

DESCRIPTION

TITLE OF INVENTION

MOUNTING APPARATUS, MOUNTING METHOD, AND MOUNTING CONTROL

PROGRAM

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Technical Field

[0001] The present invention relates to a mounting apparatus, a mounting method, and a mounting control program.

Related Art

10 **[0002]** In a bonding apparatus, which is an example of the conventional mounting apparatus, first, a work target such as a die pad is imaged from directly above with a camera to confirm the position thereof. Then, after retracting the camera, a head portion supporting a bonding tool is moved directly above the work target, and the bonding work is performed. The bonding apparatus employing such a configuration not only takes time to work but also has a problem of
15 accumulation of movement errors with respect to the work target position. Therefore, it has been considered to use an imaging unit employing a Scheimpflug optical system that is capable of imaging the work target from an oblique direction (see, for example, Patent Literature 1).

Citation List

Patent Literature

20 **[0003]** [Patent Literature 1] Japanese Patent Laid-Open No. 2014-179560

SUMMARY OF INVENTION

Technical Problem

[0004] However, it has been found that, due to structural characteristics of the optical system,
25 minute displacements of the optical system elements due to a temperature change in the

surrounding environment are likely to appear as displacements of the output image in the plane direction in the imaging unit employing a Scheimpflug optical system. The displacements of the output image in the plane direction cause an error in calculating the target position where the semiconductor chip should be placed, and consequently result in impeding the accurate mounting of the semiconductor chip on the original target position. In particular, in so-called stacked die mounting or 2.5-dimensional mounting, in which another semiconductor chip is further mounted on top of a semiconductor chip mounted on a substrate, the height of the placement surface for placing each semiconductor chip changes. In such a case, the problem that the amount of error differs for each height also becomes apparent.

[0005] The present invention was made to solve such problems, and the present invention provides a mounting apparatus, etc. that is capable of accurately determining a target position for placing each mounting body such as a semiconductor chip by using an imaging unit that employs a Scheimpflug optical system, and placing and mounting the mounting body at the target position on a substrate even if the temperature of the surrounding environment changes and even when a plurality of mounting bodies are mounted on top of each other.

Solution to Problem

[0006] A mounting apparatus according to the first aspect of the present invention includes a mounting tool picking up and holding a mounting body, and placing and mounting the mounting body on a substrate placed on a stage or a planned placement area set for another mounting body already mounted on the substrate; top-view imaging units, in which optical systems and imaging elements are arranged to satisfy a Scheimpflug condition so that a plane parallel to a stage surface of the stage becomes a focal plane, for imaging from above the planned placement area from the same side as the mounting tool with respect to the stage surface; a bottom-view imaging unit for imaging from below the mounting body that is in a state of being held by the mounting tool from a side opposite to the top-view imaging units with respect to the stage surface; a calibration

controller calculating calibration values for calibrating a difference between coordinate values calculated based on top-view images output by the top-view imaging units and coordinate values calculated based on a bottom-view image output by the bottom-view imaging unit; and a mounting controller placing and mounting the mounting body on the planned placement area so that a reference position of the mounting body held by the mounting tool coincides with a target position of the planned placement area. The calibration controller calculates the calibration values for each assumed placement height of the planned placement area based on the top-view images and the bottom-view image output by the top-view imaging units and the bottom-view imaging unit by imaging a calibration index arranged to match the placement height. The mounting controller adjusts a position of the mounting tool so that a planned contact surface of the mounting body for contacting the planned placement area is at the placement height to recognize the reference position based on the bottom-view image output by the bottom-view imaging unit by imaging the planned contact surface, and adjusts positions of the top-view imaging units so that the focal plane falls on the same plane as the placement height to recognize the target position based on the top-view images obtained by the top-view imaging units by imaging the planned placement area and the calibration values corresponding to the placement height.

[0007] A mounting method according to the second aspect of the present invention is provided for a mounting body using a mounting apparatus, which includes a mounting tool picking up and holding the mounting body and placing and mounting the mounting body on a substrate placed on a stage or a planned placement area set for another mounting body already mounted on the substrate; top-view imaging units in which respective optical systems and imaging elements are arranged to satisfy a Scheimpflug condition so that a plane parallel to a stage surface of the stage becomes a focal plane, for imaging from above the planned placement area from the same side as the mounting tool with respect to the stage surface; and a bottom-view imaging unit for imaging from below the mounting body that is in a state of being held by the mounting tool from a side

opposite to the top-view imaging units with respect to the stage surface. The mounting method includes a calibration control step of calculating calibration values for calibrating a difference between coordinate values calculated based on top-view images output by the top-view imaging units and coordinate values calculated based on a bottom-view image output by the bottom-view imaging unit; and a mounting control step of placing and mounting the mounting body on the planned placement area so that a reference position of the mounting body held by the mounting tool coincides with a target position of the planned placement area. The calibration control step calculates the calibration values for each assumed placement height of the planned placement area based on the top-view images and the bottom-view image output by the top-view imaging units and the bottom-view imaging unit by imaging a calibration index arranged to match the placement height. The mounting control step adjusts a position of the mounting tool so that a planned contact surface of the mounting body for contacting the planned placement area is at the placement height to recognize the reference position based on the bottom-view image output by the bottom-view imaging unit by imaging the planned contact surface, and adjusts positions of the top-view imaging units so that the focal plane falls on the same plane as the placement height to recognize the target position based on the top-view images obtained by the top-view imaging units by imaging the planned placement area and the calibration values corresponding to the placement height.

[0008] A mounting control program according to the third aspect of the present invention is provided for controlling a mounting apparatus, which includes a mounting tool picking up and holding a mounting body and placing and mounting the mounting body on a substrate placed on a stage or a planned placement area set for another mounting body already mounted on the substrate; top-view imaging units in which respective optical systems and imaging elements are arranged to satisfy a Scheimpflug condition so that a plane parallel to a stage surface of the stage becomes a focal plane, for imaging from above the planned placement area from the same side as the

mounting tool with respect to the stage surface; and a bottom-view imaging unit for imaging from below the mounting body that is in a state of being held by the mounting tool from a side opposite to the top-view imaging units with respect to the stage surface. The mounting control program causes a computer to execute: a calibration control step of calculating calibration values for
5 calibrating a difference between coordinate values calculated based on top-view images output by the top-view imaging units and coordinate values calculated based on a bottom-view image output by the bottom-view imaging unit; and a mounting control step of placing and mounting the mounting body on the planned placement area so that a reference position of the mounting body held by the mounting tool coincides with a target position of the planned placement area. The
10 calibration control step calculates the calibration values for each assumed placement height of the planned placement area based on the top-view images and the bottom-view image output by the top-view imaging units and the bottom-view imaging unit by imaging a calibration index arranged to match the placement height. The mounting control step adjusts a position of the mounting tool so that a planned contact surface of the mounting body for contacting the planned placement
15 area is at the placement height to recognize the reference position based on the bottom-view image output by the bottom-view imaging unit by imaging the planned contact surface, and adjusts positions of the top-view imaging units so that the focal plane falls on the same plane as the placement height to recognize the target position based on the top-view images obtained by the top-view imaging units by imaging the planned placement area and the calibration values
20 corresponding to the placement height.

Effects of Invention

[0009] According to the present invention, it is possible to provide a mounting apparatus, etc. that is capable of accurately determining a target position for placing each mounting body such as a semiconductor chip by using an imaging unit that employs a Scheimpflug optical system, and
25 placing and mounting the mounting body at the target position on a substrate even if the

temperature of the surrounding environment changes and even when a plurality of mounting bodies are mounted on top of each other.

BRIEF DESCRIPTION OF DRAWINGS

5 [0010]

FIG. 1 is an overall configuration diagram of the flip chip bonder including the bonding apparatus according to this embodiment.

FIG. 2 is a system configuration diagram of the bonding apparatus.

FIG. 3 is an explanatory diagram for illustrating the Scheimpflug optical system.

10 FIG. 4 is a diagram showing how three imaging units image the calibration index adjusted to the height of the first planned surface.

FIG. 5 is a diagram showing how three imaging units image the calibration index adjusted to the height of the second planned surface.

FIG. 6 is a diagram showing how the bonding tool picks up the first semiconductor chip.

15 FIG. 7 is a diagram showing how the third imaging unit images the first semiconductor chip.

FIG. 8 is a diagram schematically showing the bottom-view image output by the third imaging unit.

FIG. 9 is a diagram showing how the first imaging unit and the second imaging unit image the lead frame which is the planned placement area.

20 FIG. 10 is a partial perspective diagram of FIG. 9.

FIG. 11 is a diagram showing the procedure for calculating the target coordinates on the die pad for placing the first semiconductor chip from the first top-view image and the second top-view image.

FIG. 12 is a diagram showing how the bonding tool places and bonds the first semiconductor chip
25 to the target position.

FIG. 13 is a diagram showing how the bonding tool is retracted.

FIG. 14 is a diagram showing how the third imaging unit images the second semiconductor chip.

FIG. 15 is a diagram schematically showing the bottom-view image output by the third imaging unit.

5 FIG. 16 is a diagram showing how the first imaging unit and the second imaging unit image the first semiconductor chip which is the planned placement area.

FIG. 17 is a diagram showing the procedure for calculating the target coordinates on the first semiconductor chip for placing the second semiconductor chip from the first top-view image and the second top-view image.

10 FIG. 18 is a diagram showing how the bonding tool places and bonds the second semiconductor chip to the target position.

FIG. 19 is a flowchart illustrating the bonding procedure of the semiconductor chip.

FIG. 20 is a sub-flowchart illustrating the procedure of the calibration control step.

FIG. 21 is a sub-flowchart illustrating the procedure of the bonding control step.

15 FIG. 22 is a diagram showing how three imaging units image the calibration index adjusted to the height of the first planned surface in another embodiment.

FIG. 23 is a flowchart illustrating the bonding procedure of the semiconductor chip in another embodiment.

FIG. 24 is a diagram illustrating the arrangement of the calibration indices of the calibration unit
20 in yet another embodiment.

DESCRIPTION OF EMBODIMENTS

[0011] Hereinafter, the present invention will be described through embodiments of the invention, but the invention according to the scope of the claims is not limited to the following
25 embodiments. Moreover, not all the configurations described in the embodiments are essential

as means for solving the problems. In each drawing, when there are multiple structures with the same or similar configurations, some may be given reference numerals and the same reference numerals may be omitted for others in order to avoid complication.

[0012] FIG. 1 is an overall configuration diagram of a flip chip bonder including a bonding apparatus 100 as a mounting apparatus according to this embodiment. The flip chip bonder is mainly composed of the bonding apparatus 100 and a chip supply apparatus 500. The chip supply apparatus 500 is an apparatus that places a diced semiconductor chip 310 as a mounting body on the upper surface and supplies the diced semiconductor chip 310 to the bonding apparatus 100. Specifically, chip supply apparatus 500 includes a pickup mechanism 510 and a reversing mechanism 520. The pickup mechanism 510 is a device that pushes up any placed semiconductor chip 310 toward the reversing mechanism 520. The reversing mechanism 520 is a device that sucks and reverses the semiconductor chip 310 pushed up by the pickup mechanism 510 to change the orientation thereof in the up-and-down direction. In this embodiment, two types of semiconductor chips 310 are prepared, which are a first semiconductor chip 310a and a second semiconductor chip 310b. The bonding apparatus 100 is an apparatus that picks up the first semiconductor chip 310a or the second semiconductor chip 310b, which is sucked while being reversed by the reversing mechanism 520, with a bonding tool 120, which will be described later, and laminates and bonds it to a lead frame 330. In this embodiment, the first semiconductor chip 310a is placed on the lead frame 330 and bonded, and the second semiconductor chip 310b is stacked on the first semiconductor chip 310a and bonded. The lead frame 330 is an example of a substrate placed on the stage 190.

[0013] The bonding apparatus 100 mainly includes a head portion 110, the bonding tool 120, a first imaging unit 130, a second imaging unit 140, a third imaging unit 150, a calibration unit 170, and the stage 190. The head portion 110 supports the bonding tool 120, the first imaging unit 130, and the second imaging unit 140, and is movable in the plane direction and the vertical

direction by a head drive motor 111. In this embodiment, the plane direction is the horizontal direction defined by the X-axis direction and the Y-axis direction, and the vertical direction (height direction) is the Z-axis direction orthogonal to the X-axis direction and the Y-axis direction, as shown in the drawing.

5 **[0014]** The bonding tool 120 is movable in the height direction with respect to the head portion 110 or rotatable around the Z-axis by a tool drive motor 121. The bonding tool 120 is an example of the mounting tool, and has a collet 122 for sucking the semiconductor chip 310 at the tip portion and a heater 124 for heating the semiconductor chip 310 sucked by the collet 122. The bonding tool places the semiconductor chip 310 sucked by the collet 122 at a predetermined position, and
10 heats and bonds the semiconductor chip 310 with the heater 124 while applying pressure with the tip portion of the collet 122.

[0015] The first imaging unit 130 and the second imaging unit 140 are top-view imaging units for imaging the lead frame 330 from above. The first imaging unit 130 includes a first optical system 131 and a first imaging element 132, and is obliquely provided on the head portion 110
15 with the optical axis thereof directed downward from the bonding tool 120. The first optical system 131 and the first imaging element 132 are arranged to satisfy a Scheimpflug condition so that a plane parallel to the stage surface of the stage 190 becomes a focal plane 110a.

[0016] The second imaging unit 140 includes a second optical system 141 and a second imaging element 142, and is obliquely provided on the head portion 110 on the side opposite to the first
20 imaging unit 130 with respect to the bonding tool 120 with the optical axis thereof directed downward from the bonding tool 120. The second optical system 141 and the second imaging element 142 are arranged to satisfy the Scheimpflug condition so that a plane parallel to the stage surface of the stage 190 becomes the focal plane 110a. In the following description, the first imaging unit 130 and the second imaging unit 140 may be collectively referred to as the “top-view
25 imaging units.”

[0017] The third imaging unit 150 is a bottom-view imaging unit for imaging the semiconductor chip 310 in a state of being held by the collet 122 of the bonding tool 120 from below. As shown in the drawing, the third imaging unit 150 is arranged in a space on the side opposite to the space in which the top-view imaging units are arranged when the stage surface of the stage 190 is taken as a dividing surface. The third imaging unit 150 includes a third optical system 151 and a third imaging element 152, and is installed with the optical axis thereof directed upward. The third imaging unit 150 is a general imaging unit in which the third optical system 151 and the third imaging element 152 are arranged to be orthogonal to the optical axis, and a focal plane 150a thereof is parallel to the light receiving surface of the third imaging element 152. In addition, in the following description, the third imaging unit 150 may be referred to as the “bottom-view imaging unit.”

[0018] The calibration unit 170 mainly includes an index drive motor 171, an index plate 172, a calibration index 173, a support base 174, and a rod 175. The calibration index 173 is a reference mark with a defined reference position, for example, the intersection of a cross mark. The index plate 172 is, for example, a thin plate of glass or transparent resin, and has the calibration index 173 printed on one surface thereof. That is, the calibration index 173 can be observed from either side of the index plate 172. In this embodiment, the calibration index 173 is printed on the surface of the index plate 172 opposite to the surface facing the third imaging unit 150. If two calibration indices 173 are respectively printed on both sides of the index plate 172 without any deviation in the reference positions in the XY directions, the index plate 172 does not need to be transparent. In that case, the thickness of the index plate 172 is set so that the calibration index 173 facing the third imaging unit 150 falls within the range of the depth of field of the third imaging unit 150. Further, the calibration index 173 may be provided not only by printing but also by attaching a sticker, scribing the surface of the index plate 172, or the like.

[0019] The index drive motor 171 rotates the index plate 172 around the Z-axis to move the

calibration index 173 near the center of the field of view of the third imaging unit 150 or retract the calibration index 173 from the field of view. Further, the index drive motor 171 advances and retracts the rod 175 in the height direction. An end of the index plate 172 is rotatably fastened to one end of the rod 175, and the support base 174 is fastened to the other end. The third imaging unit 150 is fixed to the support base 174. That is, when the index plate 172 is rotated to bring the calibration index 173 into the field of view of the third imaging unit 150, the distance between the calibration index 173 and the focal plane 150a of the third imaging unit 150 is adjusted by the rod 175 so that the calibration index 173 always falls on the focal plane 150a of the third imaging unit 150. Since the third optical system 151 takes a certain depth range sandwiching the focal plane 150a as the depth of field, a deviation in the distance between them is allowed within the range of the depth of field.

[0020] The index drive motor 171 can advance and retract the rod 175 in the height direction to adjust the height of the calibration index 173 while keeping the focal plane 150a of the third imaging unit 150 on the printed surface of the calibration index 173. Specifically, the height of the calibration index 173 can be aligned with a first planned surface 330a (upper surface of the lead frame 330), which is the planned placement surface for placing the first semiconductor chip 310a, and the second planned surface 330b (upper surface of the first semiconductor chip 310a bonded to the lead frame 330), which is the planned placement surface for placing the second semiconductor chip 310b. In other words, the index drive motor 171 can advance and retract the rod 175 in the height direction to match the focal plane 150a of the third imaging unit 150 with the first planned surface 330a and the second planned surface 330b. In this case, the calibration index 173 may be retracted from the field of view of the third imaging unit 150.

[0021] FIG. 2 is a system configuration diagram of the bonding apparatus 100. A control system of the bonding apparatus 100 is mainly composed an arithmetic processor 210, a storage part 220, an input/output device 230, the first imaging unit 130, the second imaging unit 140, the

third imaging unit 150, the head drive motor 111, the tool drive motor 121, and the index drive motor 171.

[0022] The arithmetic processor 210 is a processor (CPU: Central Processing Unit) that performs control over the bonding apparatus 100 and processing of execution of programs. The processor may be configured to cooperate with an arithmetic processing chip such as an ASIC (Application Specific Integrated Circuit) and a GPU (Graphics Processing Unit). The arithmetic processor 210 reads out a bonding control program stored in the storage part 220 and executes various processes related to bonding control.

[0023] The storage part 220 is a non-volatile storage medium, and is configured by, for example, an HDD (Hard Disk Drive). In addition to the bonding control program, the storage part 220 can store various parameter values, functions, lookup tables, etc. used for control and calculation. The storage part 220 particularly stores calibration data 221. The calibration data 221 will be specifically described later, and the calibration data 221 is data related to calibration values for calibrating a difference between the coordinate values calculated based on the top-view image and the coordinate values calculated based on the bottom-view image for the same observation target.

[0024] The input/output device 230 includes, for example, a keyboard, a mouse, and a display monitor, and is a device that accepts a menu operation performed by the user and presents information to the user. For example, the arithmetic processor 210 may display the acquired top-view image or bottom-view image on the display monitor, which is one of the input/output device 230.

[0025] The first imaging unit 130 receives an imaging request signal from the arithmetic processor 210 and performs imaging, and transmits the first top-view image output by the first imaging element 132 to the arithmetic processor 210 as an image signal. The second imaging unit 140 receives an imaging request signal from the arithmetic processor 210 and performs imaging, and transmits the second top-view image output by the second imaging element 142 to

the arithmetic processor 210 as an image signal. The third imaging unit 150 receives an imaging request signal from the arithmetic processor 210 and performs imaging, and transmits the bottom-view image output by the third imaging element 152 to the arithmetic processor 210 as an image signal.

5 **[0026]** The head drive motor 111 receives a drive signal from the arithmetic processor 210 and moves the head portion 110 in the horizontal plane direction and the height direction. The tool drive motor 121 receives a drive signal from the arithmetic processor 210 and moves the bonding tool 120 in the height direction and rotates the bonding tool 120 around the Z-axis. The index drive motor 171 receives a drive signal from the arithmetic processor 210, and rotates the index
10 plate 172 and advances and retracts the rod 175 in the height direction.

[0027] The arithmetic processor 210 also plays a role as a functional arithmetic part that executes various calculations according to the processing instructed by the bonding control program. The arithmetic processor 210 can function as an image acquisition part 211, a drive controller 212, a calibration controller 213, and a bonding controller 214. The image acquisition
15 part 211 transmits the imaging request signals to the first imaging unit 130, the second imaging unit 140, and the third imaging unit 150, and acquires the image signals of the first top-view image, the second top-view image, and the bottom-view image. The drive controller 212 moves the head portion 110, the bonding tool 120, the index plate 172, and the third imaging unit 150 to the target positions by transmitting the drive signals corresponding to the control amounts to the head
20 drive motor 111, the tool drive motor 121, and the index drive motor 171. In addition, by transmitting drive signals to the pickup mechanism 510 and the reversing mechanism 520, the semiconductor chip 310 serving as the target is pushed up or sucked and reversed.

[0028] The calibration controller 213 controls the image acquisition part 211, the drive controller 212, etc. to calculate the calibration values for each assumed placement height of the
25 planned placement area based on the top-view images and the bottom-view image output by the

top-view imaging units and the bottom-view imaging unit by imaging the calibration index 173 arranged to coincide with the placement height. Specifically, the calibration controller 213 adjusts the position of the index plate 172 so that the calibration index 173 falls on the same plane as the planned placement area of the semiconductor chip 310, and adjusts the position of the head portion 110 so that the focal plane 110a of the top-view imaging units also falls on the same plane as the planned placement area. In addition, when the position of the index plate 172 is adjusted as described above, the focal plane 150a of the bottom-view imaging unit also falls on the same plane as the planned placement area, and therefore, after the adjustment, the bottom-view imaging unit is caused to image the calibration index 173.

[0029] The bonding controller 214 is an example of the mounting controller, and controls the image acquisition part 211, the drive controller 212, etc. to recognize the reference position of the semiconductor chip 310 based on the bottom-view image output by the bottom-view imaging unit by imaging the semiconductor chip 310 held by the bonding tool 120. At this time, the bonding controller 214 adjusts the position of the bonding tool 120 so that the planned contact surface of the semiconductor chip 310 for contacting the planned placement area is equal to the placement height of the planned placement area, and adjusts so that the focal plane 150a of the bottom-view imaging unit is also equal to the placement height of the planned placement area. Then, the semiconductor chip 310 is placed and bonded to the planned placement area by the bonding tool 120 so that the reference position coincides with the target position determined based on the above-described calibration values and the top-view images output by the top-view imaging units by imaging the planned placement area for placing the semiconductor chip 310. At this time, the bonding controller 214 adjusts the position of the head portion 110 so that the focal plane 110a of the top-view imaging units is equal to the placement height of the planned placement area. Specific control and processing of the calibration controller 213 and the bonding controller 214 will be described in detail later.

[0030] FIG. 3 is an explanatory diagram illustrating the Scheimpflug optical system employed in the first imaging unit 130. A similar Scheimpflug optical system is employed in the second imaging unit 140, but the Scheimpflug optical system of the first imaging unit 130 will be described as a representative here.

5 **[0031]** In FIG. 3, a plane S_1 is the focal plane 110a parallel to the stage surface of the stage 190. A virtual plane S_2 is a plane that includes the principal plane of the first optical system 131 composed of an object-side lens group 131a and an image-side lens group 131b. A plane S_3 is a plane that includes the light receiving surface of the first imaging element 132. In this embodiment, the Scheimpflug optical system includes the first optical system 131 and the first
10 imaging element 132 that are arranged to satisfy the Scheimpflug condition. An arrangement that satisfies the Scheimpflug condition refers to an arrangement in which the plane S_1 , the virtual plane S_2 , and the virtual plane S_3 intersect one another on a common straight line P.

[0032] A diaphragm 133 is arranged between the object-side lens group 131a and the image-side lens group 131b to restrict the light flux passing therethrough. The depth of field D_P can be
15 adjusted by the diameter of the diaphragm 133. Accordingly, if the first planned surface 330a or the second planned surface 330b is positioned within this depth of field, the first imaging unit 130 can image the pad reference mark and the lamination reference mark, which will be described later, in a focused state. In this sense, the positional control for matching the focal plane 110a with the first planned 330a and the second planned surface 330b allows a deviation within the range of the
20 depth of field D_P .

[0033] The second imaging unit 140 has a configuration similar to that of the first imaging unit 130, and the second imaging unit 140 and the first imaging unit 130 are arranged on the head portion 110 symmetrically with respect to the YZ plane that includes the central axis of the bonding tool 120. Accordingly, like the first imaging unit 130, the second imaging unit 140 can
25 also image the pad reference mark and the lamination reference mark in a focused state. The

focal plane of the first imaging unit 130 and the focal plane of the second imaging unit 140 preferably coincide at the focal plane 110a, but even if a deviation occurs, the pad reference mark and the lamination reference mark can be imaged in a focused state as long as the depth of field partially overlaps.

5 **[0034]** Now, when the imaging unit employing such a Scheimpflug optical system is used, it is possible to observe directly below the bonding tool 120 from an oblique direction. Thus, the planned placement area can be observed with the top-view imaging units even in a state where the semiconductor chip 310 is held by the bonding tool 120 and the bonding tool 120 is moved directly above the planned placement area for the semiconductor chip 310. That is, after moving the
10 bonding tool 120 directly above the planned placement area, the target position for placing the semiconductor chip 310 can be determined based on the top-view images output by the top-view imaging units. Then, since the semiconductor chip 310 may be moved to the target position from that state, the movement of the head portion 110 and the bonding tool 120 can be greatly suppressed, which makes it possible to reduce a positional deviation due to the movement and
15 shorten the lead time.

[0035] However, it has been found that, in an imaging unit that employs a Scheimpflug optical system, due to arrangement characteristics of the optical system and the imaging element, the output image may be displaced in the plane direction even when the optical system and the imaging element are slightly displaced due to a temperature change in the surrounding environment. That
20 is, it has been found that the image may shift depending on the temperature of the surrounding environment. Such a phenomenon causes an error in the target position when the target position for placing the semiconductor chip 310 is determined based on the top-view image, and results in impeding accurate bonding of the semiconductor chip to the original target position. In particular, when the bonding tool 120 is provided with the heater 124 for heating the semiconductor chip 310,
25 the temperature change around the Scheimpflug optical system increases. In addition, in so-

called stacked die mounting or 2.5-dimensional mounting, in which another semiconductor chip is further bonded on top of a semiconductor chip bonded to a substrate, the height of the placement surface for placing each semiconductor chip changes. In such a case, the problem that the amount of error differs for each height also becomes apparent.

5 **[0036]** Therefore, in this embodiment, a calibration process is executed at a predetermined timing when a temperature change in the surrounding environment is expected, and the calibration values for calibrating the difference between the coordinate values calculated based on the top-view image and the coordinate values calculated based on the bottom-view image for the same observation target are calculated for each height planned to be placed on. Then, in a bonding
10 process of bonding the semiconductor chip 310 to the target position on the planned placement area, the accurate target position is determined by using any of the calibration values calculated by the calibration process. The calibration process and the bonding process will be described in order hereinafter.

[0037] The calibration controller 213 is responsible for executing the calibration process. The
15 calibration controller 213 first causes the first imaging unit 130, the second imaging unit 140, and the third imaging unit 150 to image the calibration index 173. FIG. 4 is a diagram showing how the three imaging units image the calibration index 173 adjusted to the height of the first planned surface 330a.

[0038] As shown in the drawing, the calibration controller 213 drives the index drive motor 171
20 via the drive controller 212 to move the index plate 172 into the field of view of the third imaging unit 150 when starting the calibration process. When the index plate 172 is moved into the field of view of the third imaging unit 150, the calibration index 173 provided on the index plate 172 is positioned substantially centrally with respect to the field of view of the third imaging unit 150 fixed to the support base 174. Furthermore, the calibration controller 213 drives the index drive
25 motor 171 to adjust the rod 175 up and down so that the printed surface of the calibration index

173 falls on the same plane as the first planned surface 330a which is the placement surface for placing the first semiconductor chip 310a. At this time, the focal plane 150a of the third imaging unit 150 also falls on the same plane as the first planned surface 330a.

[0039] The calibration controller 213 subsequently drives the head drive motor 111 via the drive controller 212 to move the head portion 110 so that the focal plane 110a of the top-view imaging unit coincides with the first planned surface 330a and so that the calibration index 173 is positioned directly below the bonding tool 120. The bonding tool 120 is retracted to a position where the bonding tool 120 does not enter the field of view of the top-view imaging unit.

[0040] With each thus arranged, the calibration controller 213 acquires the first top-view image from the first imaging unit 130, the second top-view image from the second imaging unit 140, and the bottom-view image from the third imaging unit 150 via the image acquisition part 211. Then, the three-dimensional coordinates (X_{hra} , Y_{hra} , Z_{hra}) of the calibration index 173 are calculated from the image coordinates of the images of the calibration index 173 respectively reflected in the first top-view image and the second top-view image. Further, the three-dimensional coordinates (X_{sra} , Y_{sra} , Z_{sra}) of the calibration index 173 are calculated from the image coordinates of the image of the calibration index 173 reflected in the bottom-view image. If the top-view imaging units are not affected by the temperature change in the surrounding environment and maintain the state where the coordinates between the imaging units are correctly adjusted in the initial state of the bonding apparatus 100, it should be at least $X_{hra} = X_{sra}$ and $Y_{hra} = Y_{sra}$.

[0041] However, as described above, after the use of the bonding apparatus 100 is started for a while, the three-dimensional coordinates calculated from the top-view images include an error due to the influence of the temperature change in the surrounding environment. Thus, the error (ΔX_a , ΔY_a) is used as the first calibration values for the first planned surface 330aa. Specifically, the error is expressed as a difference and can be set as $\Delta X_a = X_{sra} - X_{hra}$ and $\Delta Y_a = Y_{sra} - Y_{hra}$. If the first calibration values for the first planned surface 330a are calculated in advance in this way,

supposing that the top-view imaging unit images a certain observation target on the first planned surface 330a afterward and the three-dimensional coordinates calculated from the top-view image thereof are $(X_{hta}, Y_{hta}, Z_{hta})$, the three-dimensional coordinates can be corrected as $(X_{hta} + \Delta X_a, Y_{hta} + \Delta Y_a, Z_{hta})$ by adding the calibration values. It can be said that, assuming that the same observation target could be imaged by the bottom-view imaging unit, the corrected coordinate values have no error with respect to the coordinate values calculated from the bottom-view image obtained in that case. The calibration controller 213 stores the first calibration values calculated in this way in the storage part 220 as the calibration data 221.

[0042] The calibration controller 213 subsequently calculates the second calibration values for the second planned surface 330b, which is the placement surface for placing the second semiconductor chip 310b. In this embodiment, the second planned surface 330b is the upper surface of the first semiconductor chip 310a bonded to the lead frame 330. FIG. 5 is a diagram showing how three imaging units image the calibration index adjusted to the height of the second planned surface 330b.

[0043] The calibration controller 213 drives the index drive motor 171 to lift and adjust the rod 175 so that the printed surface of the calibration index 173 falls on the same plane as the second planned surface 330b which is the placement surface for placing the second semiconductor chip 310b. At this time, the focal plane 150a of the third imaging unit 150 also falls on the same plane as the second planned surface 330b. The calibration controller 213 subsequently drives the head drive motor 111 via the drive controller 212 to lift the head portion 110 so that the focal plane 110a of the top-view imaging unit coincides with the second planned surface 330b.

[0044] With each thus arranged, the calibration controller 213 acquires the first top-view image from the first imaging unit 130, the second top-view image from the second imaging unit 140, and the bottom-view image from the third imaging unit 150 via the image acquisition part 211. Then, the three-dimensional coordinates $(X_{hrb}, Y_{hrb}, Z_{hrb})$ of the calibration index 173 are calculated from

the image coordinates of the images of the calibration index 173 respectively reflected in the first top-view image and the second top-view image. Further, the three-dimensional coordinates (X_{srb} , Y_{srb} , Z_{srb}) of the calibration index 173 are calculated from the image coordinates of the image of the calibration index 173 reflected in the bottom-view image.

5 [0045] Similar to the first calibration values, if the calibration values for the second planned surface 330b are the second calibration values (ΔXb , ΔYb), it can be obtained that $\Delta Xb = X_{srb} - X_{hrb}$ and $\Delta Yb = Y_{srb} - Y_{hrb}$. If the second calibration values for the second planned surface 330b are calculated in advance in this way, supposing that the top-view imaging unit images an observation target on the second planned surface 330b afterward and the three-dimensional
10 coordinates calculated from the top-view image thereof are (X_{htb} , Y_{htb} , Z_{htb}), the three-dimensional coordinates can be corrected as ($X_{htb} + \Delta Xb$, $Y_{htb} + \Delta Yb$, Z_{htb}) by adding the second calibration values. It can be said that, assuming that the same observation target could be imaged by the bottom-view imaging unit, the corrected coordinate values have no error with respect to the coordinate values calculated from the bottom-view image obtained in that case. The calibration
15 controller 213 stores the second calibration values calculated in this way in the storage part 220 as the calibration data 221.

[0046] The calibration data 221 is referred to in the bonding process, which will be described later, until it is evaluated that the temperature of the surrounding environment may have changed and the calibration process needs to be performed again. In other words, when it is evaluated
20 that the calibration process needs to be performed again, the calibration controller 213 repeats the above process to update the calibration values.

[0047] A timing at which the bonding controller 214 completes the bonding of semiconductor chips 310 for a preset lot can be considered as an example where it is evaluated that the calibration process needs to be performed again. Specifically, the calibration controller 213 may execute
25 the calibration process in accordance with the timing at which a new lot of semiconductor chips

310 is supplied to the chip supply apparatus 500. For example, the first calibration values may be updated at the timing when a new lot of first semiconductor chips 310a is supplied, and the second calibration values may be updated at the timing when a new lot of second semiconductor chips 310b is supplied.

5 **[0048]** In addition, the working time of the bonding work executed by the bonding controller 214 may be used as a guideline. For example, it can be determined that the calibration process is performed when the bonding work is performed continuously for 60 minutes. Furthermore, a temperature detector for detecting the temperature of the top-view imaging unit may be provided in the head portion 110, and the timing may be a timing at which the temperature detector detects
10 a preset temperature. Specifically, a plurality of temperatures are set in advance, and the calibration process is executed when it is detected that the ambient temperature fluctuates across any of the set temperatures. If the calibration values are updated in this way, it is possible to suppress an error of the coordinate values calculated from the top-view image within a certain range over a period in which the bonding process is continued.

15 **[0049]** The bonding controller 214 is responsible for executing the bonding process. The bonding controller 214 first picks up the target semiconductor chip 310. FIG. 6 is a diagram showing how the bonding tool 120 picks up the first semiconductor chip 310a.

20 **[0050]** The bonding controller 214 drives the head drive motor 111 via the drive controller 212 to move the head portion 110 above the chip supply apparatus 500, and drives the tool drive motor 121 to lower the bonding tool 120. In parallel with this, the pickup mechanism 510 pushes up one of the target first semiconductor chips 310a to be bonded among the semiconductor chips 310 placed on the chip supply apparatus 500 toward the reversing mechanism 520, and the reversing mechanism 520 sucks and reverses the first semiconductor chip 310a. Then, the lowered bonding tool 120 sucks and picks up the first semiconductor chip 310a with the collet 122 and lifts
25 the bonding tool 120.

[0051] When the index plate 172 is positioned within the field of view of the third imaging unit 150, the bonding controller 214 retracts the index plate 172 from the field of view of the third imaging unit 150 before and after the work of the bonding tool 120 picking up the first semiconductor chip 310a. Specifically, the bonding controller 214 drives the index drive motor 171 via the drive controller 212 to move the index plate 172. Further, when the focal plane 150a of the third imaging unit 150 does not coincide with the first planned surface 330a, the index drive motor 171 is driven via the drive controller 212 so as to lift or lower the rod 175 to match the focal plane 150a with the first planned surface 330a.

[0052] Next, the bonding controller 214 causes the third imaging unit 150 to image the first semiconductor chip 310a sucked by the bonding tool 120. FIG. 7 is a diagram showing how the third imaging unit 150 images the first semiconductor chip 310a sucked by the bonding tool 120.

[0053] The bonding controller 214 drives the head drive motor 111 via the drive controller 212 to move the head portion 110 so that the focal plane 110a of the top-view imaging units coincides with the first planned surface 330a and so that the third imaging unit 150 is positioned directly below the bonding tool 120. Then, by driving the tool drive motor 121, the bonding tool 120 is lowered so that the planned contact surface of the held first semiconductor chip 310a for contacting the lead frame 330 coincides with the first planned surface 330a. When such arrangement adjustment is completed, the bonding controller 214 causes the third imaging unit 150 to image the first semiconductor chip 310a held by the bonding tool 120 via the image acquisition part 211.

[0054] FIG. 8 is a diagram schematically showing the bottom-view image output by the third imaging unit 150 by imaging the first semiconductor chip 310a held by the bonding tool 120. Each subject image in the drawing will be described with the corresponding reference number of the subject as it is.

[0055] As described above, the bonding tool 120 is picked up and held by sucking the semiconductor chip 310 (first semiconductor chip 310a and second semiconductor chip 310b)

prepared by the chip supply apparatus 500 with the collet 122. At this time, the bonding tool 120 attempts to suck the center of the semiconductor chip 310 in a preset orientation, but in reality, the semiconductor chip 310 may be sucked with a deviation. Therefore, the bonding controller 214 confirms at what position and in what orientation the semiconductor chip 310 is actually held, and
5 recognizes the reference position for placing the semiconductor chip 310 on the lead frame 330.

[0056] Since the bottom-view image shown in FIG. 8 is an image captured by the third imaging unit 150 looking up at the first semiconductor chip 310a, the collet 122 that holds the first semiconductor chip 310a is also reflected. Thus, the bonding controller 214 calculates the image coordinates of a collet center 123 by detecting a circle that is the contour of the collet 122.

[0057] Further, the first semiconductor chip 310a in this embodiment is provided with a chip reference mark 311a on the planned contact surface for contacting the lead frame 330, and the bonding controller 214 calculates the image coordinates of the chip reference mark 311a reflected in the bottom-view image. From the image coordinates of the collet center 123 and the image coordinates of the chip reference mark 311a thus calculated, the bonding controller 214 can
15 recognize at what position and in what orientation the first semiconductor chip 310a is actually held with respect to the collet 122. For example, if the position where the chip reference mark 311a is provided is the reference position for placing the first semiconductor chip 310a on the planned placement area of the lead frame 330, the bonding controller 214 can calculate the three-dimensional coordinates of the reference position of the first semiconductor chip 310a at the time
20 when the bottom-view image is captured. Thus, even if the bonding tool 120 and the head portion 110 are moved after that, the three-dimensional coordinates of the reference position can be tracked as long as the collet 122 continues to hold the first semiconductor chip 310a.

[0058] After recognizing the three-dimensional coordinates of the reference position, the bonding controller 214 drives the tool drive motor 121 to lift the bonding tool 120 to a position
25 where the held first semiconductor chip 310a is retracted from the field of view of the top-view

imaging units. Then, by driving the head drive motor 111, the head portion 110 is moved so that the bonding tool 120 is directly above the die pad which is the planned placement area on which the first semiconductor chip 310a is to be placed and so that the focal plane 110a of the top-view imaging units coincides with the first planned surface 330a. The lifting of the bonding tool 120 and the movement of the head portion 110 may be performed in parallel.

[0059] FIG. 9 is a diagram showing how the first imaging unit 130 and the second imaging unit 140 image the planned placement area on the lead frame 330 with the head portion 110 and the bonding tool 120 arranged as described above. Further, FIG. 10 is a partial perspective diagram of FIG. 9. The lead frame 330 in this embodiment has one die pad 320 in each unit area 322 that will be cut out in the future to be housed in one package. The die pad 320 shown in the drawing is the planned placement area on which the first semiconductor chip 310a is to be placed. In addition, each unit area 322 is provided with a pad reference mark 321 indicating the reference position thereof.

[0060] In the state of the arrangement as shown in FIG. 9 and FIG. 10, the first imaging unit 130 and the second imaging unit 140 can respectively catch the die pad 320 and the pad reference mark 321 included in the same unit area 322 within the field of view and image them in a focused state. The bonding controller 214 uses the first top-view image output by the first imaging unit 130 and the second top-view image output by the second imaging unit 140 to calculate the coordinates of the target position with which the reference position should coincide when placing the first semiconductor chip 310a on the die pad 320.

[0061] FIG. 11 is a diagram showing the procedure for calculating the target coordinates for placing the first semiconductor chip 310a from the first top-view image and the second top-view image. Since the first imaging unit 130 images the die pad 320 and the pad reference mark 321 from the side of the pad reference mark 321 with respect to the die pad 320, in the first top-view image which is the output image thereof, the unit area 322 is reflected in a trapezoidal shape

expanding toward the side of the pad reference mark 321. Conversely, the second imaging unit 140 images the die pad 320 and the pad reference mark 321 from the opposite side of the pad reference mark 321 with respect to the die pad 320, in the second top-view image which is the output image thereof, the unit area 322 is reflected in a trapezoidal shape narrowing toward the side of the pad reference mark 321.

[0062] The bonding controller 214 determines the image coordinates (x_{1k}, y_{1k}) of the pad reference mark 321 from the first top-view image, and also determines the image coordinates (x_{2k}, y_{2k}) of the pad reference mark 321 from the second top-view image. Then, for example, by referring to a conversion table for converting image coordinates into three-dimensional coordinates, index coordinates (X_k, Y_k, Z_k) which are three-dimensional coordinates of the pad reference mark 321 are calculated from these image coordinates. The coordinate values of the index coordinates are a provisional target position for calculating an accurate target position, and as described above, include an error due to the influence of the temperature change in the surrounding environment. Thus, the first calibration values $(\Delta X_a, \Delta Y_a)$ are read out from the calibration data 221 and corrected. The corrected index coordinates $(X_k + \Delta X_a, Y_k + \Delta Y_a, Z_k)$ obtained in this way can be expected to have no error with respect to the spatial coordinates calculated from the bottom-view image.

[0063] Since the preset target position of the die pad 320 and the relative position of the pad reference mark 321 are known, the bonding controller 214 can accurately calculate the coordinates (X_{Ta}, Y_{Ta}, Z_{Ta}) of the target position from the corrected index coordinates $(X_k + \Delta X_a, Y_k + \Delta Y_a, Z_k)$.

[0064] After determining the coordinates of the target position, the first semiconductor chip 310a is placed at the target position and bonded. FIG. 12 is a diagram showing how the bonding tool 120 places and bonds the first semiconductor chip 310a to the target position.

[0065] As described above, the bonding controller 214 tracks and grasps the three-dimensional

coordinates of the reference position of the first semiconductor chip 310a with respect to the movement of the bonding tool 120 and the head portion 110, and moves the first semiconductor chip 310a so that this reference position coincides with the target position of the die pad 320. Specifically, the position of the head portion 110 in the XY directions is finely adjusted by driving the head drive motor 111 via the drive controller 212, and the amount of rotation of the bonding tool 120 around the Z-axis is finely adjusted by driving the tool drive motor 121. Then, the bonding tool 120 is lowered with the X coordinate and the Y coordinate of the reference position respectively coinciding with the X coordinate and the Y coordinate of the target position, to place the first semiconductor chip 310a on the die pad 320. Thereafter, the first semiconductor chip 310a is heated by the heater 124 while being pressed by the tip portion of the collet 122 to be bonded to the die pad 320.

[0066] In this embodiment, as illustrated with reference to FIG. 4, the first calibration values are calculated by aligning the focal plane 110a of the top-view imaging units and the printed surface of the calibration index 173 with the first planned surface 330a. That is, the position of the head portion 110 in the Z direction when the first calibration values are calculated is the same as the position of the head portion 110 in the Z direction when the top-view imaging units image the chip reference mark 311a. Further, as illustrated with reference to FIG. 7 and FIG. 8, the three-dimensional coordinates of the chip reference mark 311a are calculated by aligning the planned contact surface of the first semiconductor chip 310a held by the collet 122 with the first planned surface 330a. That is, the position of the bonding tool 120 in the Z direction when the three-dimensional coordinates of the chip reference mark 311a are calculated is the same as the position of the bonding tool 120 in the Z direction when the first semiconductor chip 310a is placed on the die pad 320.

[0067] Thus, there is no need to consider an error between the actual three-dimensional coordinates and the recognized three-dimensional coordinates in the XY directions, which may

occur when the head portion 110 and the bonding tool 120 are moved in the Z direction. For example, in the state of FIG. 9, the bonding tool 120 holds the first semiconductor chip 310a and retracts from the field of view of the top-view imaging units, but the X coordinate and the Y coordinate of the actual reference position in this state may not coincide with the X coordinate and the Y coordinate recognized by the bonding controller 214 due to the influence of play between elements of the moving mechanism that moves the bonding tool 120 up and down. However, the height of the bonding tool 120 when the first semiconductor chip 310a is placed on the first planned surface 330a as shown in FIG. 12 is the same as the height of the bonding tool 120 when the three-dimensional coordinates of the chip reference mark 311a are calculated, and error factors due to the moving mechanism are eliminated. In other words, the X coordinate and the Y coordinate of the actual reference position when the first semiconductor chip 310a is placed on the first planned surface 330a coincide with the X coordinate and the Y coordinate recognized by the bonding controller 214. From this point of view, it is effective to match the focal plane 110a and the printed surface of the calibration index 173 with the first planned surface 330a when calculating the first calibration values, and match the planned contact surface of the first semiconductor chip 310a with the first planned surface 330a when calculating the three-dimensional coordinates of the chip reference mark 311a.

[0068] FIG. 13 is a diagram showing how the bonding tool 120 is retracted. After the bonding of the first semiconductor chip 310a is completed as shown in the drawing, the bonding controller 214 drives the tool drive motor 121 via the drive controller 212 to lift the bonding tool 120.

[0069] Subsequently, the bonding controller 214 starts a process of laminating and bonding the second semiconductor chip 310b to the first semiconductor chip 310a that has been bonded. Similar to the pickup of the first semiconductor chip 310a as illustrated in FIG. 6, the bonding controller 214 reverses one of the second semiconductor chips 310b to be bonded among the semiconductor chips 310 placed on the chip supply apparatus 500 with the pickup mechanism 510

and the reversing mechanism 520, and sucks and picks up the second semiconductor chip 310b with the collet 122.

[0070] FIG. 14 is a diagram showing how the third imaging unit 150 images the second semiconductor chip 310b sucked to the bonding tool 120. As shown in the drawing, the bonding controller 214 lifts the rod 175 to match the focal plane 150a with the second planned surface 330b so that the focal plane 150a of the third imaging unit 150 coincides with the second planned surface 330b which is the planned placement surface for placing the second semiconductor chip 310b.

[0071] Subsequently, by driving the head drive motor 111 via the drive controller 212, the head portion 110 is moved so that the focal plane 110a of the top-view imaging unit coincides with the second planned surface 330b and so that the third imaging unit 150 is positioned directly below the bonding tool 120. Then, by driving the tool drive motor 121, the bonding tool 120 is lowered so that the planned contact surface of the held second semiconductor chip 310b for contacting the first semiconductor chip 310a to be laminated on coincides with the second planned surface 330b. When such arrangement adjustment is completed, the bonding controller 214 causes the third imaging unit 150 to image the second semiconductor chip 310b held by the bonding tool 120 via the image acquisition part 211.

[0072] FIG. 15 is a diagram schematically showing the bottom-view image output by the third imaging unit 150 by imaging the second semiconductor chip 310b held by the bonding tool 120. Similar to the case of the first semiconductor chip 310a, the bonding controller 214 confirms the suction position and orientation of the second semiconductor chip 310b with respect to the collet 122, and recognizes the reference position for placing the second semiconductor chip 310b on the first semiconductor chip 310a.

[0073] The bonding controller 214 calculates the image coordinates of the collet center 123 by detecting a circle that is the contour of the collet 122. Further, the second semiconductor chip 310b in this embodiment is provided with a chip reference mark 311b on the planned contact

surface for contacting the first semiconductor chip 310a, and the bonding controller 214 calculates the image coordinates of the chip reference mark 311b reflected in the bottom-view image. From the image coordinates of the collet center 123 and the image coordinates of the chip reference mark 311b thus calculated, the bonding controller 214 can recognize at what position and in what orientation the second semiconductor chip 310b is actually held with respect to the collet 122. Thus, even if the bonding tool 120 and the head portion 110 are moved after that, the three-dimensional coordinates of the reference position can be tracked as long as the collet 122 continues to hold the second semiconductor chip 310b.

[0074] After recognizing the three-dimensional coordinates of the reference position, the bonding controller 214 drives the tool drive motor 121 to lift the bonding tool 120 to a position where the held second semiconductor chip 310b is retracted from the field of view of the top-view imaging units. Then, by driving the head drive motor 111, the head portion 110 is moved so that the bonding tool 120 is directly above the first semiconductor chip 310a on which the second semiconductor chip 310b is to be placed and so that the focal plane 110a of the top-view imaging units coincides with the second planned surface 330b. The lifting of the bonding tool 120 and the movement of the head portion 110 may be performed in parallel.

[0075] FIG. 16 is a diagram showing how the first imaging unit 130 and the second imaging unit 140 image the planned placement area on the first semiconductor chip 310a with the head portion 110 and the bonding tool 120 arranged in this manner. In such a state, the first imaging unit 130 and the second imaging unit 140 can respectively capture the target planned placement area on the first semiconductor chip 310a within the field of view and image it in a focused state. The bonding controller 214 uses the first top-view image output by the first imaging unit 130 and the second top-view image output by the second imaging unit 140 to calculate the coordinates of the target position with which the reference position should coincide when placing the second semiconductor chip 310b on the first semiconductor chip 310a.

[0076] FIG. 17 is a diagram showing the procedure for calculating the target coordinates for placing the second semiconductor chip 310b from the first top-view image and the second top-view image. The first semiconductor chip 310a laminated as shown in the drawing is already bonded within the unit area 322 on the lead frame 330, and in both the first top-view image and the second top-view image, the lamination reference mark 323 indicating the reference position on the upper surface of the first semiconductor chip 310a is reflected.

[0077] The bonding controller 214 determines the image coordinates (x_{1j} , y_{1j}) of the lamination reference mark 323 from the first top-view image, and determines the image coordinates (x_{2j} , y_{2j}) of the lamination reference mark 323 from the second top-view image. Then, index coordinates (X_j , Y_j , Z_j) which are three-dimensional coordinates of the pad reference mark 321 are calculated from these image coordinates. The coordinate values of the index coordinates are provisional target positions for calculating an accurate target position, and as described above, include an error due to the influence of the temperature change in the surrounding environment. Thus, the second calibration values (ΔX_b , ΔY_b) are read out from the calibration data 221 and corrected. The corrected index coordinates ($X_j + \Delta X_b$, $Y_j + \Delta Y_b$, Z_j) obtained in this way can be expected to have no error with respect to the spatial coordinates calculated from the bottom-view image. Since the preset target position of the first semiconductor chip 310a and the relative position of the lamination reference mark 323 are known, the bonding controller 214 can accurately calculate the coordinates (X_{Tb} , Y_{Tb} , Z_{Tb}) of the target position from the corrected index coordinates ($X_j + \Delta X_b$, $Y_j + \Delta Y_b$, Z_j).

[0078] After determining the coordinates of the target position, the second semiconductor chip 310b is placed at the target position and bonded. FIG. 18 is a diagram showing how the bonding tool 120 places and bonds the second semiconductor chip 310b to the target position of the first semiconductor chip 310a.

[0079] As described above, the bonding controller 214 tracks and grasps the three-dimensional

coordinates of the reference position of the second semiconductor chip 310b with respect to the movement of the bonding tool 120 and the head portion 110, and moves the second semiconductor chip 310b so that this reference position coincides with the target position of the first semiconductor chip 310a. Specifically, the position of the head portion 110 in the XY direction is finely adjusted by driving the head drive motor 111 via the drive controller 212, and the amount of rotation of the bonding tool 120 around the Z-axis is finely adjusted by driving the tool drive motor 121. Then, the bonding tool 120 is lowered with the X coordinate and the Y coordinate of the reference position respectively coinciding with the X coordinate and the Y coordinate of the target position, to place the second semiconductor chip 310b on the first semiconductor chip 310a. Thereafter, the second semiconductor chip 310b is heated by the heater 124 while being pressed by the tip portion of the collet 122 to be bonded to the first semiconductor chip 310a.

[0080] In this embodiment, as illustrated with reference to FIG. 5, the second calibration values are calculated by aligning the focal plane 110a of the top-view imaging units and the printed surface of the calibration index 173 with the second planned surface 330b. That is, the position of the head portion 110 in the Z direction when the second calibration values are calculated is the same as the position of the head portion 110 in the Z direction when the top-view imaging units image the chip reference mark 311b. Further, as illustrated with reference to FIG. 14 and FIG. 15, the three-dimensional coordinates of the chip reference mark 311b are calculated by aligning the planned contact surface of the second semiconductor chip 310b held by the collet 122 with the second planned surface 330b. That is, the position of the bonding tool 120 in the Z direction when the three-dimensional coordinates of the chip reference mark 311b are calculated is the same as the position of the bonding tool 120 in the Z direction when the second semiconductor chip 310b is placed on the first semiconductor chip 310a.

[0081] Thus, there is no need to consider an error between the actual three-dimensional coordinates and the recognized three-dimensional coordinates in the XY directions, which may

occur when the head portion 110 and the bonding tool 120 are moved in the Z direction. For example, in the state of FIG. 16, the bonding tool 120 holds the second semiconductor chip 310b and retracts from the field of view of the top-view imaging units, but the X coordinate and the Y coordinate of the actual reference position in this state may not coincide with the X coordinate and the Y coordinate recognized by the bonding controller 214 due to the influence of play between elements of the moving mechanism that moves the bonding tool 120 up and down. However, the height of the bonding tool 120 when the second semiconductor chip 310b is placed on the second planned surface 330b as shown in FIG. 18 is the same as the height of the bonding tool 120 when the three-dimensional coordinates of the chip reference mark 311b are calculated, and error factors due to the moving mechanism are eliminated. In other words, the X coordinate and the Y coordinate of the actual reference position when the second semiconductor chip 310b is placed on the second planned surface 330b coincide with the X coordinate and the Y coordinate recognized by the bonding controller 214. From this point of view, it is effective to match the focal plane 110a and the printed surface of the calibration index 173 with the second planned surface 330b when calculating the second calibration values, and match the planned contact surface of the second semiconductor chip 310b with the second planned surface 330b when calculating the three-dimensional coordinates of the chip reference mark 311b.

[0082] After the bonding of the second semiconductor chip 310b is completed, the bonding controller 214 drives the tool drive motor 121 via the drive controller 212 to lift the bonding tool 120. When bonding a new semiconductor chip 310 (first semiconductor chip 310a and second semiconductor chip 310b), the bonding controller 214 returns to the state of FIG. 6 and repeats the process again.

[0083] Next, the entire bonding procedure, including the calibration process and the bonding process described above, will be summarized in accordance with flowcharts. FIG. 19 is a flowchart illustrating the bonding procedure of the semiconductor chip 310.

[0084] The calibration controller 213 starts a calibration control step to perform the calibration process in step S11. Details will be described later as a sub-flow. The first calibration control step may be skipped when the bonding process is started from the initial state in which the coordinates between the imaging units are correctly adjusted.

5 **[0085]** After the calibration controller 213 finishes the execution of the calibration control step, the procedure proceeds to step S12, and the bonding controller 214 starts a bonding control step to perform the bonding process. Details will be described later as a sub-flow.

[0086] After the bonding controller 214 finishes the execution of the bonding control step, the procedure proceeds to step S13, and the calibration controller 213 determines whether the state of
10 the bonding apparatus 100 at that time satisfies a preset calibration timing condition. The preset calibration timing condition is a set condition that may require the calibration process to be performed again. For example, as described above, the number of processed lots, the working time of the bonding work, the temperature detected by the temperature detector, etc. are candidates for the set condition.

15 **[0087]** If the calibration controller 213 determines in step S13 that the condition is satisfied, the procedure returns to step S11. If it is determined that the condition is not satisfied, the procedure proceeds to step S14. When proceeding to step S14, the bonding controller 214 determines whether all scheduled bonding processes are completed. If it is determined that there remain semiconductor chips 310 to be bonded, the procedure returns to step S12, and if it is determined
20 that all the bonding processes are completed, the series of processes ends.

[0088] FIG. 20 is a sub-flowchart illustrating the procedure of the calibration control step. In the calibration control step, mainly the process illustrated with reference to FIG. 4 and FIG. 5 is executed. The calibration controller 213 substitutes “1” for a counter n in step S1101. Subsequently, in step S1102, the index plate 172 is moved to put the calibration index 173 into
25 the center of the field of view of the third imaging unit 150.

[0089] The procedure proceeds to step S1103, and the calibration controller 213 adjusts the heights of the focal plane 150a of the third imaging unit 150 and the printed surface of the calibration index 173 so that the focal plane 150a of the third imaging unit 150 and the printed surface of the calibration index 173 coincide with the n^{th} planned surface. For example, if $n = 1$,
5 the heights are adjusted to coincide with the first planned surface 330a. In subsequent step S1104, the head portion 110 is moved so that the printed surface of the calibration index 173 falls on the focal plane 110a of the first imaging unit 130 and the second imaging unit 140 and so that the calibration index 173 is positioned directly below the bonding tool 120.

[0090] In step S1105, the calibration controller 213 causes each imaging unit to image via the
10 image acquisition part 211 and acquires the first top-view image from the first imaging unit 130, the second top-view image from the second imaging unit 140, and the bottom-view image from the third imaging unit 150. Then, in subsequent step S1106, the three-dimensional coordinates of the calibration index 173 are calculated based on the image coordinates of the images of the calibration index 173 respectively reflected in the first top-view image and the second top-view
15 image, and the three-dimensional coordinates of the calibration index 173 are calculated based on the image of the calibration index 173 reflected in the bottom-view image. The calibration controller 213 calculates, as the n^{th} calibration values for the n^{th} planned surface, the difference in the XY plane direction among the three-dimensional coordinates thus calculated. The calculated calibration values are stored in the storage part 220 as the calibration data 221.

20 **[0091]** The calibration controller 213 proceeds to step S1107 and increments the counter n . Then, in step S1108, it is confirmed whether the incremented counter n has exceeded a planned total lamination number n_0 . In this embodiment described above, since the first semiconductor chip 310a as the first layer is bonded on the lead frame 330, and the second semiconductor chip 310b as the second layer is bonded thereon, the planned total lamination number is “2.” If the
25 counter n does not exceed the planned total lamination number n_0 , the procedure returns to step

S1103 to calculate the n^{th} calibration values corresponding to the incremented n . If the counter n exceeds the planned total lamination number n_0 , the procedure proceeds to step S1109.

[0092] In step S1109, the calibration controller 213 moves the index plate 172 to retract the calibration index 173 from the field of view of the third imaging unit 150. After the calibration index 173 is retracted, the procedure returns to the main flow. The calibration index 173 may be retracted during the subsequent bonding process.

[0093] FIG. 21 is a sub-flowchart illustrating the procedure of the bonding control step. In the bonding control step, mainly the process illustrated with reference to FIG. 6 to FIG. 18 is executed. The bonding controller 214 substitutes “1” for the counter n in step S1201.

[0094] The procedure proceeds to step S1202, the head portion 110 is moved above the chip supply apparatus 500 and the bonding tool 120 is lowered. Then, the n^{th} semiconductor chip to be placed as the n^{th} layer, among the semiconductor chips 310 placed on the chip supply apparatus 500, is reversed by the pickup mechanism 510 and the reversing mechanism 520, and sucked and picked up by the collet 122. For example, if $n = 1$, the first semiconductor chip 310a is picked up. After the n^{th} semiconductor chip is picked up, the bonding tool 120 is lifted.

[0095] In step S1203, the bonding controller 214 adjusts the height of the third imaging unit 150 so that the focal plane 150a of the third imaging unit 150 coincides with the n^{th} planned surface. In subsequent step S1204, the head portion 110 is moved so that the n^{th} planned surface coincides with the focal plane 110a of the first imaging unit 130 and the second imaging unit 140 and so that the third imaging unit 150 is positioned directly below the bonding tool 120. Furthermore, in step S1205, the bonding tool 120 is lowered so that the planned contact surface of the held n^{th} semiconductor chip for contacting the lamination target coincides with the n^{th} planned surface.

[0096] When such arrangement adjustment is completed, in step S1206, the bonding controller 214 causes the third imaging unit 150 to image the planned contact surface of the n^{th} semiconductor chip held by the bonding tool 120. Then, in step S1207, the bottom-view image

output by the third imaging unit 150 is acquired, and the three-dimensional coordinates of the reference position of the n^{th} semiconductor chip are recognized based on the image coordinates of the reflected chip reference mark.

[0097] In step S1208, the bonding controller 214 lifts the bonding tool 120 to a position where the held n^{th} semiconductor chip is retracted from the field of view of the top-view imaging units, and moves the head portion 110 so that the bonding tool 120 is directly above the planned placement area on which the n^{th} semiconductor chip is to be placed. In subsequent step S1209, the height of the head portion 110 is adjusted so that the focal plane 110a of the top-view imaging units coincides with the n^{th} planned surface.

[0098] When such arrangement adjustment is completed, in step S1210, the bonding controller 214 causes the first imaging unit 130 and the second imaging unit 140 to image the vicinity of the planned placement area including the reference marks such as the pad reference mark 321 and the lamination reference mark 323. Then, in step S1211, the first top-view image output by the first imaging unit 130 and the second top-view image output by the second imaging unit 140 are acquired, and the three-dimensional coordinates of the target position are calculated based on the image coordinates of the reflected reference marks and the n^{th} calibration values.

[0099] After the target position is determined, the procedure proceeds to step S1212, and the bonding controller 214 moves the head portion 110 and the bonding tool 120 so that the reference position of the n^{th} semiconductor chip coincides with the target position, and places the n^{th} semiconductor chip on the planned placement area. Thereafter, the n^{th} semiconductor chip is pressurized/heated to complete the bonding. After the bonding of the n^{th} semiconductor chip is completed, the bonding tool 120 is lifted.

[0100] The bonding controller 214 proceeds to step S1213 and increments the counter n . Then, in step S1214, it is confirmed whether the incremented counter n has exceeded the planned total lamination number n_0 . In this embodiment described above, since the first semiconductor chip

310a as the first layer is bonded on the lead frame 330 and the second semiconductor chip 310b as the second layer is bonded thereon, the planned total lamination number is “2.” If the counter n does not exceed the planned total lamination number n_0 , the procedure returns to step S1202 to execute the bonding of the n^{th} semiconductor chip corresponding to the incremented n . If the counter n exceeds the planned total lamination number n_0 , the procedure returns to the main flow.

[0101] In the embodiment described above, the calibration process and the bonding process are separated, and the calibration process is performed when the state of the bonding apparatus 100 satisfies the preset calibration timing condition. Accordingly, once the calibration process is executed, the calculated calibration values are held in the storage part 220, and the calibration values are continuously referred to each time in the bonding process performed until the next calibration process is executed. However, the procedure may be set such that the calibration process is incorporated into a series of bonding processes, and the n^{th} calibration values are updated each time during the process of bonding each n^{th} semiconductor chip. Other such embodiments will be described below. In the following other embodiments, the configuration of the bonding apparatus itself is the same as that of the above-described embodiments, and thus the description thereof will be omitted and mainly the difference in the processing procedure will be described.

[0102] FIG. 22 is a diagram illustrating how three imaging units image the calibration index adjusted to the height of the first planned surface 330a in another embodiment. In this embodiment, the calibration process for calculating the n^{th} calibration values is executed between the pickup process of the n^{th} semiconductor chip and the imaging process of the n^{th} semiconductor chip performed by the third imaging unit 150.

[0103] More specifically, FIG. 22 shows how the collet 122 retracts from the field of view of the top-view imaging units while holding the first semiconductor chip 310a to be bonded. The first semiconductor chip 310a held by the collet 122 is subsequently placed and bonded to the

planned placement area on the lead frame 330, as indicated by the dotted line. The other aspects are the same as those where the three imaging units shown in FIG. 4 image the calibration index 173. Specifically, the position of the head portion 110 is adjusted so that the focal plane 110a of the top-view imaging units coincides with the first planned surface 330a and the printed surface of the calibration index 173 whose height is adjusted to coincide with the first planned surface. In addition, the calibration index 173 is arranged near the center of the field of view of each imaging unit.

[0104] The calibration controller 213 calculates the first calibration values as described above based on the first top-view image, the second top-view image, and the bottom-view image captured by the imaging units. After the calibration controller 213 calculates the first calibration values, the bonding controller 214 subsequently lowers the bonding tool 120 and executes the process following the imaging of the first semiconductor chip 310a performed by the third imaging unit 150 illustrated with reference to FIG. 7. The process of calculating the first calibration values and the process of calculating the reference position of the first semiconductor chip 310a may be performed in reverse order. Thus, the first calibration values calculated in the calibration process executed in synchronization with the bonding process are used only for alignment of the first semiconductor chip 310a to be bonded in the bonding process.

[0105] The same applies to the process of bonding the second semiconductor chip 310b, the calibration process for calculating the second calibration values is executed between the pickup process of the second semiconductor chip 310b and the imaging process of the second semiconductor chip 310b performed by the third imaging unit 150. After calculating the second calibration values based on the first top-view image, the second top-view image, and the bottom-view image captured by the imaging units, the calibration controller 213 subsequently lowers the bonding tool 120 and executes the process following the imaging of the second semiconductor chip 310b performed by the third imaging unit 150 illustrated with reference to FIG. 14. Thus,

the second calibration values calculated in the calibration process executed in synchronization with the bonding process are used only for alignment of the second semiconductor chip 310b to be bonded in the bonding process.

[0106] Thus, if the calibration controller 213 causes each imaging unit to image the calibration index with an adjusted height in synchronization with the process of the bonding controller 214 causing the third imaging unit 150 to image the n^{th} semiconductor chip, and updates the n^{th} calibration values, it is possible to shorten the time interval between the time when the n^{th} calibration values are calculated and the time when the n^{th} calibration values are used. Accordingly, it can be expected to achieve more accurate alignment with respect to the temperature change in the surrounding environment.

[0107] FIG. 23 is a flowchart illustrating the bonding procedure of the semiconductor chip in another embodiment. The same processing procedures as illustrated with reference to FIG. 19 to FIG. 21 are given the same step numbers, and the description of the processing contents thereof is omitted. As described above, this embodiment is a processing procedure that incorporates the calibration process into each bonding process, so the flow of the process will be mainly described.

[0108] The bonding controller 214 substitutes “1” for the counter n in step S1201. The procedure proceeds to step S1202, and the n^{th} semiconductor chip to be placed as the n^{th} layer, among the semiconductor chips 310 placed on the chip supply apparatus 500, is sucked and picked up by the collet 122. Before or after step S1201 or in parallel with step S1201, the calibration controller 213 executes step S1102 to move the index plate 172 and put the calibration index 173 into the center of the field of view of the third imaging unit 150.

[0109] Subsequently, the procedure proceeds to step S1103, and the calibration controller 213 adjusts the heights of the focal plane 150a of the third imaging unit 150 and the printed surface of the calibration index 173 so that the focal plane 150a of the third imaging unit 150 and the printed surface of the calibration index 173 coincide with the n^{th} planned surface. Then, in step S1104,

the head portion 110 is moved so that the printed surface of the calibration index 173 falls on the focal plane 110a of the first imaging unit 130 and the second imaging unit 140 and so that the calibration index 173 is positioned directly below the bonding tool 120.

[0110] In subsequent step S1105, the calibration controller 213 causes the first imaging unit 130, the second imaging unit 140, and the third imaging unit 150 to image, and further calculates the n^{th} calibration values in step S1106. After calculating the n^{th} calibration values, the procedure proceeds to step S1109 to retract the calibration index 173 from the field of view of each imaging unit.

[0111] After the calibration controller 213 retracts the calibration index 173, the bonding controller 214 executes step S1205 to lower the planned contact surface of the n^{th} semiconductor chip until the planned contact surface coincides with the n^{th} planned surface. Step S1205 to step S1212 are the same as the processing procedure illustrated with reference to FIG. 21. Nevertheless, the calibration values used in the calculation for determining the target position in step S1211 are the n^{th} calibration values calculated in step S1106 executed prior to step S1205.

[0112] When proceeding from step S1212 to step S1213, the bonding controller 214 increments the counter n . Then, in step S1214, it is confirmed whether the incremented counter n has exceeded the planned total lamination number n_0 . If the counter n does not exceed the planned total lamination number n_0 , the procedure returns to step S1202 to execute the bonding of the n^{th} semiconductor chip corresponding to the incremented n . If the counter n exceeds the planned total lamination number n_0 , the procedure proceeds to step S14.

[0113] When proceeding to step S14, the bonding controller 214 determines whether all the scheduled bonding processes are completed. If it is determined that there remain semiconductor chips to be bonded, the procedure returns to step S1201, and if it is determined that all the bonding processes are completed, the series of processes ends.

[0114] In the embodiment described above, in order to allow each imaging unit to image the

calibration index 173 under better conditions, the calibration index 173 is moved near the center of the field of view of each imaging unit. Therefore, in the bonding process, it is necessary to retract the calibration index 173 from the field of view of each imaging unit. Moreover, in order to calculate the n^{th} calibration values, it is necessary to match the printed surface of the calibration index 173 with the n^{th} planned surface.

[0115] Therefore, another embodiment that can omit such retraction work and height adjustment work of the calibration index 173 will be described. FIG. 24 is a diagram illustrating the arrangement of the calibration indices of the calibration unit 170' in another embodiment.

[0116] For example, if each imaging unit has an optical system with performance that does not have aberration in the peripheral portion of the field of view to cause an error in position calculation, the calibration index may be arranged in the peripheral portion of the field of view so as to be observed at all times. That is, if there is almost no influence on the calculation of the calibration values and the calibration index does not interfere when the third imaging unit 150 images the planned contact surface of the semiconductor chip during the bonding process, the calibration index may be constantly arranged in the peripheral portion of the field of view of each imaging unit.

[0117] The calibration unit 170' is provided with a plurality of calibration indices corresponding to each of the n^{th} planned surface fixed to the peripheral portion of the field of view of the third imaging unit 150. Specifically, for example, the first index plate 172a is fixedly provided in one area of the peripheral portion of the field of view of the third imaging unit 150 so that the upper surface thereof coincides with the first planned surface, and the first calibration index 173a is printed on the upper surface. The second index plate 172b printed with the second calibration index 173b and the third index plate 172c printed with the third calibration index 173c are also fixedly provided in one area of the peripheral portion of the field of view of the third imaging unit 150 so as to correspond to the second and third planned surfaces, respectively. The intervals

between the calibration indices are adjusted so that the respective images do not overlap each other in the top-view images and the bottom-view image captured by the imaging units. Although the configuration illustrated here is for the case where the planned total lamination number is “3,” the calibration indices are provided according to the planned total lamination number. By using the calibration unit 170’ configured in this way, it is possible to omit the retraction work and the height adjustment work of the calibration index, which contributes to simplifying the configuration of the calibration unit and shortening the lead time required for the bonding process.

[0118] In addition, in the embodiment described above, the top-view imaging units include the first imaging unit 130 and the second imaging unit 140, but the top-view imaging units may include three or more imaging units each employing a Scheimpflug optical system. Further, in the embodiment described above, the three-dimensional coordinates of the object are calculated by using the parallax between the first top-view image and the second top-view image, but the method of calculating the three-dimensional coordinates using the top-view imaging units is not limited thereto. For example, other auxiliary means may be used with one top-view imaging unit that employs a Scheimpflug optical system. For example, the head portion 110 may be provided with a light projection part capable of pattern light projection, and the shape of the light projection pattern observed on an observation surface may be analyzed based on the top-view image output by the top-view imaging unit so as to calculate the three-dimensional coordinates of the object. In addition, although the embodiment illustrates a flip chip bonder, the present invention is not limited thereto and can be applied to a die bonder, a surface mounter for mounting electronic components on a substrate or the like, and other mounting apparatuses.

Reference Signs List

[0119]

100 ... bonding apparatus, 110 ... head portion, 110a ... focal plane, 111 ... head drive motor, 120 ... bonding tool, 121 ... tool drive motor, 122 ... collet, 123 ... collet center, 124 ... heater, 130... first

imaging unit, 131... first optical system, 131a ... object-side lens group, 131b ... image-side lens group, 132 ... first imaging element, 133 ... diaphragm, 140 ... second imaging unit, 141 ... second optical system, 142 ... second imaging element, 150 ... third imaging unit, 151 ... third optical system, 152 ... third imaging element, 170, 170' ... calibration unit, 171 ... index drive motor, 172 ...
 5 index plate, 172a ... first index plate, 172b ... second index plate, 172c ... third index plate, 173 ... calibration index, 173a ... first calibration index, 173b ... second calibration index, 173c ... third calibration index, 174 ... support base, 175 ... rod, 190 ... stage, 210 arithmetic processor, 211 ... image acquisition part, 212 ... drive controller, 213 ... calibration controller, 214 ... bonding controller, 220 ... storage part, 221 ... calibration data, 230 ... input/output device, 310 ...
 10 semiconductor chip, 310a ... first semiconductor chip, 310b ... second semiconductor chip, 311a ... chip reference mark, 311b ... chip reference mark, 320 ... die pad, 321 ... pad reference mark, 322 ... unit area, 323 ... lamination reference mark, 330 ... lead frame, 330a ... first planned surface, 330b ... second planned surface, 500 ... chip supply apparatus, 510 ... pickup mechanism, 520 ... reversing mechanism

WHAT IS CLAIMED IS:

1. A mounting apparatus, comprising:

a mounting tool picking up and holding a mounting body, and placing and mounting the mounting body on a substrate placed on a stage or a planned placement area set for another mounting body already mounted on the substrate;

top-view imaging units, in which optical systems and imaging elements are arranged to satisfy a Scheimpflug condition so that a plane parallel to a stage surface of the stage becomes a focal plane, for imaging from above the planned placement area from the same side as the mounting tool with respect to the stage surface;

a bottom-view imaging unit for imaging from below the mounting body that is in a state of being held by the mounting tool from a side opposite to the top-view imaging units with respect to the stage surface;

a calibration controller calculating calibration values for calibrating a difference between coordinate values calculated based on top-view images output by the top-view imaging units and coordinate values calculated based on a bottom-view image output by the bottom-view imaging unit; and

a mounting controller placing and mounting the mounting body on the planned placement area so that a reference position of the mounting body held by the mounting tool coincides with a target position of the planned placement area,

wherein the calibration controller calculates the calibration values for each assumed placement height of the planned placement area based on the top-view images and the bottom-view image output by the top-view imaging units and the bottom-view imaging unit by imaging a calibration index arranged to match the placement height, and

the mounting controller adjusts a position of the mounting tool so that a planned contact surface of the mounting body for contacting the planned placement area is at the placement height

to recognize the reference position based on the bottom-view image output by the bottom-view imaging unit by imaging the planned contact surface, and adjusts positions of the top-view imaging units so that the focal plane falls on the same plane as the placement height to recognize the target position based on the top-view images obtained by the top-view imaging units by imaging the planned placement area and the calibration values corresponding to the placement height.

2. The mounting apparatus according to claim 1, comprising an adjusting mechanism that adjusts the calibration index to the corresponding placement height according to the calibration values to be calculated.

3. The mounting apparatus according to claim 1, wherein a plurality of the calibration indices are provided according to the assumed placement height.

4. The mounting apparatus according to any one of claims 1 to 3, wherein the calibration controller calculates and updates the calibration values for each placement height each time the mounting controller completes mounting of the mounting bodies for a preset lot.

5. The mounting apparatus according to any one of claims 1 to 4, wherein the calibration controller calculates and updates the calibration values for each placement height based on a working time of a mounting work executed by the mounting controller.

6. The mounting apparatus according to any one of claims 1 to 5, comprising a temperature detector that detects a temperature of the top-view imaging units,

wherein the calibration controller calculates and updates the calibration values for each placement height when the temperature detector detects a preset temperature.

7. The mounting apparatus according to any one of claims 1 to 3, wherein the calibration controller causes the top-view imaging units and the bottom-view imaging unit to image the calibration index in synchronization with a process that the mounting controller causes the bottom-view imaging unit to image the planned contact surface of the mounting body, and calculates the calibration values corresponding to the placement height of the mounting body.

8. The mounting apparatus according to any one of claims 1 to 7, wherein the top-view imaging units comprise a first imaging unit and a second imaging unit that are adjusted so that focal planes of the first imaging unit and the second imaging unit coincide, and

the mounting controller corrects a provisional target position calculated based on a first top-view image output by the first imaging unit by imaging the planned placement area and a second top-view image output by the second imaging unit by imaging the planned placement area by the calibration values to recognize the target position.

9. A mounting method for a mounting body using a mounting apparatus, which comprises a mounting tool picking up and holding the mounting body and placing and mounting the mounting body on a substrate placed on a stage or a planned placement area set for another mounting body already mounted on the substrate; top-view imaging units in which respective optical systems and imaging elements are arranged to satisfy a Scheimpflug condition so that a plane parallel to a stage surface of the stage becomes a focal plane, for imaging from above the planned placement area from the same side as the mounting tool with respect to the stage surface; and a bottom-view imaging unit for imaging from below the mounting body that is in a state of being held by the mounting tool from a side opposite to the top-view imaging units with respect to the stage surface, the mounting method comprising:

a calibration control step of calculating calibration values for calibrating a difference between coordinate values calculated based on top-view images output by the top-view imaging units and coordinate values calculated based on a bottom-view image output by the bottom-view imaging unit; and

a mounting control step of placing and mounting the mounting body on the planned placement area so that a reference position of the mounting body held by the mounting tool coincides with a target position of the planned placement area,

wherein the calibration control step calculates the calibration values for each assumed

placement height of the planned placement area based on the top-view images and the bottom-view image output by the top-view imaging units and the bottom-view imaging unit by imaging a calibration index arranged to match the placement height, and

the mounting control step adjusts a position of the mounting tool so that a planned contact
5 surface of the mounting body for contacting the planned placement area is at the placement height to recognize the reference position based on the bottom-view image output by the bottom-view imaging unit by imaging the planned contact surface, and adjusts positions of the top-view imaging units so that the focal plane falls on the same plane as the placement height to recognize the target position based on the top-view images obtained by the top-view imaging units by imaging the
10 planned placement area and the calibration values corresponding to the placement height.

10. A mounting control program for controlling a mounting apparatus, which comprises a mounting tool picking up and holding a mounting body and placing and mounting the mounting body on a substrate placed on a stage or a planned placement area set for another mounting body already mounted on the substrate; top-view imaging units in which respective optical systems and
15 imaging elements are arranged to satisfy a Scheimpflug condition so that a plane parallel to a stage surface of the stage becomes a focal plane, for imaging from above the planned placement area from the same side as the mounting tool with respect to the stage surface; and a bottom-view imaging unit for imaging from below the mounting body that is in a state of being held by the mounting tool from a side opposite to the top-view imaging units with respect to the stage surface,
20 the mounting control program causing a computer to execute:

a calibration control step of calculating calibration values for calibrating a difference between coordinate values calculated based on top-view images output by the top-view imaging units and coordinate values calculated based on a bottom-view image output by the bottom-view imaging unit; and

25 a mounting control step of placing and mounting the mounting body on the planned

placement area so that a reference position of the mounting body held by the mounting tool coincides with a target position of the planned placement area,

wherein the calibration control step calculates the calibration values for each assumed placement height of the planned placement area based on the top-view images and the bottom-view image output by the top-view imaging units and the bottom-view imaging unit by imaging a calibration index arranged to match the placement height, and

the mounting control step adjusts a position of the mounting tool so that a planned contact surface of the mounting body for contacting the planned placement area is at the placement height to recognize the reference position based on the bottom-view image output by the bottom-view imaging unit by imaging the planned contact surface, and adjusts positions of the top-view imaging units so that the focal plane falls on the same plane as the placement height to recognize the target position based on the top-view images obtained by the top-view imaging units by imaging the planned placement area and the calibration values corresponding to the placement height.