part
		4a	Rail part
		5	Cutting table
		5a	Holding member
15		5b	Rotation mechanism
		5c	Movement mechanism
		5d	First position checking camera
		5e	First cleaner
		6	Spindle part
20		6a	Blade
		6b	Second position checking camera
		6c	Rotation axis
		7	Conveying part
		7a	Second cleaner
25		11	Inspection table
		12	First optical inspection camera
		13	Second optical inspection camera

	14	Arrangement part
	15	Extraction part
	15a	Good product tray
	15b	Defective product tray
5	16, 17	Illumination part
	17a	Dome
	17b	LED
	20	Monitor
	50	Computer
10	70	Control unit
	72	CPU
	74	RAM
	76	ROM
	80	Storage unit
15	81	Control program
	90	Input/output I/F
	95	Acceptance unit
	A1	Cutting module
	AN1	Inclination information
20	AX1	Axis
	B1	Inspection/storage module
	D1 to D5, DX1	Point
	DO1	Dot
	FA1 to FA4	Face
25	M1	Magazine
	P1	Package substrate
	PI1 to PI19	Partial image

IM1 to IM5 Composite image

PL1 Calibration plate

S1 Electronic component

VP1 Virtual plane

CLAIMS

[Claim 1] An inspection system comprising:

a table configured to hold an electronic component;

5 a camera configured to capture an image of a part of the electronic component and generate first partial image data;

a first movement mechanism configured to move at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a first axis is changed;

10 a second movement mechanism configured to move at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a second axis is changed; and

a control unit configured to control each of the camera, the first movement mechanism, and the second movement mechanism such that a plurality of first partial
15 image data respectively indicating different parts of the electronic component are generated,

wherein the control unit executes: first processing for subjecting each of the plurality of first partial image data to correction performed with consideration given to an inclination of the camera with respect to the first axis and correction with
20 consideration given to a difference between an angle formed by the first axis and the second axis and a reference angle; second processing for generating composite image data by compositing the plurality of first partial image data after correction: and third processing for inspecting the electronic component based on the composite image data.

25 [Claim 2] The inspection system according to claim 1,

wherein the reference angle is 90°.

[Claim 3] The inspection system according to claim 1 or 2,
 wherein the camera includes a lens, and
 in the first processing, each of the plurality of first partial image data is further
 subjected to correction performed with consideration given to distortion of the lens.

5

[Claim 4] The inspection system according to any one of claims 1 to 3, further
 comprising:

 a third movement mechanism configured to move the camera along a third
 axis that is orthogonal to the first axis and the second axis,

10 wherein the control unit controls the third movement mechanism such that a
 focus position of the camera along the third axis is individually adjusted when each of
 the plurality of first partial image data is generated.

[Claim 5] The inspection system according to claim 4,

15 wherein the control unit controls the third movement mechanism such that the
 focus position is adjusted by referring to a virtual plane, and

 the virtual plane is generated based on the focus position at each of at least
 three points surrounding an imaging position of the camera.

20 [Claim 6] The inspection system according to any one of claims 1 to 5,
 wherein, in the first processing, the control unit subjects each of the plurality
 of first partial image data to the correction performed with consideration given to the
 inclination of the camera with respect to the first axis and the correction performed
 with consideration given to the difference between the angle formed by the first axis
25 and the second axis and the reference angle in this order.

[Claim 7] The inspection system according to any one of claims 1 to 6,

wherein first correction data is used for the correction performed with consideration given to the inclination of the camera with respect to the first axis, and second correction data is used for the correction performed with consideration given to the difference between the angle formed by the first axis and the second axis and
5 the reference angle,

each of the first correction data and the second correction data is generated in advance,

the camera captures an image of a calibration plate and generates second partial image data, and

10 the second correction data is generated based on the second partial image data that has been corrected using the first correction data.

[Claim 8] A semiconductor manufacturing apparatus comprising:

the inspection system according to any one of claims 1 to 7; and
15 a manufacturing system for manufacturing the electronic component,
wherein the electronic component is a semiconductor device, and
the inspection system inspects the electronic component manufactured by the manufacturing system.

20 [Claim 9] An inspection method using an inspection system,

wherein the inspection system includes:

a table configured to hold an electronic component;

a camera configured to capture an image of a part of the electronic component and generate partial image data;

25 a first movement mechanism configured to move at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a first axis is changed;

a second movement mechanism configured to move at least one of the table and the camera such that a relative positional relationship between the electronic component and the camera in a direction along a second axis is changed; and

the inspection method including:

- 5 generating a plurality of partial image data respectively indicating different parts of the electronic component;

 subjecting each of the plurality of partial image data to correction performed with consideration given to an inclination of the camera with respect to the first axis and correction performed with consideration given to a difference between an angle

- 10 formed by the first axis and the second axis and a reference angle;

 generating composite image data by compositing the plurality of partial image data after correction; and

 inspecting the electronic component based on the composite image data.