

may be greatly crushed. Particularly, in the case where the chip is normally pressurized with the constant load, the mounting tool is slightly distorted. When the bump is melted and a reaction force acting on the mounting tool from the chip decreases, this distortion is instantly eliminated, and the tip of the mounting tool moves in a direction of pressing and crushing the molten bump. As a result, the molten bump may be crushed more than expected. In this case, there is also a risk that the pressed and crushed bump may extend in a plane direction and a short circuit failure may be caused between the pressed and crushed bump and its adjacent bump.

[0006] That is, in the conventional art, there is a risk that a short circuit failure may occur, and quality of a semiconductor device cannot be appropriately maintained. Thus, the present specification discloses a manufacturing apparatus and a manufacturing method of a semiconductor device, in which the quality of the semiconductor device can be appropriately maintained.

Means for Solving the Problems

[0007] A manufacturing apparatus of a semiconductor device disclosed in the present specification is characterized as follows. The manufacturing apparatus includes: a stage, supporting a substrate; a bonding head, including a mounting tool that holds a chip provided with a bump on a bottom surface thereof, a tool heater that is mounted on the mounting tool in order to heat the chip, and a lifting and lowering mechanism that moves the mounting tool in a vertical direction; and a controller, controlling driving of the bonding head and performing bonding processing for bonding the chip to the substrate. The controller performs, in the bonding processing: first processing in which, after the chip is brought into contact with the substrate, the tool heater and the lifting and lowering mechanism are driven, and as heating of the chip is started, the chip is pressurized against the substrate; distortion elimination processing in which, after the first processing and before melting of the bump, the lifting and lowering mechanism is driven in a lifting direction, thereby eliminating distortion of the bonding head; and second processing in which, after the distortion elimination processing, position control is

performed on the lifting and lowering mechanism so as to cancel thermal expansion and contraction of the bonding head, thereby maintaining a gap amount between the bottom surface of the chip and an upper surface of the substrate at a specified target value.

[0008] In this case, the controller may perform distortion elimination amount detection processing prior to the bonding processing. In the distortion elimination amount detection processing, while the mounting tool and the stage are maintained at a predetermined temperature, after the lifting and lowering mechanism is driven and the substrate is pressed by the mounting tool, a pressing load on the substrate by the mounting tool may be detected while the lifting and lowering mechanism is driven in the lifting direction, and a movement amount of the lifting and lowering mechanism from start of the driving in the lifting direction until stop of fluctuation of the pressing load may be stored as a distortion elimination amount. In the distortion elimination processing, the lifting and lowering mechanism may be driven in the lifting direction based on the distortion elimination amount.

[0009] The controller may perform melting timing detection processing in which a melting timing of the bump is detected prior to bonding of the chip to the substrate. In the melting timing detection processing, after the chip is brought into contact with the substrate, the chip may be heated according to a specified temperature profile, and time from start of the heating until melting of the bump may be stored as a melting time. The controller may determine an execution timing of the distortion elimination processing based on the melting time.

[0010] The lifting and lowering mechanism may include a slide shaft that is mechanically connected to the mounting tool, a drive source that lifts and lowers the slide shaft, and a position sensor that detects an axial position of the slide shaft as a detected position. The controller may perform target profile generation processing prior to the bonding processing. In the target profile generation processing, after the lifting and lowering mechanism is driven and the mounting tool is brought into contact with the substrate, the mounting tool may be heated according to a specified temperature profile. Based on a change in the detected position

mounting tool 20 via the slide shaft 32. The slide shaft 32 is attached to the moving body 46 via the leaf spring 34 that can be distorted in the Z-axis direction. Further, the guide member 36 is fixed to the moving body 46. The slide shaft 32 is inserted into a through hole formed in the guide member 36, and is slidable along the through hole.

[0019] When a current is applied to the VCM 30, the mover 30b moves in the Z-axis direction with respect to the moving body 46. At this time, the slide shaft 32 and the mounting tool 20 fixed to the slide shaft 32 move in the Z-axis direction together with the mover 30b while elastically deforming the leaf spring 34. In order to detect the movement of the slide shaft 32, a linear encoder 50 is provided in the first unit 24a. The linear encoder 50 includes a movable part 50a provided in the vicinity of an upper end of the slide shaft 32 and a fixed part 50b whose position is fixed. The linear encoder 50 outputs a relative displacement amount between the movable part 50a and the fixed part 50b. The linear encoder 50 may be a magnetic encoder magnetically detecting a displacement or an optical encoder optically detecting a displacement. In the case of the optical encoder, the fixed part 50b includes a scale in which multiple slit holes are formed in a displacement direction, and the movable part 50a includes a light source and a light receiving element arranged on both sides of the scale to sandwich the scale. In the case of the magnetic encoder, the fixed part 50b includes a magnetic scale, and the movable part 50a includes a magnetic sensor. A value detected by the linear encoder 50 is output to the controller 16.

[0020] The second unit 24b lifts and lowers the first unit 24a in the Z-axis direction with respect to a base member 38. The second unit 24b includes a lifting and lowering motor 40 as a drive source. An axially extending leadscrew 42 is connected to the lifting and lowering motor 40 via a coupling. With driving of the lifting and lowering motor 40, the leadscrew 42 rotates on its axis. A moving block 44 is screwed to the leadscrew 42. The moving block 44 is fixed to an upper surface of the stator 30a of the VCM 30. The moving body 46 is fixed to a side surface of the stator 30a. The moving body 46 is slidable along a guide rail 48 fixed to the base member 38.

[0025] When the semiconductor chip 100 is bonded, the mounting tool 20 applies a specified standard load F_s to the semiconductor chip 100 and presses the semiconductor chip 100 against the substrate 110. At this time, a predetermined reaction force acts on the mounting tool 20 from the semiconductor chip 100. In response to this reaction force, the slide shaft 32 may be distorted as indicated by the chain double-dashed line in FIG. 4. When the slide shaft 32 is distorted, it is natural that the axial position of the movable part 50a of the linear encoder 50 changes accordingly. Also, in this case, the actual position of the semiconductor chip 100 cannot be accurately grasped from the detected position P_d detected by the linear encoder 50 or the like, and the gap amount G cannot be accurately managed.

[0026] In the case where the bump 104 continues to be heated and pressurized while the slide shaft 32 is distorted, the reaction force from the semiconductor chip 100 sharply decreases at the moment when the bump 104 is melted. In this case, distortion of the slide shaft 32 is instantly eliminated, and the bottom surface of the mounting tool 20 sharply drops. In this case, the molten bump 104 is pushed by the mounting tool 20, and there is a risk that the bump 104 may be excessively pressed and crushed.

[0027] In this example, in order to avoid such a problem, before melting of the bump 104, the lifting and lowering mechanism is driven in the lifting direction and distortion of the slide shaft 32 is eliminated. In addition, position control is performed on the mounting tool 20 so as to cancel thermal expansion and contraction of the peripheral members, thereby maintaining the gap amount G at a predetermined target value. A detailed procedure of such bonding is hereinafter described with reference to FIG. 5 and FIG. 6. FIG. 5 is a flowchart showing a flow of the bonding processing. FIG. 6 includes graphs showing temporal changes of various parameters in the bonding processing. (a) of FIG. 6 is a graph showing the axial position (hereinafter referred to as “detected position P_d ”) of the mounting tool 20 that is obtained from a detected value from a position sensor (such as the linear encoder 50) provided in the lifting and lowering mechanism. (b) of FIG. 6 is a graph showing an actual distance (hereinafter referred

to as “distance D_r ”) to the bottom surface of the mounting tool 20 with reference to the upper surface of the stage 12 in the case where the mounting tool 20 holds the semiconductor chip 100. (c) of FIG. 6 is a graph showing a change in a pressing load F_p applied to the semiconductor chip 100 by the lifting and lowering mechanism. (d) of FIG. 6 is a graph showing a driving state of the tool heater 26. In the distance D_r , a reference position of the distance changes due to distortion or thermal expansion of the stage 12.

[0028] When the semiconductor chip 100 is bonded to the substrate 110, the controller 16 drives the lifting and lowering mechanism to lower the semiconductor chip 100 and bring the semiconductor chip 100 into contact with the substrate 110 (S10, S12). Specifically, the controller 16 first drives the lifting and lowering motor 40 to lower the mounting tool 20 to the vicinity of the substrate 110 at high speed. Subsequently, while the lifting and lowering motor 40 is stopped, the VCM 30 is driven to lower the mounting tool 20 at low speed. At this time, a change in the detected position P_d is monitored. If the detected position P_d does not change any more, it is determined that contact is achieved. As described above, since the slide shaft 32 or the like is slightly distorted, there is a slight error between an actual contact timing and a contact timing detected by the controller 16.

[0029] In the example of FIG. 6, the semiconductor chip 100 actually contacts the substrate 110 at time t_1 , and the distance D_r does not change any more after time t_1 . However, after the semiconductor chip 100 actually contacts the substrate 110, the detected position P_d still changes due to distortion of the slide shaft 32 or the like. Hence, the controller 16 determines that the contact occurs at time t_2 when the slide shaft 32 or the like is sufficiently distorted and the detected position P_d does not change any more.

[0030] If contact is detected (Yes in S12), the controller 16 executes first processing (S14 to S18) in which the semiconductor chip 100 is pressurized with a constant load and heated. Specifically, the controller 16 starts load control of the lifting and lowering mechanism so that the previously specified standard load F_s is applied to the semiconductor chip 100 (S14). That

case, by driving the VCM 30 in the lifting direction by the distortion elimination amount Aa , distortion of the bonding head 14 (particularly the slide shaft 32) is eliminated. In the example of FIG. 6, the VCM 30 is driven during a period from time $t4$ to time $t5$ until the detected position Pd rises by the distortion elimination amount Aa . At this time, the distance Dr of the mounting tool 20 does not change, distortion of the slide shaft 32 is eliminated, and the pressing load Fp sharply decreases.

[0034] If distortion can be eliminated, the controller 16 executes second processing (S22 to S26) for maintaining the gap amount G at the target value. Specifically, the controller 16 starts position control of the VCM 30 according to a previously generated target profile (S22). The target profile is a movement profile that specifies a target movement position of the lifting and lowering mechanism. The controller 16 performs position feedback control on the VCM 30 so that a difference between a command position obtained from the target profile and the detected position Pd approaches zero. Here, as described above, the detected position Pd is affected by thermal expansion and contraction of the mounting tool 20 and the stage 12, and a deviation occurs between the detected position Pd and the distance Dr between the upper surface of the stage 12 and the bottom surface of the mounting tool 20. That is, due to thermal expansion of the stage 12 and the mounting tool 20, the controller 16 may detect, as the detected position Pd , a position different from the distance Dr from a height $D1$ of the stage 12 after distortion is eliminated. The target profile is set so that an error caused by this thermal expansion and contraction is canceled and the actual gap amount G is maintained at the target value.

[0035] This is specifically described with reference to FIG. 6. In the case where the distance Dr of the mounting tool 20 is maintained constant based on the height $D1$ after distortion is eliminated, the detected position Pd is affected by thermal expansion and contraction of the mounting tool 20 and thus changes as indicated by the chain double-dashed line in (a) of FIG. 6. That is, the detected position Pd in the case where $Dr=D1$ is maintained gradually rises after time $t3$ when the tool heater 26 is turned ON, and gradually drops after time

processing. Hereinafter, these processings are described.

[0042] First of all, the distortion elimination amount detection processing is described with reference to FIG. 7 and FIG. 8. As described above, in the bonding processing, immediately before melting of the bump 104, the VCM 30 is driven in the lifting direction by the distortion elimination amount Aa. Accordingly, distortion of the bonding head 14 (particularly the mounting tool 20 and the slide shaft 32) is eliminated. The distortion elimination amount Aa used at this time is detected by the distortion elimination amount detection processing performed prior to the bonding processing. FIG. 7 is a flowchart showing a flow of the distortion elimination amount detection processing. FIG. 8 includes graphs showing changes in the detected position Pd and a detected load Fd in the distortion elimination amount detection processing.

[0043] When the distortion elimination amount detection processing is performed, the mounting tool 20 is used while not holding the semiconductor chip 100. A load sensor (for example, a load cell) is disposed in advance on the bottom surface of the mounting tool 20 or the upper surface of the substrate 110, so as to be able to detect the pressing load on the substrate 110 by the mounting tool 20 as the detected load Fd in advance. Further, the mounting tool 20 and the substrate 110 are set at the same predetermined temperature as each other in advance. If such preparations are ready, the controller 16 drives the lifting and lowering mechanism to lower the mounting tool 20 that does not hold the semiconductor chip 100 until the mounting tool 20 contacts the substrate 110 (S30, S32). In the example of FIG. 8, it is determined that contact is achieved at time t2 when the detected position Pd stops fluctuating. At this time, a current applied to the VCM 30 is adjusted so that the mounting tool 20 presses the substrate 110 with the standard load Fs. The predetermined temperature is, for example, room temperature (20 °C). However, the mounting tool and the stage may be heated by a heater to 50 °C or 100 °C. In this example, the distortion elimination amount Aa detected by the distortion elimination amount detection processing is defined as a lifting amount of the VCM 30 in the distortion elimination

of the bump 104. As a result, it can be prevented that the mounting tool 20 is instantly greatly lowered when the bump 104 is melted. As a result, the bump 104 can be prevented from being excessively crushed.

[0053] Next, the target profile generation processing is described with reference to FIG. 11 and FIG. 12. As described above, in the bonding processing, after the bump 104 is melted, the gap amount G is maintained at the specified target value by performing position control on the lifting and lowering mechanism so as to cancel thermal expansion and contraction of the bonding head 14. In the target profile generation processing, the target profile used in this position control is generated. FIG. 11 is a flowchart showing a flow of the target profile generation processing. FIG. 12 illustrates changes of various parameters in the target profile generation processing. More specifically, (a) of FIG. 12 is a graph showing a reference profile 90 acquired by the target profile generation processing, and (b) of FIG. 12 is a graph showing the driving state of the tool heater 26 in the target profile generation processing. (c) of FIG. 12 is a graph showing an offset processed reference profile 90*, an ideal profile 92, and a target profile 94.

[0054] When the target profile generation processing is performed, the mounting tool 20 is in a state of not holding the semiconductor chip 100. The controller 16 drives the lifting and lowering mechanism to lower the mounting tool 20 that does not hold the semiconductor chip 100 until the mounting tool 20 contacts the substrate 110 (S70, S72). If the mounting tool 20 contacts the substrate 110, the controller 16 starts control of the tool heater 26 (S76). The control of the tool heater 26 is performed according to the same temperature profile as the bonding processing. That is, in the bonding processing, a timing to turn ON or a timing to turn OFF the tool heater 26 is specified in advance, and such a timing is stored as a temperature profile in the memory of the controller 16. In step S76, the control of the tool heater 26 according to this temperature profile is started. The controller 16 initializes the parameter i and sets $i=0$ (S78). If the control of the tool heater 26 is started, the controller 16 repeats

processing (S80) for storing the current detected position P_d as $P[i]$ in the memory and processing (S84) for incrementing the parameter i at predetermined sampling intervals, until an end timing of the bonding processing is reached (until Yes in S82).

[0055] In the example of FIG. 12, the control of the tool heater 26 is started at time t_1 , and the tool heater 26 is turned ON at time t_1 . The detected position P_d at time t_1 (see the graph of (a) of FIG. 12) is stored as an initial position $P[0]$ in the memory. By starting the temperature profile and turning on the tool heater 26, the temperature of the mounting tool 20 and the slide shaft 32 gradually rises, and the mounting tool 20 and the slide shaft 32 are thermally expanded. As a result, the detected position P_d detected by the linear encoder 50 gradually rises even though the position of the bottom surface of the mounting tool 20 has not changed. Further, at time t_3 in the example of FIG. 12, thermal expansion of the slide shaft 32 or the like converges, and the detected position P_d also becomes constant. After that, at time t_4 , when the tool heater 26 is turned OFF in order to start cooling, the temperature of the slide shaft 32 or the like is lowered, and thermal expansion is eliminated. Hence, after time t_4 , the detected position P_d is gradually lowered. Then, after time t_5 when the temperature of the slide shaft 32 or the like returns to a predetermined temperature, the detected position P_d is maintained at a constant value. Then, at time t_6 which is the end timing, the acquisition of the detected position P_d is ended. In steps S80 to S84, data as shown in (a) of FIG. 12 is acquired as the reference profile 90. A value obtained by subtracting the value of the position $P[i]$ at the time of the melting time T_m -the margin α (time t_a in FIG. 12) from the reference profile 90 is a thermal expansion amount of the bonding head 14.

[0056] If the reference profile 90 is obtained, the controller 16 generates the target profile 94 based on the previously stored ideal profile 92 and the reference profile 90 (S86). The ideal profile 92 is a movement profile in the case where the bonding head 14 is in an ideal state without occurrence of thermal expansion or distortion.

[0057] In (c) of FIG. 12, the solid line indicates the target profile 94, the chain double-

dashed line indicates the ideal profile 92, and the chain line indicates the offset processed reference profile 90* in which the position at time t_a is adjusted (that is, offset processed) to the ideal profile 92. As shown in FIG. 12, in the ideal profile 92, at time t_2 when the bump 104 is melted, the ideal profile 92 drops by the target crushing amount G_d . Thereafter, the same height position is maintained. Then, the ideal profile 92 rises after time t_6 when the bump 104 is cured.

[0058] The target profile 94 is obtained by adding the thermal expansion amount of the bonding head 14 obtained from the reference profile 90 to the ideal profile 92. As described above, the thermal expansion amount is obtained by subtracting the value of the position $P[i]$ at the time of the melting time T_m -the margin α (time t_a) from the reference profile 90. By adding the thermal expansion amount to the ideal profile 92, the target profile 94 as indicated by the solid line in the graph of (c) of FIG. 12 can be obtained. When the actual bonding processing is performed, position control is performed on the lifting and lowering mechanism according to the target profile 94. By using the target profile 94, even if the bonding head 14 is thermally expanded, the position of the bottom surface of the mounting tool 20 and the gap amount G can be maintained constant.

[0059] As is clear from the above description, according to this example, the distortion elimination amount A_a , the melting timing, and the target profile are acquired in advance. When the actual bonding processing is performed, before melting of the bump 104, the lifting and lowering mechanism is driven in the lifting direction by the distortion elimination amount A_a and distortion of the bonding head 14 is eliminated. Then, the lifting and lowering mechanism is driven according to the target profile that cancels thermal expansion. By such a configuration, the molten bump 104 can be effectively prevented from being excessively crushed, and good quality of the semiconductor device can be maintained. The configuration described so far is one example. If the lifting and lowering mechanism is driven in the lifting direction to eliminate distortion of the bonding head 14 before melting of the bump 104, and then the lifting and lowering mechanism is driven so as to cancel thermal expansion, other configurations may

WHAT IS CLAIMED IS:

1. A manufacturing apparatus of a semiconductor device, comprising:

a stage, supporting a substrate;

a bonding head, comprising a mounting tool that holds a chip provided with a bump on a bottom surface thereof, a tool heater that is mounted on the mounting tool in order to heat the chip, and a lifting and lowering mechanism that moves the mounting tool in a vertical direction; and

a controller, controlling driving of the bonding head and performing bonding processing for bonding the chip to the substrate,

wherein the controller performs, in the bonding processing:

first processing in which, after the chip is brought into contact with the substrate, the tool heater and the lifting and lowering mechanism are driven, and as heating of the chip is started, the chip is pressurized against the substrate;

distortion elimination processing in which, after the first processing and before melting of the bump, the lifting and lowering mechanism is driven in a lifting direction, thereby eliminating distortion of the bonding head; and

second processing in which, after the distortion elimination processing, position control is performed on the lifting and lowering mechanism so as to cancel thermal expansion and contraction of the bonding head, thereby maintaining a gap amount between the bottom surface of the chip and an upper surface of the substrate at a specified target value.

2. The manufacturing apparatus of a semiconductor device according to claim 1, wherein

the controller performs distortion elimination amount detection processing prior to the bonding processing;

in the distortion elimination amount detection processing, while the mounting tool and the stage are maintained at a predetermined temperature, after the lifting and lowering mechanism is driven and the substrate is pressed by the mounting tool, a pressing load on the

substrate by the mounting tool is detected while the lifting and lowering mechanism is driven in the lifting direction, and a movement amount of the lifting and lowering mechanism from start of the driving in the lifting direction until stop of fluctuation of the pressing load is stored as a distortion elimination amount;

in the distortion elimination processing, the lifting and lowering mechanism is driven in the lifting direction based on the distortion elimination amount.

3. The manufacturing apparatus of a semiconductor device according to claim 1 or 2, wherein

the controller performs melting timing detection processing in which a melting timing of the bump is detected prior to bonding of the chip to the substrate;

in the melting timing detection processing, after the chip is brought into contact with the substrate, the chip is heated according to a specified temperature profile, and time from start of the heating until melting of the bump is stored as a melting time;

the controller determines an execution timing of the distortion elimination processing based on the melting time.

4. The manufacturing apparatus of a semiconductor device according to any one of claims 1 to 3, wherein

the lifting and lowering mechanism comprises a slide shaft that is mechanically connected to the mounting tool, a drive source that lifts and lowers the slide shaft, and a position sensor that detects an axial position of the slide shaft as a detected position;

the controller performs target profile generation processing prior to the bonding processing;

in the target profile generation processing, after the lifting and lowering mechanism is driven and the mounting tool is brought into contact with the substrate or the stage, the mounting tool is heated according to a specified temperature profile, and based on a change in the detected position detected by the position sensor as obtained at that time, a thermal expansion amount of

the bonding head is acquired, and a movement profile in which the thermal expansion amount is canceled is generated as a target profile;

in the second processing, position control is performed on the lifting and lowering mechanism according to the target profile.

5. A manufacturing method of a semiconductor device, in which a bonding head comprising a mounting tool, a tool heater that is mounted on the mounting tool, and a lifting and lowering mechanism that moves the mounting tool in a vertical direction is driven, and a chip held by the mounting tool is bonded to a substrate supported on a stage, wherein the manufacturing method of a semiconductor device comprises:

a first step in which, after the mounting tool is lowered and the chip is brought into contact with the substrate, the tool heater and the lifting and lowering mechanism are driven, and as heating of the chip is started, the chip is pressurized against the substrate;

a distortion elimination step in which, after the first step and before melting of a bump provided on a bottom surface of the chip, the lifting and lowering mechanism is driven in a lifting direction, thereby eliminating distortion of the bonding head; and

a second step in which, after the distortion elimination step, position control is performed on the lifting and lowering mechanism so as to cancel thermal expansion and contraction of the bonding head, thereby maintaining a gap amount between the bottom surface of the chip and an upper surface of the substrate at a specified target value.