

METHOD FOR PRODUCING SEMICONDUCTOR DEVICE AND APPARATUS FOR PRODUCING THE SAME

Technical Field

The present invention relates to a method for producing a semiconductor device and an apparatus for producing the same.

Background Art

These days, semiconductor chips are downsized and high-densely mounted, so that importance of a flip chip bonding technology using anisotropic conductive paste (ACP) or anisotropic conductive film (ACF) has been highly increased. Anisotropic conductive paste contains conductive particles and binder, and thermosetting resins, e.g., epoxy resin, are used as binder with considering high-temperature properties and a high bonding force.

Conventionally, a production method including a step of pressing and heating a work, in which plurality of LED elements are mounted on mounting surfaces of a circuit board through anisotropic conductive paste, has been proposed (see Patent Literature 1: Japanese Patent No. 6565902). Another production method, in which bypass wiring patterns are disconnected by connecting LED chips to parts of a circuit board where the bypass wiring patterns are formed through anisotropic conductive paste, has been proposed (see Patent Literature 2: Japanese Patent No. 6147645). A further method using a reflow furnace capable of heating a work being carried

by a conveyor has been known (see Patent Literature 3: Japanese Patent No. 4818952).

Summary of Invention

Technical Problem

As an example, a semiconductor device, which is used for a backlight of a high definition display unit and in which a large number of semiconductor chips having a width of 0.1 mm order are matrically mounted on a circuit board, exists. In this case, if a work is pressed and heated as described in Patent Literature 1, defective chips, which are caused by displacement of semiconductor chips, stress and distortion applied thereto, etc., will be easily produced. Further, in case of using the circuit board in which the bypass patterns are formed as described in Patent Literature 2, it is difficult to highly densely mount semiconductor chips. Especially, in case of using anisotropic conductive paste including conductive particles and thermosetting resin, if the thermosetting resin is thermal cured, it is impossible to perform rework. However, any of Patent Literatures 1-3 do not describe about rework of defective chips.

Solution to Problem

The present invention has been invented according to the above described circumstances, and an object is to provide a method for producing a semiconductor device and an apparatus for producing the same, each of which is capable of dramatically increasing yield of the semiconductor device necessary for a high-density mounting technology by putting a

work, in which plurality of semiconductor chips are mounted on a circuit board through anisotropic conductive paste including conductive particles and thermosetting resin, in an energizable-reworkable state.

In the present invention, the above described problems are solved by the following solution disclosed as an embodiment.

The method for producing a semiconductor device relating to the present invention comprises: a mounting step for transferring anisotropic conductive paste, in which conductive particles are dispersed in uncured thermosetting resin, to semiconductor chips and mounting the semiconductor chips onto a circuit board by flip chip mounting technology; and a first heating step for heating a work, in which plurality of the semiconductor chips are mounted on the circuit board through the anisotropic conductive paste, in a first reflow furnace, the first reflow furnace comprises: a heating zone in which temperature is set at a melting temperature of solder included in the conductive particles or higher; a cooling zone in which temperature is set lower than the melting temperature of the solder included in the conductive particles; a first conveyor being extended from an entrance to the heating zone; and a second conveyor being extended from the cooling zone to an exit, the work is carried through the first reflow furnace, for a period of time shorter than a curing time of the thermosetting resin, by the first conveyor and the second conveyor, and the first heating step comprises: heating the work, along a temperature rising curve whose average temperature rising rate

is 4-8°C/second, in a first heating zone of the heating zone by pitch-feeding the work to the first heating zone and staying therein; next, melting the solder by pitch-feeding the work to a second heating zone of the heating zone and staying therein; and then carrying the work to the cooling zone so as to cure the solder and put the work in an energizable-reworkable state.

Preferably, the first heating step comprises steps of: heating the work, in the first heating zone, for 20-40 seconds until reaching a peak temperature; heating the work, in the second heating zone, for 5-30 seconds so as to maintain the peak temperature; and cooling the work in the cooling zone. As an example, the semiconductor chips are LEDs, the method further comprises: a continuity test step for performing a continuity test of the work after the first heating step; a defective chip removing step for removing a continuity-defective chip, by a defective chip removing machine, when the continuity-defective chip is detected from the LEDs in the continuity test step; and a re-mounting step for transferring anisotropic conductive paste to a new LED which is used instead of the continuity-defective chip, and mounting the new LED onto a mounting place from which the continuity-defective chip has been removed, and the defective chip removing step comprises steps of: sucking a mounting place of the continuity-defective chip, by a vacuum suction head, with heating the mounting place in a noncontact state, so as to re-melt the solder; and removing the continuity-defective chip and the thermosetting resin of a bonding part from the circuit board. Further, as an example, after the re-mounting step, the first heating step and the continuity test step are

repeated until detecting no continuity-defective chip, and, in the continuity test step, data of presence/absence of the lighting LEDs, which are made connection with arrangement data of the LEDs, are stored in storing means, and the place of the continuity-defective chip is identified from the data.

With the above described structure, the solder of the anisotropic conductive paste has been cured, so that a continuity-defective chip can be detected from the semiconductor chips mounted on the circuit board by electric energization. Further, the thermosetting resin of the anisotropic conductive paste, which has been heated for the period of time shorter than the curing time, is in a gel state, so that the continuity-defective chip can be removed from the semiconductor chips mounted on the circuit board and the work can be reworked. As to the curing time of the thermosetting resin of the anisotropic conductive paste, a recommended curing condition of a material manufacturer may be employed as an example; another curing condition, which is a time of being in the gel state of the thermosetting resin of the anisotropic conductive paste shorter than the curing time and is calculated on the basis of experimental data, may be employed; and a condition introduced from a combination of the above conditions may be employed as a curing condition.

The apparatus for producing a semiconductor device relating to the present inventio comprises: an applying machine for transferring anisotropic conductive paste, in which conductive particles are dispersed in uncured thermosetting

resin, to semiconductor chips; a mounting machine for mounting the semiconductor chips onto a circuit board by flip chip mounting technology; a first reflow furnace for heating a work, in which plurality of the semiconductor chips are mounted on the circuit board through the anisotropic conductive paste; and a control unit, the first reflow furnace comprises: a heating zone in which temperature is set at a melting temperature of solder included in the conductive particles or higher; a cooling zone in which temperature is set lower than the melting temperature of the solder included in the conductive particles; a first conveyor being extended from an entrance to the heating zone; and a second conveyor being extended from the cooling zone to an exit, the work is carried through the first reflow furnace, for a period of time shorter than a curing time of the thermosetting resin, by the first conveyor and the second conveyor, a presser roller, which contacts an upper surface of the circuit board when transferring the work from the first conveyor to the second conveyor, is provided to a place between the first conveyor and the second conveyor, and the control unit performs steps of: heating the work, along a temperature rising curve whose average temperature rising rate is $4-8^{\circ}\text{C}/\text{second}$, in a first heating zone of the heating zone by pitch-feeding the work to the first heating zone and staying therein; next, melting the solder by pitch-feeding the work to a second heating zone of the heating zone and staying therein; and then carrying the work to the cooling zone so as to cure the solder and put the work in an energizable-reworkable state.

Preferably, the presser roller comprises rollers, which

are pivotably supported on a shaft and arranged with prescribed intervals, and contacts the surface of the circuit board, except mounting surfaces, by own weights of the rollers, and the control unit performs steps of: heating the work, in the first heating zone, for 20-40 seconds until reaching a peak temperature; heating the work, in the second heating zone, for 5-30 seconds so as to maintain the peak temperature; and cooling the work in the cooling zone. As an example, the semiconductor chips are LEDs, the apparatus further comprises: a continuity test machine for performing a continuity test of the work; and a defective chip removing machine for removing a continuity-defective chip when the continuity-defective chip is detected from the LEDs by the continuity test machine, the defective chip removing machine performs steps of: sucking a mounting place of the continuity-defective chip, by a vacuum suction head, with heating a mounting place in a noncontact state, so as to re-melt the solder; and removing the continuity-defective chip and the thermosetting resin of a bonding part from the circuit board, and the control unit controls the applying machine and the mounting machine to perform steps of: transferring anisotropic conductive paste to a new LED; and mounting the new LED onto the mounting place from which the continuity-defective chip has been removed. Further, as an example, the continuity test machine stores data of presence/absence of the lighting LEDs, which are made connection with arrangement data of the LEDs, in storing means, and identifies the place of the continuity-defective chip.

With the above described structure, the work is carried to the heating zone by the first conveyor so as to rapidly melt the solder of the conductive particles of the anisotropic conductive paste, then the work is carried to the cooling zone by the second conveyor so as to rapidly cure the solder of the conductive particles of the anisotropic conductive paste, and the work is carried through the first reflow furnace for a period of time shorter than the curing time of the thermosetting resin. Therefore, the work can be putted in the energizable-reworkable state.

Advantageous Effects of Invention

In the method for producing a semiconductor device and the apparatus for producing the same of the present invention, the work can be putted in the energizable-reworkable state. Therefore, as an example, in case of matrically mounting a large number of semiconductor chips having a width of 0.1 mm order onto the circuit board, yield of the semiconductor device necessary for a high-density mounting technology can be dramatically increased.

Brief Description of Drawings

[Fig. 1] Fig. 1 is a schematic diagram showing an inside of a first reflow furnace of an apparatus for producing a semiconductor device relating to an embodiment of the present invention.

[Fig. 2] Fig. 2A is a schematic diagram in which a work is carried to a first heating zone of a first reflow furnace shown in Fig. 1, Fig. 2B is a schematic diagram in which the work is

carried to a second heating zone after the state shown in Fig. 2A, and Fig. 2C is a schematic diagram in which the work is carried to a first cooling zone after the state shown in Fig. 2B.

[Fig. 3] Fig. 3A is a schematic diagram in which the work is carried to a second cooling zone after the state shown in Fig. 2C, Fig. 3B is a schematic diagram in which the work is carried to a labyrinth on an exit side after the state shown in Fig. 3A, and Fig. 3C is a schematic diagram in which the work is carried to the exit after the state shown in Fig. 3B.

[Fig. 4] Fig. 4 is a graph of temperature profile of the work in the first reflow furnace shown in Fig. 1.

[Fig. 5] Fig. 5 is a schematic diagram of a circuitry of the apparatus for producing the semiconductor device relating to the embodiment.

[Fig. 6] Fig. 6A is a schematic sectional view of the work, in which anisotropic conductive paste is applied onto a circuit board and semiconductor chips are mounted thereon, Fig. 6B is a schematic sectional view of the work, in which first heating and a continuity test are performed after the state shown in Fig. 6A, and Fig. 6C is a schematic sectional view of the work, in which a defective chip is removed after the state shown in Fig. 6B.

[Fig. 7] Fig. 7A is a schematic sectional view of the work, in which a new semiconductor chip is mounted at the place from which the defective chip has been removed after the state shown in Fig. 6C, Fig. 7B is a schematic sectional view of the work, in which the first heating and the continuity test are performed after the state shown in Fig. 7A, and Fig. 7C is a schematic sectional view of the work, in which second heating

and examination are performed after the state shown in Fig. 7B.

[Fig. 8] Fig. 8 is a flowchart showing a production process of the semiconductor device relating to the embodiment.

[Fig. 9] Fig. 9 is a flowchart showing another production process of the semiconductor device relating to the embodiment.

Description of Embodiments

An embodiment of the present invention will now be described in detail with reference to the attached drawings. Fig. 1 shows a part or whole of an apparatus 1 for producing a semiconductor device of the present embodiment, especially a schematic sectional view of an inside of a first reflow furnace 3 is shown. In the drawing, a left side is an entrance side (an upstream side), and a right side is an exit side (a downstream side). The first reflow furnace 3 comprises: a main body 30 in which a carrying mechanism and a heating mechanism are accommodated; and a controller 35. In the example shown in Fig. 1, a control unit 2 for controlling each of units constituting the apparatus 1 is provided to the first reflow furnace 3 or located close thereto. In some cases, the control unit 2 may include the controller 35. Note that, in all of the drawings, structural elements having the same function are assigned the same symbol and re-explanation will be omitted.

In a production process, a work 90 is an intermediate before completing a semiconductor device 94, and a first

intermediate 90a, a second intermediate 90b, a third intermediate 90c, a fourth intermediate 90d and a fifth intermediate 90e exist as shown in Figs. 6A-7C. The work 90 includes a circuit board 93, semiconductor chips 91 and anisotropic conductive paste 92.

A schematic sectional view of an example of the semiconductor device 94 is shown in Fig. 7C. Mounting surfaces, in which wiring patterns composed of an electric conductor, e.g., copper, are formed, are formed in an upper surface 93a of the circuit board 93, and electrodes 93e are exposed therein. In each of the semiconductor chips 91, electrodes 91e are respectively provided to one end side of a chip-shaped main body and the other end side thereof, a lower surface 91b of the semiconductor chip 91 is mounted on the upper surface 93a of the circuit board 93, and the electrodes 91e and the electrodes 93e are electrically connected to each other by solder. The semiconductor device 94 is a product, in which plurality of the semiconductor chips 91 are flip chip-mounted on the circuit board 93 and electrically connected thereto, and a large number of the semiconductor chips 91 are, as an example, matrixly mounted on the circuit board 93. The semiconductor chip 91 is a known chip-shaped semiconductor and used as, for example, LED, transistor, integrated circuit element, etc. The anisotropic conductive paste 92 includes: conductive particles 92a for electrically solder-connecting the electrodes 91e and the electrodes 93e to each other; and thermosetting resin 92b for bonding and fixing the semiconductor chips 91 and the substrate 93 to each other.

The anisotropic conductive paste 92 is in a liquid form or gel form, and the conductive particles 92a are dispersed in the uncured thermosetting resin 92b. Known thermosetting resins, e.g., epoxy, polyimide, may be employed. The conductive particles 92a are composed of solder or an electrically conductive metal constituting solder, and other known electrically conductive metals, e.g., gold, silver, copper, tin, zinc, nickel, bismuth, indium, and their alloys may be employed.

Fig. 1 schematically shows the inside of the first reflow furnace 3. In the first reflow furnace 3, an input conveyor 33, a first conveyor 31, a presser roller 34 and a second conveyor 32 are arranged, in order, from the upstream side. In the main body 30, an entrance 30a, a labyrinth 36a, a heating zone 3b, a cooling zone 3c, a labyrinth 36f and an exit 30f are arranged, in order, from the upstream side. The input conveyor 33 is extended from the upstream side of the entrance 30a to the upstream side of the labyrinth 36a, so that the work 90a (90) is carried from the upstream side of the entrance 30a to the upstream side of the labyrinth 36a. The first conveyor 31 is extended from the downstream side of the input conveyor 33 to the upstream side of the second conveyor 32, so that the work 90, which has been transferred from the input conveyor 33, is carried to the heating zone 3b via the labyrinth 36a on the entrance side. The presser roller 34 maintains a carrying speed of the work 90 when the work 90 is carried from the heating zone 3b to the cooling zone 3c. The second conveyor 32 is extended from the downstream side of the first conveyor 31 to

the downstream side of the exit 30f, so that the work 90, which has been transferred from the first conveyor 31, is carried to the next step via the cooling zone 3c, the labyrinth 36f on the exit side and the exit 30f.

Namely, in the first reflow furnace 3, the first conveyor 31 is extended from the entrance side to the heating zone 3b, and the second conveyor 32 is successively extended from the cooling zone 3c to the exit side. As an example, the first conveyor 31 may be extended from the upstream side of the entrance 30a to the heating zone 3b; and, in another example, the second conveyor 32, which carries the work via the cooling zone 3c and the labyrinth 36f on the exit side, and another carrying conveyor, which carries the work from the labyrinth 36f on the exit side to the next step via the exit 30f, may be separately provided.

The first reflow furnace 3 performs heating of the work 90 in an inert gas atmosphere, e.g., nitrogen atmosphere, in a noncontact state, with carrying the work 90. The first conveyor 31, the second conveyor 32 and the input conveyor 33 are respectively constituted by chain rails composed of a metal capable of reducing thermal strain, e.g., titanium, titanium alloy. In the heating zone 3b, a first heating zone 3b1 and a second heating zone 3b2 are arranged in order, and they are constituted by, for example, panel type hot air heaters capable of equalizing heat distribution. In the cooling zone 3c, a first cooling zone 3c1 and a second cooling zone 3c2 are arranged in order, and they are constituted by cooling mechanisms, e.g.,

blower fan. The labyrinths 36a and 36f maintain an inner temperature of the furnace and restrains leakage of the inert gas outside. Note that, known technologies disclosed in, for example, the above described Patent Literature 3 may be employed as the labyrinths, the heaters and the cooling mechanisms.

Fig. 5 is a schematic diagram of an example of a circuitry of the apparatus 1 for producing the semiconductor device. As an example, the apparatus 1 comprises: the control unit 2; the first reflow furnace 3; an applying machine 4; a mounting machine 5; a continuity test machine 6; a defective chip removing machine 7; and a second reflow furnace 8. In the example shown in Fig. 5, the control unit 2 is a computer, and control programs 27 running on the computer are installed therein. A CPU 21 is accommodated in the control unit 2. A display unit 24 and display input means 23, e.g., keyboard, mouse, are connected to the control unit 2. The display input means 23 may be a touch panel provided on a screen of the display unit 24. In the control unit 2, a data base 22 is stored in a prescribed storage area of a secondary storage unit. The data base 22 may be stored in an external storage unit, e.g., flash memory, or a tertiary storage unit. Note that, the control unit 2 may be constituted by a known computer whose structure is partially changed. For example, firmware of the control programs 27 may be written in C-language, assembler, etc. and can be updated through web browser and command lines.

In the example shown in Fig. 5, the first reflow furnace 3

comprises the main body 30 and the controller 35; the applying machine 4 comprises a main body 40 and a controller 45; the mounting machine 5 comprises a main body 50 and a controller 55; the continuity test machine 6 comprises a main body 60 and a controller 65; the defective chip removing machine 7 comprises a main body 70 and a controller 75; and the second reflow furnace 8 comprises a main body 80 and a controller 85. The controller 25 and the controller 35 are signal-connected to each other; the controller 25 and the controller 45 are signal-connected to each other; the controller 25 and the controller 55 are signal-connected to each other; the controller 25 and the controller 65 are signal-connected to each other; the controller 25 and the controller 75 are signal-connected to each other; and the controller 25 and the controller 85 are signal-connected to each other. With this structure, real time control can be performed by transferring data. A signal connection may be constituted by a known connection system, e.g., wired LAN, wireless LAN, USB connection, network connection.

The applying machine 4 applies the anisotropic conductive paste 92 to the circuit board 93 by, as an example, a dispensing system or a printing system. Further, the anisotropic conductive paste 92 is transferred to the semiconductor chips 91 by, as an example, a transfer system. The mounting machine 5 mounts the semiconductor chips 91 onto the circuit board 93 by, as an example, a pick and place system. As an example, the applying machine 4 and the mounting machine 5 may be combined. The continuity test

machine 6 determines quality of the semiconductor chips 91 by, as an example, energizing and actuating them. The defective chip removing machine 7 comprises, as an example, a noncontact heating mechanism, and a suction or adsorption mechanism, and removes a continuity-defective chip from the semiconductor chips 91 when the continuity-defective chip is detected. As an example, the continuity test machine 6 and the defective chip removing machine 7 may be combined. The second reflow furnace 8 heats the work 90, in a noncontact state, so as to thermal cure the anisotropic conductive paste 92b when no continuity-defective chip is detected from the semiconductor chips 91. As an example, the second reflow furnace 8 may be a batch furnace.

Successively, the method for producing the semiconductor device relating to the present invention will be explained below.

Figs. 8 and 9 are flowcharts for indicating production processes of the semiconductor device 94. The method of the present embodiment comprises: a mounting step S1 in which plurality of the semiconductor chips 91 are mounted onto the circuit board 93 through the anisotropic conductive paste 92 to produce the first intermediate 90a; a first heating step S2 in which the first intermediate 90a is heated to produce a second intermediate 90b; a continuity test step S3 in which the continuity test of the second intermediate 90b is performed; a defective chip removing step S4 in which a continuity-defective chip 911 is removed from the mounted

semiconductor chips 91, to produce the third intermediate 90c, when the continuity-defective chip 911 is detected; a re-mounting step S5 in which a new semiconductor chip 912 is mounted, instead of the continuity-defective chip 911, at a place from which the continuity-defective chip 911 has been removed, to produce the fourth intermediate 90d; and a second heating step S6 in which the work is heated to thermal cure the thermosetting resin 92b when no continuity-defective chip is detected in the continuity test step S3.

In the re-mounting step S5, as an example, the anisotropic conductive paste 92b is applied to the place from which the continuity defective chip 911 has been removed, and the new semiconductor chip 912 is mounted to produce the fourth intermediate 90d; and, in another example, the anisotropic conductive paste 92b is transferred to the new semiconductor chip 912, and the new semiconductor chip 912 is mounted onto the place of the circuit board 93, from which the continuity defective chip 911 has been removed, to produce the fourth intermediate 90d.

Number of times of performing the defective chip removing step S4 and the re-mounting step S5 will be varied according to type, number, arrangement, pitch, mounting density, processing conditions, etc. of the semiconductor chips 91 to be mounted. In the flowchart of the example shown in Fig. 8, the defective chip removing step S4 and the re-mounting step S5 are repeated, at least one time, until detecting no continuity-defective chip. In the flowchart of the example

shown in Fig. 9, the defective chip removing step S4 and the re-mounting step S5 are completed by performing one time. In some cases, the defective chip removing step S4 and the re-mounting step S5 are performed one time, two times, three times, or four times or more. Considering influences of the heating with respect to properties of products, producing time, production cost, etc., preferable number of times of performing the defective chip removing step S4 and the re-mounting step S5 is less than ten times, more preferably less than five times.

Figs. 2A-3C schematically show the inside of the first reflow furnace 3 for heating the work 90 being carried therethrough. Fig. 4 is a graph of a temperature profile of the work 90 in the first reflow furnace 3. The vertical axis of the graph indicates a surface temperature of the work 90, and the horizontal axis thereof indicates carrying time of the work 90. In the present embodiment, a temperature of the heating zone 3b of the first reflow furnace 3 is set at a melting temperature of solder included in conductive particles 92a of the anisotropic conductive paste 92 or higher and set at a heating temperature recommended by a material manufacturer of the anisotropic conductive paste 92 plus 50°C or lower. A temperature of the cooling zone 3c of the first reflow furnace 3 is set at a temperature lower than the melting temperature of solder included in the conductive particles 92a of the anisotropic conductive paste 92 and set at a room temperature or higher. The control unit 2 controls to carry the work 90 into the furnace, to heat the work 90, along a prescribed temperature rising curve, in the first heating zone 3b1, to

maintain the work 90 at a peak temperature, for a prescribed period of time, in the second heating zone 3b2, to cool the work 90, along a prescribed temperature reducing curve, in the first cooling zone 3c1, so as to gradually cool the work 90 in the second cooling zone 3c2 and put the work in a handleable state for the next step, and to carry the work 90 outside.

Successively, the production process shown in Fig. 8 will be explained.

As an example, the anisotropic conductive paste 92 comprises: the conductive particles 92a composed of lead-free solder or a conductive metal constituting lead-free solder; and the thermosetting resin 92b, e.g., epoxy resin.

In the mounting step S1, the anisotropic conductive paste 92 is applied to electrodes 93e of the circuit board 93 by the applying machine 4, and plurality of the semiconductor chips 91 are mounted onto the circuit board 93 in a state where lower surfaces 91b of the semiconductor chips 91 face the upper surface 93a of the circuit board 93, by the mounting machine 5, so as to produce the first intermediate 90a as shown in Fig. 6A. Alternatively, in the mounting step S1, the anisotropic conductive paste 92 is transferred to the lower surfaces 91b of the semiconductor chips 91 by the applying machine 4, and plurality of the semiconductor chips 91 are mounted onto the circuit board 93 in a state where the lower surfaces 91b of the semiconductor chips 91 face the upper surface 93a of the circuit board 93, by the mounting machine 5, so as to produce

the first intermediate 90a as shown in Fig. 6A. The control unit 2 controls the actions of the applying machine 4 and the mounting machine 5.

In the first heating step S2 following the mounting step S1, heating the first intermediate 90a is performed so as to produce the second intermediate 90b. In the first heating step S2, as shown in Figs. 2A and 2B, the control unit 2 controls the input conveyor 33 to carry the first intermediate 90a to the entrance 30a. Next, the control unit 2 performs an interconnected operation between the input conveyor 33 and the first conveyor 31 so as to transfer the first intermediate 90a from the input conveyor 33 to the first conveyor 31. Then, the control unit 2 controls the first conveyor 31 so as to pitch-feed the first intermediate 90a to the first heating zone 3b1.

Next, the control unit 2 controls the first conveyor 31 to stay the first intermediate 90a, in the first heating zone 3b1, for a prescribed period of time, and then immediately pitch-feeds the first intermediate 90a from the first heating zone 3b1 to the second heating zone 3b2. Successively, as shown in Fig. 2C, the control unit controls 2 the first conveyor 31 and the second conveyor 32 to perform an interconnected operation therebetween so as to transfer the first intermediate 90a in the heated state from the first conveyor 31 to the second conveyor 32, and controls the second conveyor 32 to carry the first intermediate 90a to the first cooling zone 3c1, at a constant speed, so as to cool the heated first intermediate 90a, and to carry the first intermediate 90a to the second cooling

zone 3c2 at a constant speed. Then, as shown in Figs. 3B and 3C, the second intermediate 90b, which has been heated and cooled, is carried outside from the exit 30f.

In the present embodiment, the first intermediate 90a is pitch-fed to the first heating zone 3b1 and stayed therein for the prescribed period of time, so that the first intermediate 90a can be heated, along the prescribed temperature rising curve, with equal heat distribution, and the temperature of the first intermediate 90a can rapidly reach the peak temperature. Further, the first intermediate 90a, which has been heated at the peak temperature, is pitch-fed to the second heating zone 3b2 and stayed therein, so that the first intermediate 90a can be continuously heated at the peak temperature with equal heat distribution, and so that the solder of the conductive particles 92a can be completely melted.

The peak temperature of the heated first intermediate 90a is set at a temperature higher than the melting temperature of the solder of the conductive particles 92a. As a target, the peak temperature is set at a melting temperature of the solder of the conductive particles 92a plus/minus within 10°C. Preferably, the peak temperature is set at a melting temperature of the solder of the conductive particles 92a plus/minus within 5°C. With this manner, heat damage applied to the semiconductor chips 91 in the first intermediate 90a can be minimized, and melting the solder of the conductive particles 90a can be rapidly performed.

A target period of time for heating the first intermediate 90a until reaching the peak temperature, in the first heating zone 3b1, is 20-40 seconds. A target period of time for continuously heating the first intermediate 90a, with maintaining the peak temperature, in the second heating zone 3b2 is 5-30 seconds. With this manner, producing defective semiconductor chips in the first intermediate 90a caused by thermal strain and scattering the anisotropic conductive paste 92b can be prevented, thermal curing the thermosetting resin 92 can be highly restrained, cohesive properties of the conductive particles 92a can be improved, and melting the solder of the conductive particles 92a can be rapidly performed.

As an example, an average rate of the temperature rising curve of the first intermediate 90a heated in the first heating zone 3b1 is 4-8°C/second. A maximum rate of the temperature rising curve is, as an example, 4-20°C/second. Considering loss of heat conduction, a temperature of hot wind in the first heating zone 3b1 is set at a temperature higher than the peak temperature of the first intermediate 90a. The temperature of hot wind in the first heating zone 3b1 is, as an example, 20-100°C higher than the peak temperature of the first intermediate 90a. A temperature of hot wind in the second heating zone 3bs is set at a temperature lower than the temperature of hot wind in the first heating zone 3b1 and is capable of maintaining the peak temperature of the first intermediate 90a.

Namely, with the above described manner, the work 90 can be rapidly heated in the first heating zone 3b1, and melting the solder of the conductive particles 92a of the work 90 can be completed, in the second heating zone 3b2, in a short time, so that curing the thermosetting resin 92b can be highly restrained.

Then, the work 90, which has been heated at the peak temperature and in which the solder of the conductive particles 92a has been completely melted, is carried to the first cooling zone 3c1 at the constant speed and cooled, by cool wind, until curing the solder of the conductive particles 92a. A target period of time for the cooling is 10-30 seconds. Successively, the work 90, in which the solder of the conductive particles 92a has been cured, is carried to the second cooling zone 3c2 at the constant speed and cooled, by cool wind, until reaching a temperature capable of performing the continuity test and being handled. A target period of time for the cooling is 10-40 seconds. A target temperature capable of performing the continuity test is 20-40°C. With this manner, the continuity test can be rapidly started with highly restraining the thermal curing of the thermosetting resin 92b of the work 90.

In the first reflow furnace 3, the presser roller 34, which contacts the upper surface 93a of the circuit board 93 when transferring the work 90 from the first conveyor 31 to the second conveyor 32, is provided to a place between the first conveyor 31 and the second conveyor 32. By providing the presser roller 34, the work 90 can be rapidly carried to the first

cooling zone 3c1 in a state where the carrying speed of the conveyor 31 is maintained. As an example, the presser roller 34 comprises two rollers, which are arranged and pivotably supported on a shaft with a prescribed interval and which contact parts of the upper surface 93a of the circuit board 93 near both side edges except the mounting surfaces, the circuit board 93 is pressed in a parallel state by own weights of the two rollers, and the work 90 can be carried to the second conveyor 32 in the state where the carrying speed of the first conveyor 31 is maintained with restraining influence of weight load.

In the present embodiment, by the interconnected operation between the first conveyor 31 and the second conveyor 32, the work 90 can be carried through the first reflow furnace 3 for the period of time shorter than the curing time of the thermosetting resin 92b of the anisotropic conductive paste 92. Further, in the first heating step S2, the work 90 is pitch-fed to the heating zone 3b, the solder of the conductive particles 92a of the anisotropic conductive paste 92 is rapidly melted, and then the work 90 is carried to the cooling zone 3c so as to cure the solder of the conductive particles 92a of the anisotropic conductive paste 92, so that the work 90 can be rapidly put in the energizable-reworkable state.

In the continuity test step S3 following the first heating step S2, the continuity test of the second intermediate 90b is performed by the continuity test machine 6. As an example, the semiconductor chips 91 are LEDs. In case of LEDs, good ones

can be turned on, but defective ones cannot be turned on in the test, so that it can be easily judged whether the chips are good or not, and places of the defective chips can be easily identified by combining light receiving means, e.g., CCD camera, optical sensor, for generating light receiving signals and storing means for storing data of the light receiving signals which are made connection with arrangement data of the semiconductor chips 91. The semiconductor chips 91 may be chip-shaped semiconductors to which the flip chip mounting technology can be applied. Therefore, the semiconductor chips 91 may be LEDs, transistors, integrated circuit elements and other known chip-shaped semiconductors.

In the continuity test step S3, as shown in Fig. 6B, if a continuity-defective chip 911 is detected from the mounted semiconductor chips 91, the defective chip removing step S4, in which the continuity-defective chip 911 is removed from the mounted semiconductor chips 91 by the defective chip removing machine 7 to produce the third intermediate 90c, is performed. As an example, air is sucked, by a vacuum suction head, in a direction F2 with irradiating a lower surface of the continuity-defective chip 911, through the circuit board 93, with a laser beam F1 emitted from a laser head 77, so as to heat the mounting place of the continuity-defective chip 911 in a noncontact state, so that the solder of the thermosetting resin 92b is re-melt, and the continuity-defective chip 911 and the thermosetting resin 92b of a bonding part are removed from the circuit board 93. In the re-mounting step S5 following the defective chip removing step S4, the anisotropic conductive

paste 92 is applied to the place of the circuit board 93, from which the continuity-defective chip 911 has been removed, by the applying machine 4, then a new semiconductor chip 912 is mounted onto said place, as shown in Fig. 7A, so as to produce the fourth intermediate 90d. Alternatively, in the re-mounting step S5, the anisotropic conductive paste 92 is transferred to the new semiconductor chip 912 by the applying machine 4, then, as shown in Fig. 7A, the new semiconductor chip 912 is mounted onto the place of the circuit board 93, from which the continuity-defective chip 911 has been removed, so as to produce the fourth intermediate 90d.

After performing the re-mounting step S5, the control unit 2 repeats the first heating step S2 and the continuity test step S3 until detecting no defective chip so as to produce the fifth intermediate 90e shown in Fig. 7B, in which all of the mounted semiconductor chips 91 and 912 are good ones.

If no defective chip is detected in the continuity test step S3, the second heating step S6, in which the thermosetting resin 92b is thermal cured by heating the fifth intermediate 90e in the second reflow furnace 8, is performed. Considering loss of heat conduction, a target of a temperature of hot wind in the second heating step S6 is 2-5°C higher than the thermal curing temperature of the thermosetting resin 92, and the second heating is performed for a prescribed period of time. A target period of time for the heating is 20-240 minutes. As an example, the heating is performed at a rated heating temperature of the anisotropic conductive paste 92 for a rated

heating time thereof. In case that a target period of time for the second heating step S6 is 60 minutes or longer, or in case that an aging step is further performed, batch production may be performed by using a batch furnace, instead of the second reflow furnace 8, so that productivity can be improved.

The production process shown in Fig. 8 has been described above. In case that production conditions, e.g., types, number, arrangement, pitch and mounting density of the semiconductor chips 91 to be mounted, processing conditions, are consolidated, the defective chip removing step S4 and the re-mounting step S5 can be completed by respectively performing one time, so that the process shown in Fig. 9 can be employed and productivity can be improved.

In the present embodiment, the work 90 can be put in the energizable-reworkable state. As an example, in case of matrix mounting a large number of LEDs having a width of 0.1 mm order used for producing an RGB display, a backlight of LCD, etc., yield of the semiconductor device necessary for a high-density mounting technology can be dramatically increased

In the above described embodiment, the continuity test of the work 90 is performed by the continuity test machine 6, but the testing means is not limited, so it can be judged whether the semiconductor chip is good or not according to types of the semiconductor chip 91, as far as the work 90 is in the energizable-reworkable state. Other materials composed of

known conductive particles 92a and known thermosetting resin 92b may be employed for the anisotropic conductive paste 92, and a material including no curing accelerator in binder may be employed. In some use applications, lead may be included in the conductive particles 92a. Note that, the present invention is not limited to the above described embodiment.

CLAIMS

[Claim 1]

A method for producing a semiconductor device, comprising:

a mounting step for transferring anisotropic conductive paste, in which conductive particles are dispersed in uncured thermosetting resin, to semiconductor chips and mounting the semiconductor chips onto a circuit board by flip chip mounting technology; and

a first heating step for heating a work, in which plurality of the semiconductor chips are mounted on the circuit board through the anisotropic conductive paste, in a first reflow furnace,

wherein the first reflow furnace comprises: a heating zone in which temperature is set at a melting temperature of solder included in the conductive particles or higher; a cooling zone in which temperature is set lower than the melting temperature of the solder included in the conductive particles; a first conveyor being extended from an entrance to the heating zone; and a second conveyor being extended from the cooling zone to an exit, the work is carried through the first reflow furnace, for a period of time shorter than a curing time of the thermosetting resin, by the first conveyor and the second conveyor, and

the first heating step comprises: heating the work, along a temperature rising curve whose average temperature rising rate is 4-8°C/second, in a first heating zone of the heating zone by pitch-feeding the work to the first heating zone

and staying therein; next, melting the solder by pitch-feeding the work to a second heating zone of the heating zone and staying therein; and then carrying the work to the cooling zone so as to cure the solder and put the work in an energizable-reworkable state.

[Claim 2]

The method for producing a semiconductor device according to claim 1,

wherein the first heating step comprises steps of: heating the work, in the first heating zone, for 20-40 seconds until reaching a peak temperature; heating the work, in the second heating zone, for 5-30 seconds so as to maintain the peak temperature; and cooling the work in the cooling zone.

[Claim 3]

The method for producing a semiconductor device according to claim 1 or 2,

wherein the semiconductor chips are LEDs,

the method further comprises: a continuity test step for performing a continuity test of the work after the first heating step; a defective chip removing step for removing a continuity-defective chip, by a defective chip removing machine, when the continuity-defective chip is detected from the LEDs in the continuity test step; and a re-mounting step for transferring the anisotropic conductive paste to a new LED which is used instead of the continuity-defective chip, and mounting the new LED onto a mounting place from which the continuity-defective chip has been removed, and

the defective chip removing step comprises steps of: sucking the mounting place of the continuity-defective chip, by a vacuum suction head, with heating the mounting place in a noncontact state, so as to re-melt the solder; and removing the continuity-defective chip and the thermosetting resin of a bonding part from the circuit board.

[Claim 4]

The method for producing a semiconductor device according to claim 3,

wherein, after the re-mounting step, the first heating step and the continuity test step are repeated until detecting no continuity-defective chip, and

in the continuity test step, data of presence/absence of the lighting LEDs, which are made connection with arrangement data of the LEDs, are stored in storing means, and the place of the continuity-defective chip is identified from the data.

[Claim 5]

The method for producing a semiconductor device according to claim 3 or 4,

further comprising a second heating step for heating the work so as to thermal cure the thermosetting resin in case of detecting no continuity-defective chip in the continuity test step.

[Claim 6]

An apparatus for producing a semiconductor device,

comprising:

an applying machine for transferring anisotropic conductive paste, in which conductive particles are dispersed in uncured thermosetting resin, to semiconductor chips;

a mounting machine for mounting the semiconductor chips onto a circuit board by flip chip mounting technology;

a first reflow furnace for heating a work, in which plurality of the semiconductor chips are mounted on the circuit board through the anisotropic conductive paste; and

a control unit,

wherein the first reflow furnace comprises: a heating zone in which temperature is set at a melting temperature of solder included in the conductive particles or higher; a cooling zone in which temperature is set lower than the melting temperature of the solder included in the conductive particles; a first conveyor being extended from an entrance to the heating zone; and a second conveyor being extended from the cooling zone to an exit, the work is carried through the first reflow furnace, for a period of time shorter than a curing time of the thermosetting resin, by the first conveyor and the second conveyor,

a presser roller, which contacts an upper surface of the circuit board when transferring the work from the first conveyor to the second conveyor, is provided to a place between the first conveyor and the second conveyor, and

the control unit performs steps of: heating the work, along a temperature rising curve whose average temperature rising rate is 4-8°C/second, in a first heating zone of the heating zone by pitch-feeding the work to the first heating zone

and staying therein; next, melting the solder by pitch-feeding the work to a second heating zone of the heating zone and staying therein; and then carrying the work to the cooling zone so as to cure the solder and put the work in an energizable-reworkable state.

[Claim 7]

The apparatus for producing a semiconductor device according to claim 6,

wherein the presser roller comprises rollers, which are pivotably supported on a shaft and arranged with a prescribed interval, and contacts the upper surface of the circuit board, except mounting surfaces, by own weights of the rollers, and

the control unit performs steps of: heating the work, in the first heating zone, for 20-40 seconds until reaching a peak temperature; heating the work, in the second heating zone, for 5-30 seconds so as to maintain the peak temperature; and cooling the work in the cooling zone.

[Claim 8]

The apparatus for producing a semiconductor device according to claim 6 or 7,

wherein the semiconductor chips are LEDs,

the apparatus further comprises: a continuity test machine for performing a continuity test of the work; and a defective chip removing machine for removing a continuity-defective chip when the continuity-defective chip is detected from the LEDs by the continuity test machine,

the defective chip removing machine performs steps of:

sucking a mounting place of the continuity-defective chip, by a vacuum suction head, with heating the mounting place in a noncontact state, so as to re-melt the solder; and removing the continuity-defective chip and the thermosetting resin of a bonding part from the circuit board, and

the control unit controls the applying machine and the mounting machine to perform steps of: transferring the anisotropic conductive paste to a new LED; and mounting the new LED onto the mounting place from which the continuity-defective chip has been removed.

[Claim 9]

The apparatus for producing a semiconductor device according to claim 8,

wherein the continuity test machine stores data of presence/absence of the lighting LEDs, which are made connection with arrangement data of the LEDs, in storing means, and identifies the place of the continuity-defective chip.

[Claim 10]

The apparatus for producing a semiconductor device according to claim 8 or 9,

further comprising a second reflow furnace or a batch furnace for heating the work so as to thermal cure the thermosetting resin when no continuity-defective chip is detected by the continuity test machine.