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Oomae et al.

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(45) **Date of Patent: Apr. 3, 2018**

(54) **SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING SAME**

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H01L 23/31 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01L 24/48*** (2013.01); ***H01L 21/4825*** (2013.01); ***H01L 21/4882*** (2013.01); ***H01L 21/565*** (2013.01); ***H01L 23/3114*** (2013.01); ***H01L 23/4952*** (2013.01); ***H01L 23/49503*** (2013.01); ***H01L 23/49551*** (2013.01); ***H01L 23/49562*** (2013.01); ***H01L 23/49572*** (2013.01); ***H01L 23/49575*** (2013.01);
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CPC H01L 23/49568; H01L 21/565; H01L 23/49551
USPC 257/695; 438/123
See application file for complete search history.

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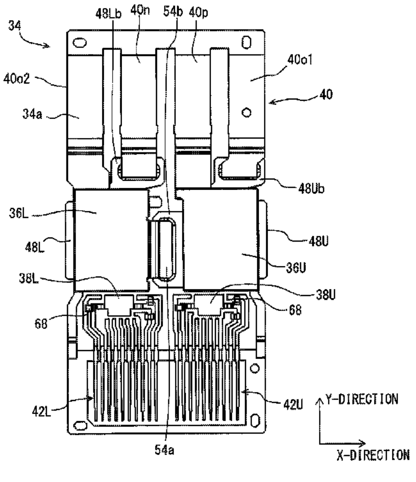
(74) *Attorney, Agent, or Firm* — Posz Law Group, PLC

(57) **ABSTRACT**

A lead frame has a first sink, an island, and a control terminal. The lead frame is bent, and at a rear surface, the island is positioned closer to one surface of a resin molded body than the first sink and a passive component mounting portion of the control terminal. A passive component is mounted on the passive component mounting portion of the control terminal through a bonding material, the passive component mounting portion being a part of one surface.

7 Claims, 9 Drawing Sheets



(51) **Int. Cl.**

H01L 23/00	(2006.01)
H01L 21/48	(2006.01)
H01L 21/56	(2006.01)
H02M 7/537	(2006.01)
H02P 27/08	(2006.01)

(52) **U.S. Cl.**

CPC ***H02M 7/537*** (2013.01); ***H02P 27/08*** (2013.01); *H01L 2224/48195* (2013.01); *H01L 2924/1203* (2013.01); *H01L 2924/1205* (2013.01); *H01L 2924/1207* (2013.01); *H01L 2924/13055* (2013.01); *H01L 2924/14253* (2013.01)

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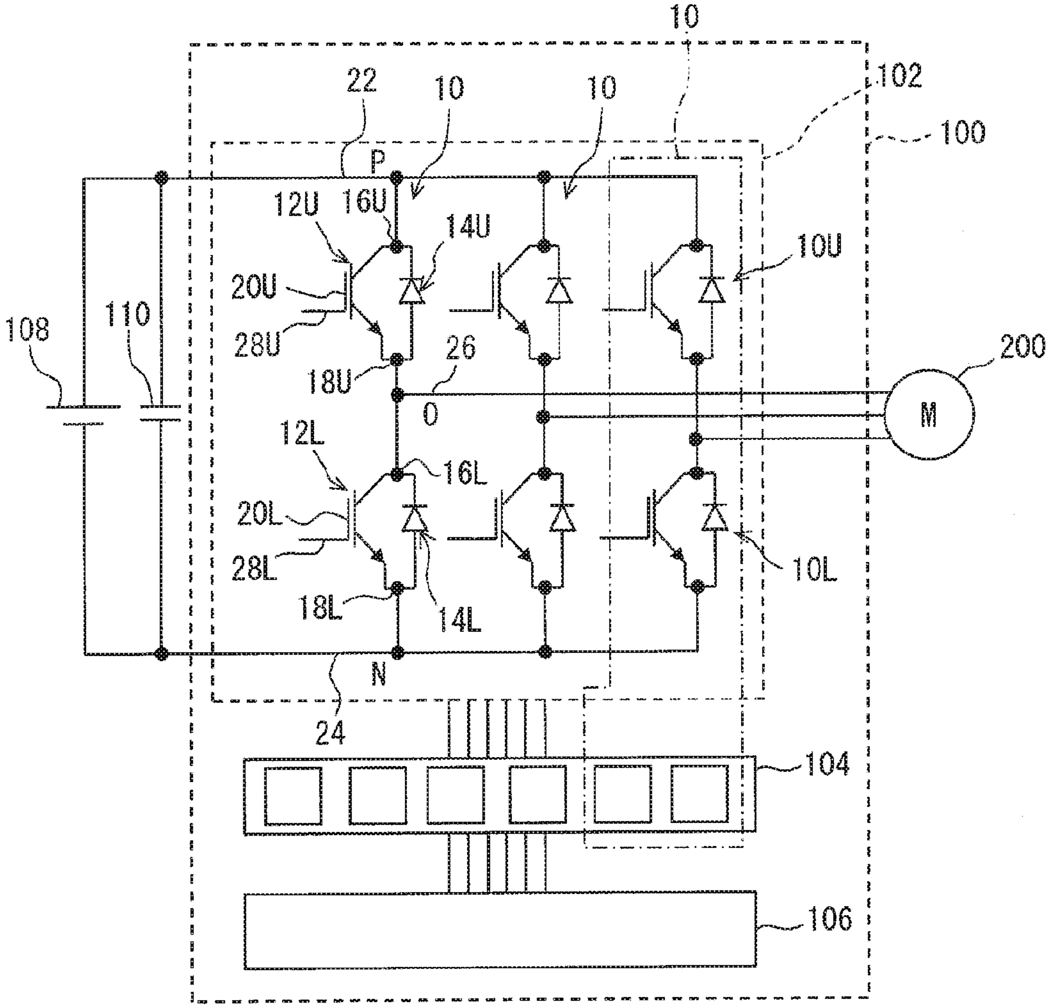
FIG. 1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18L
14L
N
24
104
106

FIG. 2

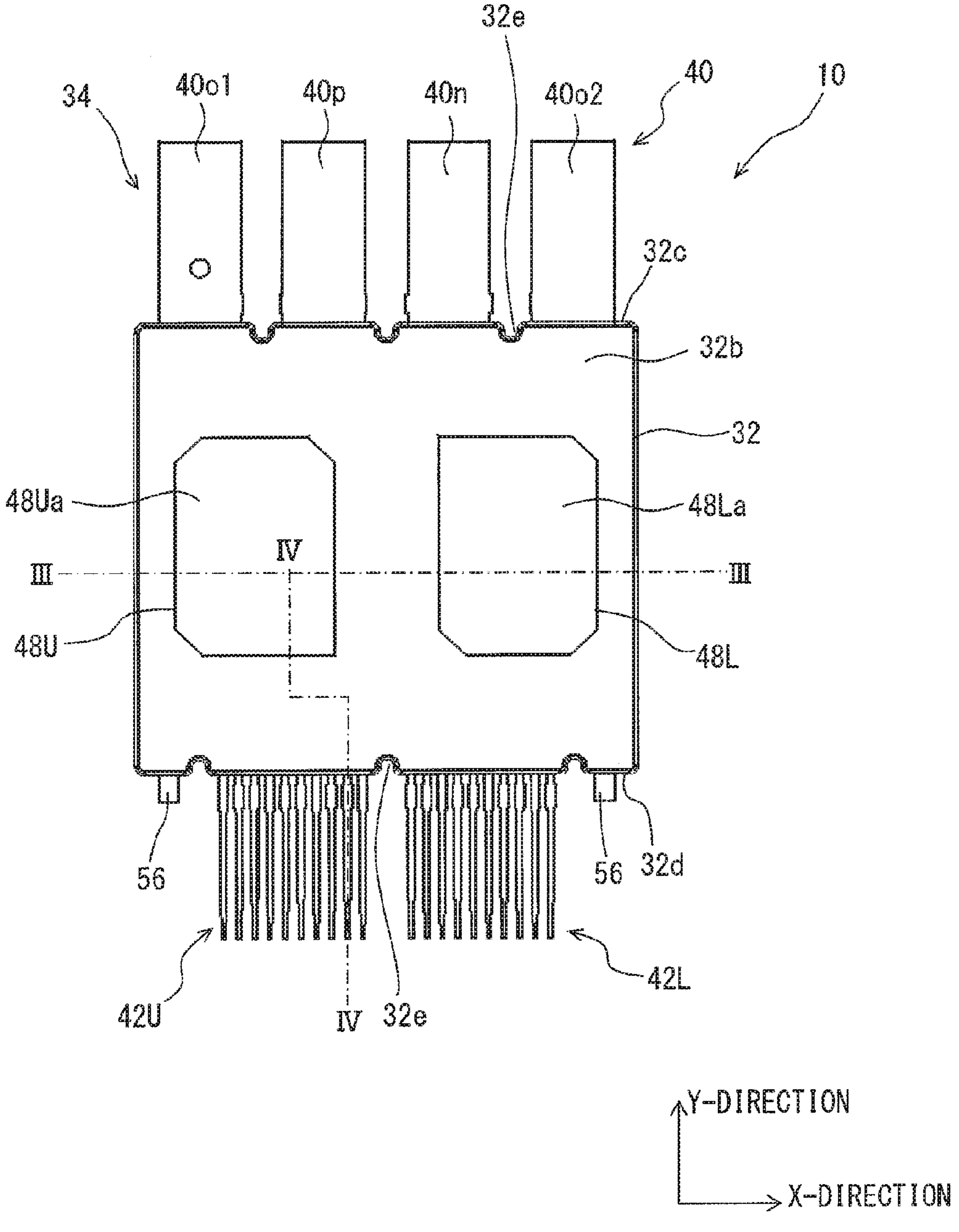
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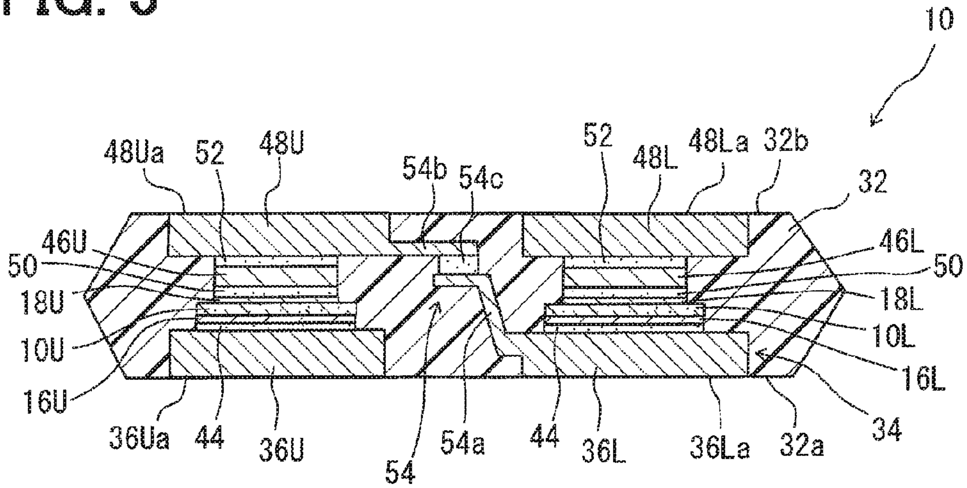
FIG. 3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36L
36La
32a
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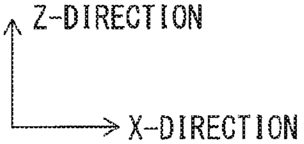
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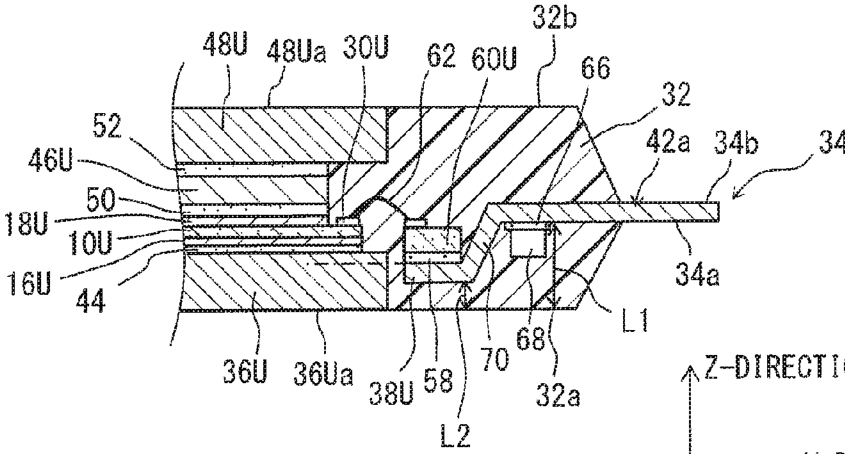
FIG. 4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58
L2
70
68
32a

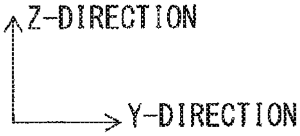
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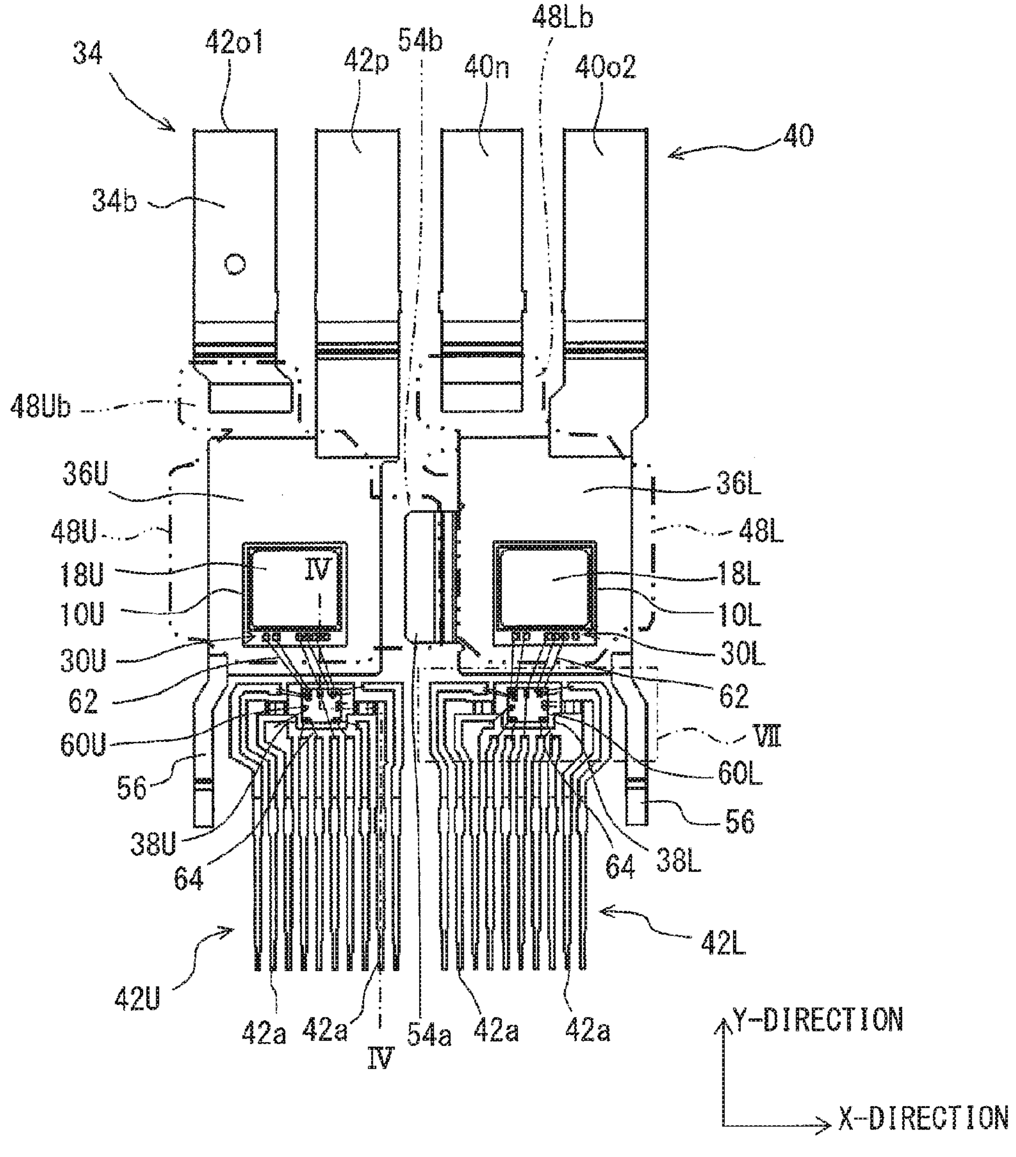
FIG. 5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18L
10U
10L
30U
30L
62
62
60U
VII
60L
56
56
38U
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IV
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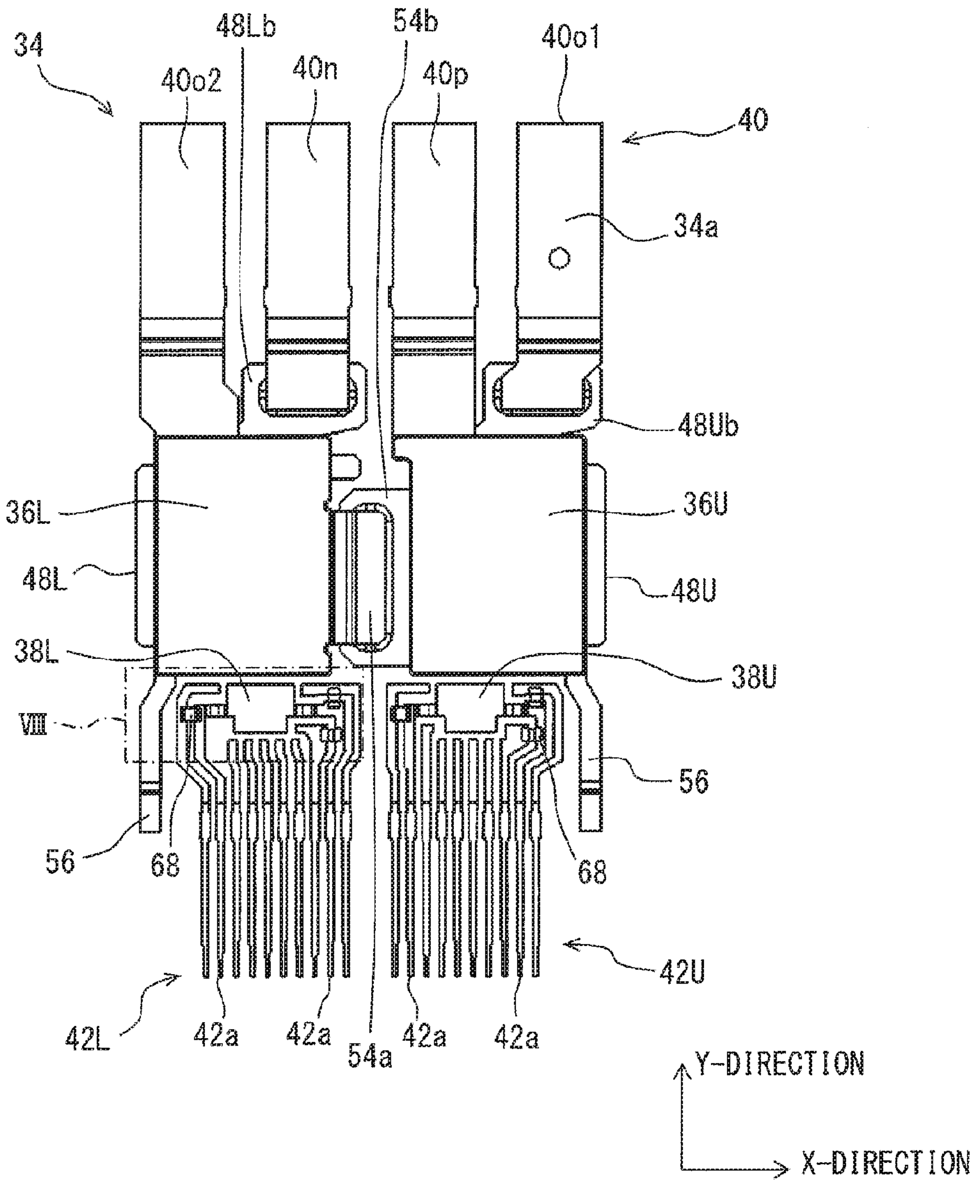
FIG. 6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X-DIRECTION

FIG. 7

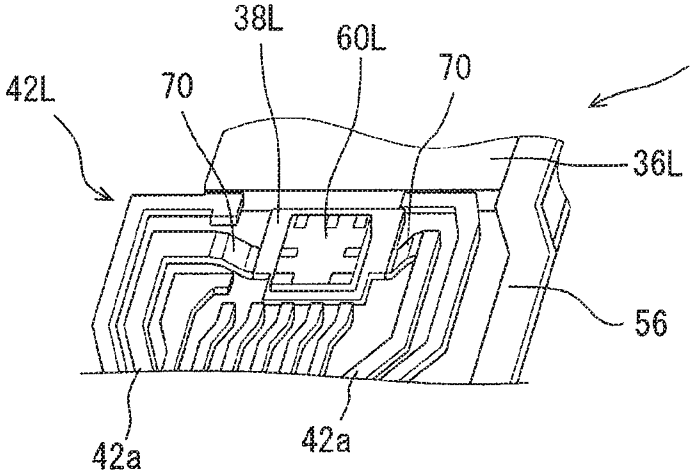


FIG. 8

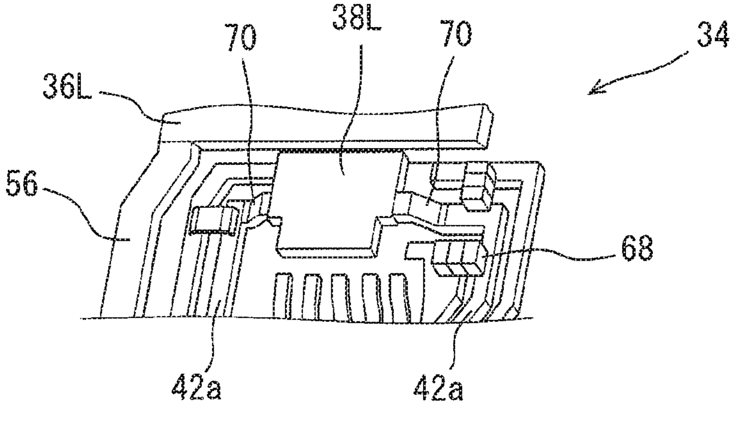
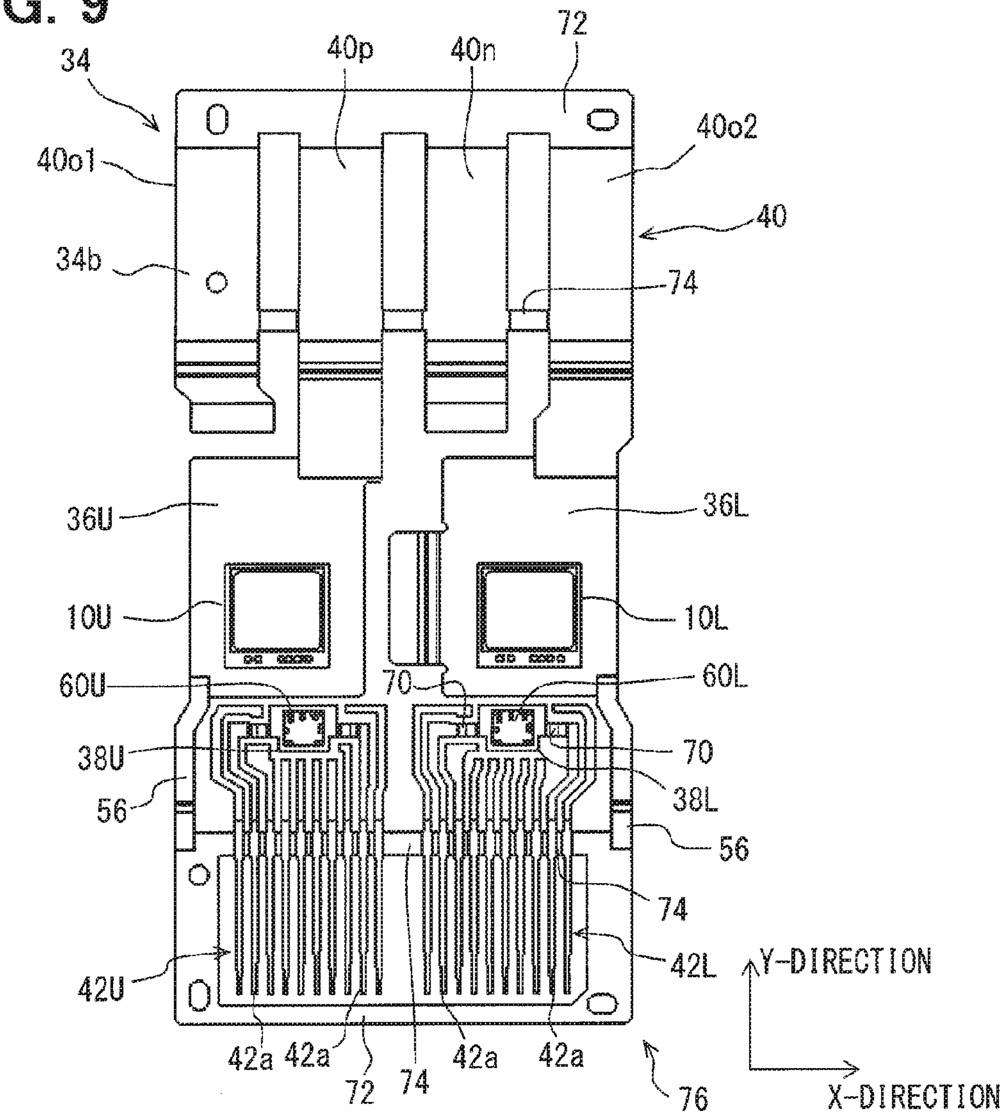


FIG. 9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38L
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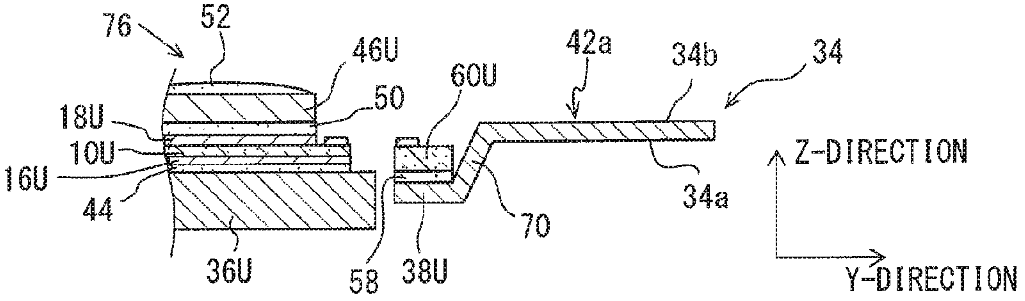
FIG. 10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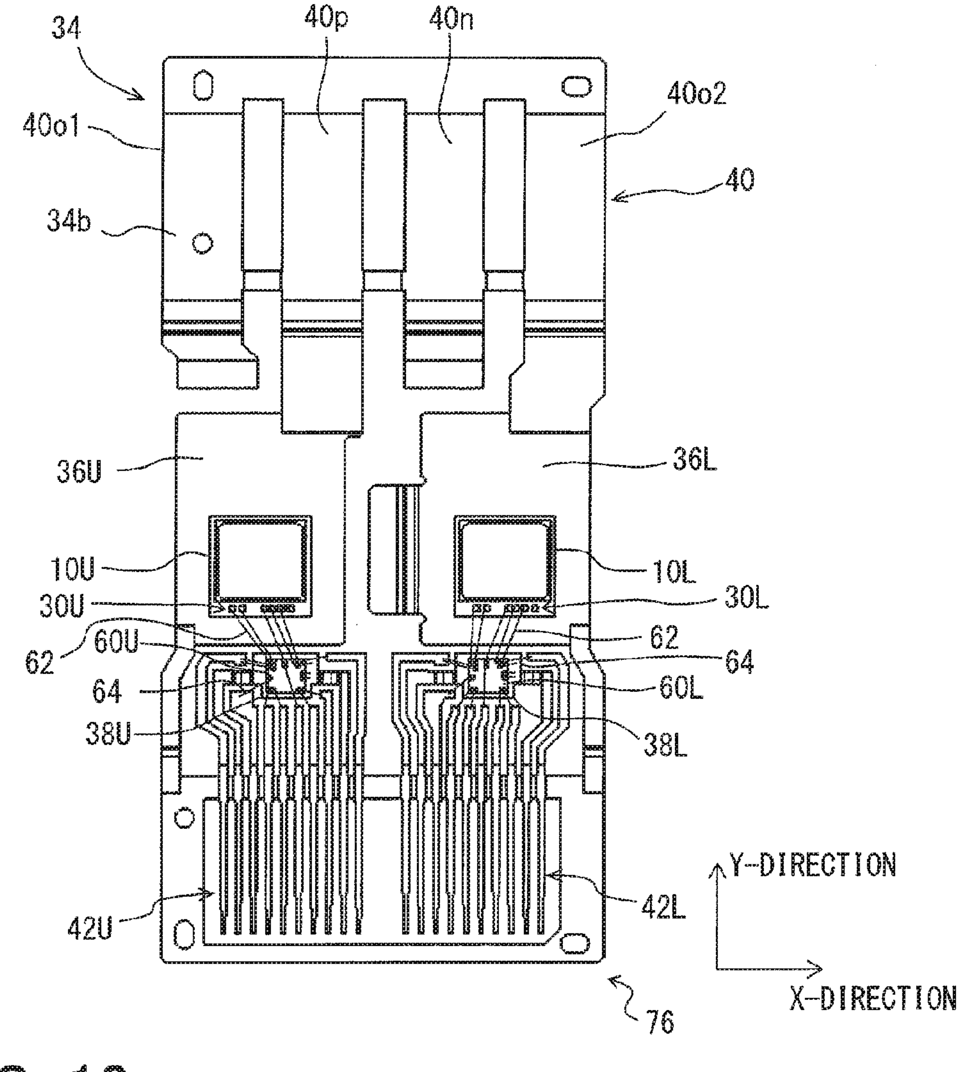
Y-DIRECTION

FIG. 11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X-DIRECTION
76

FIG. 12

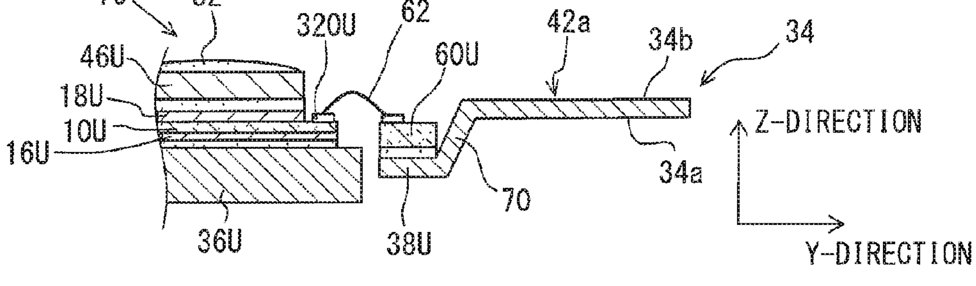
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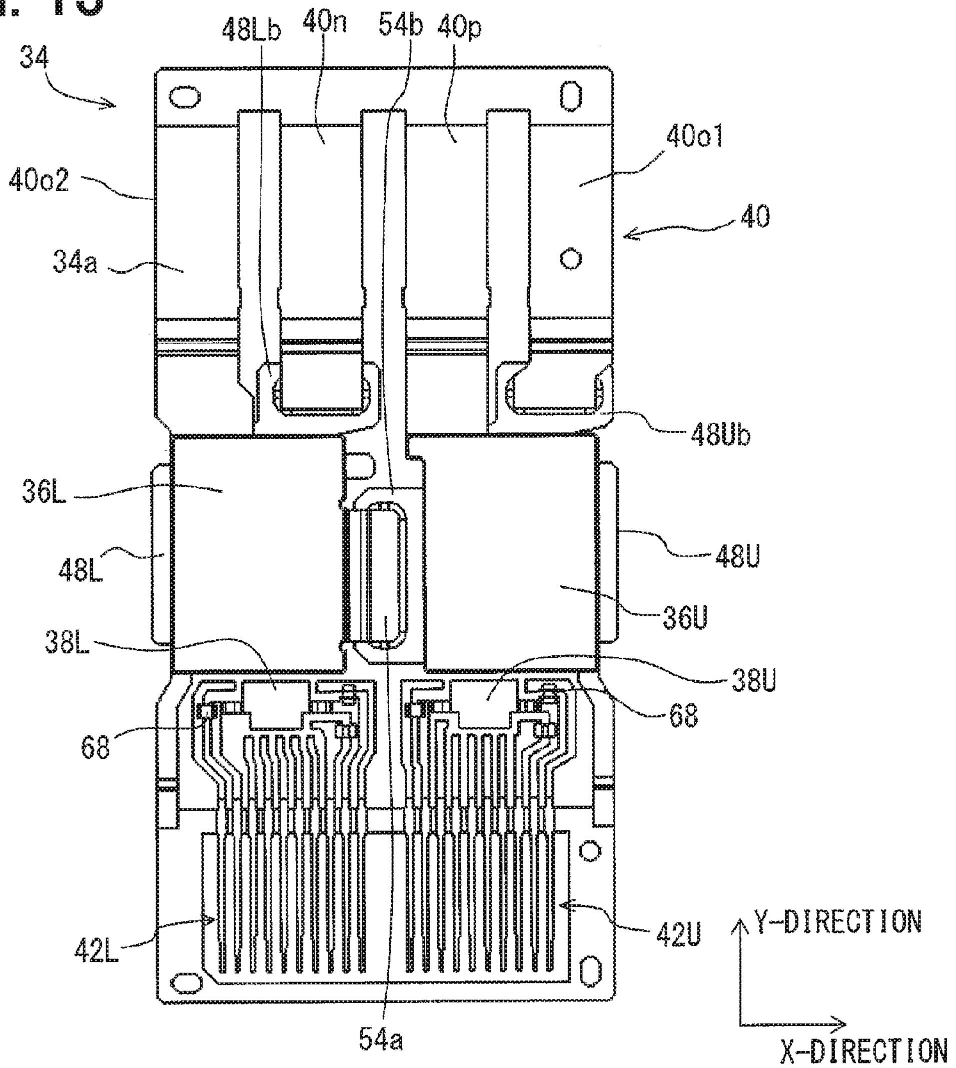
FIG. 13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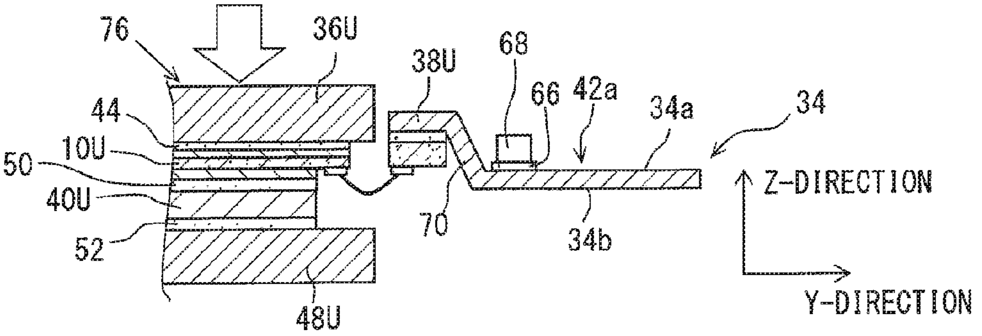
X-DIRECTION

FIG. 14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Y-DIRECTION

SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING SAME

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a U.S. national stage of International Application No. PCT/JP2015/001622 filed on Mar. 23, 2015 and is based on based on Japanese Patent Application No. 2014-64193 filed on Mar. 26, 2014, the disclosures of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a semiconductor device that includes semiconductor chips including switching elements, a resin molding for sealing the semiconductor chips, and heat sinks disposed on both surfaces of the semiconductor chips and connected to main electrodes via soldering, and also relates to a method for manufacturing this semiconductor device.

BACKGROUND ART

There has been known a semiconductor device which includes semiconductor chips including switching elements (hereinafter referred to as first semiconductor chips), a resin molding for sealing the first semiconductor chips, and heat sinks disposed both surfaces of the first semiconductor chips, and connected to main electrodes via soldering, as described in Patent Literature 1.

PRIOR ART LITERATURES

Patent Literature

Patent Literature 1: JP 2008-135613 A

SUMMARY OF INVENTION

It is an object of the present disclosure to provide a semiconductor device capable of reducing connection failure of bonding wires while avoiding increase in size, and a method for manufacturing this semiconductor device.

A semiconductor device according to an aspect of the present disclosure includes a lead frame, a first semiconductor chip, a second heat sink, a second semiconductor chip, a passive component, and a resin molding. The lead frame includes one surface and a rear surface opposite to the one surface, and further includes a first heat sink, an island, and a control terminal, the island and the control terminal being separated from the first heat sink. The first semiconductor chip includes a first main electrode disposed on facing surface of the first semiconductor chip facing the rear surface, and further includes a control electrode and a second main electrode. The second main electrode is paired with the first main electrode. The control electrode and the second main electrode are disposed on a surface of the first semiconductor chip opposite to the facing surface. The first main electrode is connected to the first heat sink. The second heat sink is disposed opposed to the surface of the first semiconductor chip on which surface the control electrode is disposed. The second heat sink is connected to the second main electrode. The second semiconductor chip is fixed to the island on the rear surface to control driving of the first semiconductor chip. The second semiconductor chip is connected to the control electrode via a first bonding wire, and connected to the control terminal via a second bonding wire. The passive component is mounted on a passive component mounting portion of the control terminals via a bonding material.

The resin molding includes a surface on the first heat sink side, and a surface on the second heat sink side in a lamination direction of the first heat sink, the second heat sink, and the first semiconductor chip. The resin molding integrally seals the first semiconductor chip, the second semiconductor chip, the passive component, at least a part of the first heat sink and the second heat sink, the first bonding wire, the second bonding wire, the island, and a part of the control terminal including the passive component mounting portion.

A part of the lead frame is bent with respect to a rest of part of the lead frame such that the island is located closer to the first heat sink side surface of the resin molding on the rear surface than the first heat sink and the passive component mounting portion of the control terminals are. The passive component is mounted on the passive component mounting portion of the control terminal on the one surface.

The semiconductor device is capable of reducing connection failure of the first bonding wire and the second bonding wire while avoiding increase in size.

A method for manufacturing a semiconductor device according to another aspect of the present disclosure is a method for manufacturing semiconductor device that includes a lead frame, a first semiconductor chip, a second heat sink, a second semiconductor chip, a passive component, and a resin molding. The lead frame includes one surface and a rear surface opposite to the one surface, and further includes a first heat sink, an island, and a control terminal, the island and the control terminal being separated from the first heat sink. The first semiconductor chip includes a first main electrode disposed on a facing surface of the first semiconductor chip facing the rear surface, and further includes a control electrode and a second main electrode. The second main electrode is paired with the first main electrode. The control electrode and the second main electrode are disposed on a surface of the first semiconductor chip opposite to the facing surface. The first main electrode is connected to the first heat sink via solder. The second heat sink is disposed opposed to the surface of the first semiconductor chip on which surface the control electrode is disposed. The second heat sink is connected to the second main electrode via solder. The second semiconductor chip is fixed to the island on the rear surface to control driving of the first semiconductor chip. The second semiconductor chip is connected to the control electrode via a first bonding wire, and connected to the control terminal via a second bonding wire. The passive component is mounted on a passive component mounting portion of the control terminal via a bonding material.

The resin molding includes a surface on the first heat sink side, and a surface on the second heat sink side in a lamination direction of the first heat sink, the second heat sink, and the first semiconductor chip. The resin molding integrally seals the first semiconductor chip, the second semiconductor chip, the passive component, at least a part of the first heat sink and the second heat sink, the first bonding wire, the second bonding wire, the island, and a part of the control terminal including the passive component mounting portion.

According to the method for manufacturing the semiconductor device, the lead frame included in the semiconductor device is bent such that the island is located closer to the first heat sink side surface of the resin molding on the rear surface than the first heat sink and the passive component mounting portion of the control terminals are. A connection body that integrates the lead frame and the first semiconductor chips is formed by reflow of the solder between the first heat sink and the first semiconductor chip. The second semiconductor chip is fixed on the island. The control electrode and the second semiconductor chip are connected via the first bonding wire after the second semiconductor chip is fixed. The second semiconductor chip and the control terminal are connected via the second bonding wire. The connection body is reversed, and positioned on the second heat sink after the second semiconductor chip is connected via the first bonding wire and the second bonding wire. Reflow of the solder between the second heat sink and the connection body is carried out. The passive component is mounted on the passive component mounting portion of the control terminal on the one surface via the bonding member. The resin molding is molded after the passive component is mounted.

The manufacturing method manufactures a semiconductor device capable of reducing connection failure of the first bonding wire and the second bonding wire while avoiding increase in size.

BRIEF DESCRIPTION OF DRAWINGS

The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

FIG. **1** is a side view illustrating a general configuration of a power converter incorporating a semiconductor device according to an embodiment of the present disclosure;

FIG. **2** is a plan view illustrating a general configuration of the semiconductor device;

FIG. **3** is a cross-sectional view of the semiconductor device taken along a line in FIG. **2**;

FIG. **4** is a cross-sectional view of the semiconductor device taken along a line IV-IV in FIG. **2**;

FIG. **5** is a plan view of the semiconductor device illustrated in FIG. **2**, not showing a resin molding, and indicating second heat sinks by alternate long and two short dashes lines;

FIG. **6** is a plan view of the semiconductor device illustrated in FIG. **2**, not showing the resin molding and bonding wires, as viewed from the lead frame side;

FIG. **7** is a perspective view illustrating an enlarged area VII indicated by an alternate long and short dash line in FIG. **5**;

FIG. **8** is a perspective view illustrating an enlarged area VIII indicated by an alternate long and short dash line in FIG. **6**;

FIG. **9** is a plan view illustrating a method for manufacturing the semiconductor device, showing a state after completion of a first reflow step;

FIG. **10** is a cross-sectional view illustrating the state after completion of the first reflow step, as a view corresponding to FIG. **4**;

FIG. **11** is a plan view illustrating the method for manufacturing the semiconductor device, showing a state after completion of a bonding step;

FIG. **12** is a cross-sectional view illustrating the state after completion of the bonding step;

FIG. **13** is a plan view illustrating the method for manufacturing the semiconductor device, showing a state after completion of a second reflow step; and

FIG. **14** is a cross-sectional view illustrating the state after completion of the second reflow step.

EMBODIMENTS FOR CARRYING OUT INVENTION

Before an embodiment of the present disclosure is described, initially touched upon herein are the circumstances under which the present inventors have arrived at the present disclosure and various modes provided according to the present disclosure. There may be considered such a semiconductor device which includes second semiconductor chips having circuits for controlling driving of switching elements, and passive components such as a chip resistor and a chip capacitor, in addition to constituent elements of the semiconductor device disclosed in Patent Literature 1, for the purpose of improvement of functions and noise resistance properties of the semiconductor device, for example.

In view of positioning easiness, for example, first heat sinks are constituted by a common lead frame, similarly to other components constituted by the common lead frame, such as islands on which the second semiconductor chips are disposed, and control terminals. The second semiconductor chips are connected to the first semiconductor chips via bonding wires. However, due to shape limitations of the bonding wires such as a connection angle, the size of the semiconductor device increases in the direction perpendicular to a lamination direction of the first semiconductor chips and the heat sinks, depending on the positions of the first semiconductor chips and the second semiconductor chips. Moreover, connection failure of the bonding wires easily occurs during connection of the bonding wires and resin molding.

Furthermore, each of the passive components has a small coating area of a bonding material, in which condition solder is difficult to wet-spread through an electrode of the passive component when the solder is constituted by a fluxless solder. For overcoming this difficulty, solder containing flux, Ag paste or like material is used as a bonding material for the passive components. However, these bonding materials generate scatterings such as flux, outgas, and fume. Accordingly, when the passive components lie on the lead frame on the same surface side as the second semiconductor chips, scattered flux or the like may contaminate the connection portions of the bonding wires, and cause connection failure of the bonding wires as a result of contamination of the bonding wires.

In consideration of the aforementioned difficulties, an object of the present disclosure is to provide a semiconductor device capable of reducing connection failure of bonding wires while avoiding increase in size, and a method for manufacturing this semiconductor device.

A semiconductor device according to an aspect of the present disclosure includes a lead frame, a first semiconductor chip, a second heat sink, a second semiconductor chip, a passive component, and a resin molding. The lead frame includes one surface and a rear surface opposite to the one surface, and further includes a first heat sink, an island, and a control terminal, the island and the control terminal being separated from the first heat sink. The first semiconductor chip includes a first main electrode disposed on facing surface of the first semiconductor chip facing the rear surface, and further includes a control electrode and a second main electrode. The second main electrode is paired with the first main electrode. The control electrode and the second main electrode are disposed on a surface of the first semiconductor chip opposite to the facing surface. The first main electrode is connected to the first heat sink. The second heat sink is disposed opposed to the surface of the first semiconductor chip on which surface the control electrode is disposed. The second heat sink is connected to the second main electrode. The second semiconductor chip is fixed to the island on the rear surface to control driving of the first semiconductor chip. The second semiconductor chip is connected to the control electrode via a first bonding wire, and connected to the control terminal via a second bonding wire. The passive component is mounted on a passive component mounting portion of the control terminals via a bonding material.

The resin molding includes a surface on the first heat sink side, and a surface on the second heat sink side in a lamination direction of the first heat sink, the second heat sink, and the first semiconductor chip. The resin molding integrally seals the first semiconductor chip, the second semiconductor chip, the passive component, at least a part of the first heat sink and the second heat sink, the first bonding wire, the second bonding wire, the island, and a part of the control terminal including the passive component mounting portion.

A part of the lead frame is bent with respect to a rest of part of the lead frame such that the island is located closer to the first heat sink side surface of the resin molding on the rear surface than the first heat sink and the passive component mounting portion of the control terminals are. The passive component is mounted on the passive component mounting portion of the control terminal on the one surface.

According to the semiconductor device, the lead frame is bent such that the island is located closer to the first heat sink side surface of the resin molding on the rear surface of the lead frame than the first heat sink and the passive component mounting portion of the control terminal are. In this case, the connection surface of the first bonding wire comes close to the first semiconductor chip and the second semiconductor chip in the lamination direction.

There are shape limitations to the bonding wire, such as a connection angle (in a range approximately from 40° to 50°, for example). When the connection surface of the first bonding wire is separated away in the lamination direction, the connection surface of the first bonding wire are required to be located away in the direction perpendicular to the lamination direction to obtain a predetermined connection angle, for example. According to the arrangement of the semiconductor device described above, however, the first semiconductor chip and the second semiconductor chip are located close to each other also in the direction perpendicular to the lamination direction. Accordingly, the size of the semiconductor device does not increase in the direction perpendicular to the lamination direction. Moreover, the connection surface of the first bonding wire is located closer in the lamination direction, and thus failure at the time of connection of the first bonding wire decreases. Furthermore, the connection length of the first bonding wire becomes short. Accordingly, connection failure caused when the bonding wire is pressed by resin pressure during resin molding decreases.

The second semiconductor chip is mounted on the rear surface of the lead frame, and the passive component is mounted on the one surface of the lead frame. Accordingly, connection failure of the bonding wire caused by scatterings such as flux decreases even when the bonding material of the passive component is made of solder containing flux, Ag paste or the like.

When a lead fame bent by pressing an entire island and a control terminal downward is used, the distance between one surface of the lead frame and the first heat sink side surface of the resin molding becomes short in the lamination direction. In this case, technical difficulties such as exposure of the passive components from the resin mold, and decrease in the resin thickness covering the passive component arise when the passive component is mounted on surface of the control terminal on one side. When the passive component is exposed, contact between the passive component and a mold is produced during molding of the resin molding. In this case, the passive component may be damaged. Moreover, moisture or the like entering from the outside may cause separation of the resin molding, or lower electric connection reliability. When the resin thickness is small, an entrainment void is easily produced.

According to the lead frame included in the semiconductor device described above, however, the passive component mounting portion of the control terminal is disposed farther from the first heat sink side surface of the resin molding than the islands are. Accordingly, the passive component is allowed to be disposed at the passive component mounting portion of the control terminal on the one surface opposite to the rear surface where the second semiconductor chip is mounted.

A method for manufacturing a semiconductor device according to another aspect of the present disclosure is a method for manufacturing semiconductor device that includes a lead frame, a first semiconductor chip, a second heat sink, a second semiconductor chip, a passive component, and a resin molding. The lead frame includes one surface and a rear surface opposite to the one surface, and further includes a first heat sink, an island, and a control terminal, the island and the control terminal being separated from the first heat sink. The first semiconductor chip includes a first main electrode disposed on a facing surface of the first semiconductor chip facing the rear surface, and further includes a control electrode and a second main electrode. The second main electrode is paired with the first main electrode. The control electrode and the second main electrode are disposed on a surface of the first semiconductor chip opposite to the facing surface. The first main electrode is connected to the first heat sink via solder. The second heat sink is disposed opposed to the surface of the first semiconductor chip on which surface the control electrode is disposed. The second heat sink is connected to the second main electrode via solder. The second semiconductor chip is fixed to the island on the rear surface to control driving of the first semiconductor chip. The second semiconductor chip is connected to the control electrode via a first bonding wire, and connected to the control terminal via a second bonding wire. The passive component is mounted on a passive component mounting portion of the control terminal via a bonding material.

The resin molding includes a surface on the first heat sink side, and a surface on the second heat sink side in a lamination direction of the first heat sink, the second heat sink, and the first semiconductor chip. The resin molding integrally seals the first semiconductor chip, the second semiconductor chip, the passive component, at least a part of the first heat sink and the second heat sink, the first bonding wire, the second bonding wire, the island, and a part of the control terminal including the passive component mounting portion.

According to the method for manufacturing the semiconductor device, the lead frame included in the semiconductor device is bent such that the island is located closer to the first heat sink side surface of the resin molding on the rear surface than the first heat sink and the passive component mounting portion of the control terminals are. A connection body that integrates the lead frame and the first semiconductor chips is formed by reflow of the solder between the first heat sink and the first semiconductor chip. The second semiconductor chip is fixed on the island. The control electrode and the second semiconductor chip are connected via the first bonding wire after the second semiconductor chip is fixed. The second semiconductor chip and the control terminal are connected via the second bonding wire. The connection body is reversed, and positioned on the second heat sink after the second semiconductor chip is connected via the first bonding wire and the second bonding wire. Reflow of the solder between the second heat sink and the connection body is carried out. The passive component is mounted on the passive component mounting portion of the control terminal on the one surface via the bonding member. The resin molding is molded after the passive component is mounted.

According to this manufacturing method, advantageous effects similar to those of the semiconductor device described above are offered. Moreover, according to this manufacturing method, the one surface of the lead frame is positioned above the rear surface after the connection body is reversed and positioned on the second heat sink. In this case, the passive component is disposed on the one surface of the passive component mounting portion of the control terminal in the reversed connection body via the bonding material. Thereafter, the passive component is mounted by heating during reflow of the solders between the second heat sink and the connection body. Accordingly, mounting of the passive component is completed without the necessity of an additional manufacturing step. Moreover, mounting of the passive component is executed after the connection of the second semiconductor chip via the first bonding wire and the second bonding wire, and thus connection failure of the bonding wire caused by scatterings such as flux is more securely avoidable.

An embodiment according to the present disclosure is hereinafter described with reference to the drawings. Identical or equivalent parts in the respective figures referred to hereinbelow have been given identical reference numbers.

In the following description, a lamination direction of a heat sink and a first semiconductor chip, in other words, a thickness direction of the first semiconductor chip is expressed as a Z-direction. An extension direction of a main terminal and a control terminal perpendicular to the Z-direction is expressed as a Y-direction. A direction perpendicular to both the Y-direction and the Z-direction is expressed as an X-direction. A planar shape in this context refers to a shape extending along a plane defined by the X-direction and the Y-direction unless specified otherwise.

An example of a power converter incorporating a semiconductor device according to this embodiment is initially described with reference to FIG. **1**.

A power converter **100** illustrated in FIG. **1** includes an inverter **102** that drives a vehicle driving motor **200**, a driver **104** that drives the inverter **102**, and a microcomputer **106** that outputs driving signals to the inverter **102** via the driver **104**. The power converter **100** thus constructed is included in an electric car or a hybrid electric car, for example.

Each of semiconductor devices **10** includes an upper arm portion **10**U and a lower arm portion **10**L connected with each other in series between a positive electrode (high potential side) and a negative electrode (low potential side) of a direct current power supply **108**. The upper arm portion **10**U is disposed on the high potential side of the direct current power supply **108**, and the lower arm portion **10**L is disposed on the low potential side of the direct current power supply **108**.

The inverter **102** includes three phases each of which contains upper and lower arms constituted by the upper arm portion **10**U and the lower arm portion **10**L. The inverter **102** is configured to convert direct current power into three-phase alternating currents, and output the converted currents to the motor **200**. A component indicated by a reference number **110** in FIG. **1** is a smoothing capacitor.

The driver **104** includes chips respectively corresponding to the arm portion **10**U and **10**L. Each of the chips includes a circuit for controlling driving of elements of the corresponding arm portion **10**U or **10**L. According to this embodiment, each of the semiconductor devices **10** includes one phase of the upper and lower arms, and the chips of the driver **104** corresponding to these upper and lower arms. Accordingly, both the inverter **102** and the driver **104** are constituted by the three semiconductor devices **10**.

The upper arm portion **10**U includes an n-channel IGBT element **12**U, and a reflex FWD element **14**U connected to the IGBT element **12**U in anti-parallel. According to this embodiment, the IGBT element **12**U and the FWD element **14**U are provided on an identical semiconductor chip. However, the IGBT element **12**U and the FWD element **14**U may be provided on different chips.

The IGBT element **12**U includes a collector electrode **16**U and an emitter electrode **18**U that are main electrodes, and a gate electrode **20**U that is a control electrode. On the other hand, the FWD element **14**U includes a cathode electrode constituted by the foregoing collector electrode **16**U, and an anode electrode constituted by the foregoing emitter electrode **18**U.

The lower arm portion **10**L has a structure similar to the structure of the upper arm portion **10**U. The lower arm portion **10**L includes an n-channel IGBT element **12**L, and a reflex FWD element **14**L connected to the IGBT element **12**L in anti-parallel. The IGBT element **12**L and the FWD element **14**L are provided on an identical semiconductor chip. However, the IGBT element **12**L and the FWD element **14**L may be provided on different chips.

The IGBT element **12**L includes a collector electrode **16**L and an emitter electrode **18**L that are main electrodes, and a gate electrode **20**L that is a control electrode. On the other hand, the FWD element **14**L includes a cathode electrode constituted by the foregoing collector electrode **16**L, and an anode electrode constituted by the foregoing emitter electrode **18**L.

In the inverter **102**, the collector electrode **16**U of the IGBT element **12**U is electrically connected to a high-potential power supply line **22** connected to the positive electrode of the direct current power supply **108**. The emitter electrode **18**L of the IGBT element **12**L is electrically connected to a low-potential power supply line **24** (also referred to as ground line) connected to the negative electrode of the direct current power supply **108**. The emitter electrode **18**U of the IGBT element **12**U and the collector electrode **16**L of the IGBT element **12**L are connected to an output line **26** for output from the inverter **102** to the motor **200**.

In FIG. **1**, “P” indicates the positive electrode of the high-potential power supply line **22**, “N” indicates the negative electrode of the low potential power supply line **24**, and “O” indicates the output of the output line **26**. Gate terminals **28**U and **28**L are connected to the gate electrodes **20**U and **20**L, respectively.

The microcomputer **106** electrically connected to the gate terminals **28**U and **28**L via the driver **104** outputs driving signals (PWM signals) to the gate terminals **28**U and **28**L to control driving of the IGBT elements **12**U and **12**L. The microcomputer **106** includes a ROM that stores programs describing various types of control processing to be executed, a CPU that executes various types of arithmetic processing, a RAM that temporarily stores arithmetic processing results and various types of data, and other components.

The microcomputer **106** receives detection signals from not-shown current sensor, rotation sensor and the like, and generates driving signals for driving the motor **200** in accordance with torque command values received from the outside, and the foregoing detection signals received from the respective sensors. The six IGBT elements **12**U and **12**L of the inverter **102** are driven in accordance with the generated driving signals. As a result, driving currents are supplied from the direct current power supply **108** to the motor **200** via the inverter **102**. With supply of the currents, the motor **200** is driven to generate desired driving torque. Alternatively, currents corresponding to power generated by the motor **200** are rectified by the inverter **102**, and supplied for discharge of the direct current power supply **108**.

A general configuration of each of the semiconductor devices **10** is hereinafter described with reference to FIGS. **2** to **6**. A line IV-IV in FIG. **5** corresponds to a line IV-IV in FIG. **2**. FIG. **5** does not show a resin molding, and indicates second heat sinks by alternate long and two short dashes lines. FIG. **6** does not show the resin molding and bonding wires.

As described above, each of the semiconductor devices **10** includes two semiconductor chips: one of the semiconductor chips constituting the upper arm portion **10**U; and the other semiconductor chip constituting the lower arm portion **10**L. In other words, each of the semiconductor devices **10** is constituted by a so-called two-in-one package including the two IGBT elements **12**U and **12**L. The arm portions **10**U and **10**L correspond to first semiconductor chips.

The upper arm portion **10**U includes the collector electrode **16**U that is a first main electrode and is disposed on one surface of the upper arm portion **10**U in the Z-direction. The upper arm portion **10**U further includes the emitter electrode **18**U that is a second main electrode paired with the first main electrode, and a control electrode **30**U that includes the gate electrode **20**U. Both the emitter electrode **18**U and the control electrode **30**U are disposed on a surface of the upper arm portion **10**U on the side opposite to the collector electrode surface side. Similarly, the lower arm portion **10**L includes the collector electrode **16**L that is a high-potential side main electrode and disposed on one surface of the lower arm portion **10**L in the Z-direction. The lower arm portion **10**L further includes the emitter electrode **18**L that is a lower potential side electrode, and a control electrode **30**L including the gate electrode **20**L. Both the emitter electrode **18**L and the control electrode **30**L are disposed on a surface of the lower arm portion **10**L on the side opposite to the collector electrode surface side. According to this embodiment, each of the control electrodes **30**U and **30**L includes electrodes (pads) for temperature sensing, current sensing, and Kelvin emitter, in addition to the gate electrode **20**U or **20**L. Each of the arm portions **10**U and **10**L has a substantially rectangular planar shape approximately equivalent to each other, and has a thickness approximately equivalent to each other in the Z-direction. The arm portions **10**U and **10**L are disposed in a line in the X-direction, and disposed substantially at the same position in the Z-direction, i.e., disposed in parallel, with the respective collector electrode surfaces located on the same side.

As illustrated in FIGS. **2** to **6**, the semiconductor device **10** includes a resin molding **32**, a lead frame **34**, terminals **46**U and **46**L, second heat sinks **48**U and **48**L, driver ICs **60**U and **60**L, and passive components **68**, in addition to the arm portions **10**U and **10**L discussed above.

The resin molding **32** is made of a resin material having electric insulation properties. According to this embodiment, the resin molding **32** is molded from epoxy resin by transfer molding. The resin molding **32** has a substantially rectangular parallelepiped shape, and includes one surface **32***a* and a rear surface **32***b* on the side opposite to the one surface **32***a* in the Z-direction. Each of the one surface **32***a* and the rear surface **32***b* is a flat surface substantially parallel with a plane defined by the X-direction and the Y-direction. The arm portions **10**U and **10**L are sealed by the resin molding **32**.

The lead frame **34** is constituted by a partially bent metal plate, and includes one surface **34***a* and a rear surface **34***b* on the side opposite to the one surface **34***a* in the Z-direction. The one surface **32***a* and the one surface **34***a* are disposed on the same side in the Z-direction, while the rear surfaces **32***b* and **34***b* are disposed on the same side in the Z-direction. The metal plate discussed above may be a single plate, or may be a plurality of pressure-bonded metal plates, for example.

The lead frame **34** is at least made of a metal material. For example, the lead frame **34** may be made of a metal material having excellent thermal conductivity and electric conductivity, such as copper, copper alloy, and aluminum alloy. The lead frame **34** includes first heat sinks **36**U and **36**L, islands **38**U and **38**L, main terminals **40**, and control terminals **42**U and **42**L.

Each of the first heat sinks **36**U and **36**L performs a function for radiating heat generated from the corresponding arm portion **10**U or **10**L, and an electric connection function. The upper arm portion **10**U provided at the portion of the first heat sink **36**U on the rear surface **34***b* of the lead frame **34** is disposed such that the collector electrode surface faces the first heat sink **36**U. The first heat sink **36**U is connected to the collector electrode **16**U via a solder **44**. Similarly, the lower arm portion **10**L provided on the first heat sink **36**L is disposed such that the collector electrode surface faces the first heat sink **36**L. The first heat sink **36**L is electrically, mechanically, and thermally connected to the collector electrode **16**L via the solder **44**.

Each of the first heat sinks **36**U and **36**L has a substantially rectangular planar shape, and has a thickness approximately equivalent to each other. Each of the first heat sinks **36**U and **36**L has a larger size along the plane defined by the X-direction and the Y-direction than the size of the corresponding arm portion **10**U or **10**L to accommodate the arm portion **10**U or **10**L.

The rear surface **34***b* and the side surface facing the upper arm portion **10**U in the portion of the first heat sink **36**U are covered by the resin molding **32**. On the other hand, the one surface **34***a* is exposed from the one surface **32***a* of the resin molding **32**. More specifically, the one surface **34***a* is substantially flush with the one surface **32***a*. The flush state in this context refers to a state that two or more surfaces are positioned in the same plane without steps produced between these surfaces. Similarly, the rear surface **34***b* and the side surface facing the lower arm portion **10**L in the portion of the first heat sink **36**L are covered by the resin molding **32**. On the other hand, the one surface **34***a* is exposed from the one surface **32***a* of the resin molding **32**.

More specifically, the one surface **34***a* is substantially flush with the one surface **32***a*. According to this structure, the portions of the first heat sinks **36**U and **36**L contained in the one surface **34***a* of the lead frame **34** constitute exposed portions **36**Ua and **36**La exposed from the one surface **32***a* of the resin molding **32**. In this case, the exposed portions **36**Ua and **36**La function as heat radiation surfaces. The solders **44** are also sealed by the resin molding **32**.

The second heat sinks **48**U and **48**L are disposed on the arm portions **10**U and **10**L via the terminals **46**U and **46**L on the side opposite to the first heat sinks **36**U and **36**L in the Z-direction.

The terminals **46**U and **46**L are provided to secure predetermined clearances between the arm portions **10**U and **10**L and the second heat sinks **48**U and **48**L for connection of bonding wires **62** to the control electrodes **30**U and **30**L. The terminals **46**U and **46**L thermally and electrically relay the arm portions **10**U and **10**L with the second heat sinks **48**U and **48**L. Accordingly, it is preferable that the terminals **46**U and **46**L are made of a metal material having at least excellent thermal conductivity and electric conductivity.

Each of the terminals **46**U and **46**L has shape and size corresponding to those of the emitter electrode **18**U or **18**L. According to this embodiment, each of the terminals **46**U and **46**L has a rectangular parallelepiped shape. The upper arm side terminal **46**U is so disposed as to face the emitter electrode **18**U of the upper arm portion **10**U, and connected to the emitter electrode **18**U via a solder **50**. Similarly, the lower arm side terminal **46**L is so disposed as to face the emitter electrode **18**L of the lower arm portion **10**L, and connected to the emitter electrode **18**L via the solder **50**. The terminals **46**U and **46**L and the solders **50** are also sealed by the resin molding **32**.

The upper arm side second heat sink **48**U is connected to the surface of the upper arm side terminal **46**U on the side opposite to the upper arm portion **10**U via a solder **52**. Similarly, the lower arm side second heat sink **48**L is connected to the surface of the lower arm side terminal **46**L on the side opposite to the lower arm portion **10**L via the solder **52**.

Similarly to the first heat sinks **36**U and **36**L, the second heat sinks **48**U and **48**L are at least made of a metal material to secure thermal conductivity and electric conductivity. For example, the second heat sinks **48**U and **48**L may be made of a metal material having excellent thermal conductivity and electric conductivity, such as copper, copper alloy, and aluminum alloy. The second heat sinks **48**U and **48**L have substantially the same thickness. The second heat sinks **48**U and **48**L have substantially the same shape and size as those of the first heat sinks **36**U and **36**L, respectively. Accordingly, the entire arm portions **10**U and **10**L are accommodated within opposed areas of the first heat sinks **36**U and **36**L and the second heat sinks **48**U and **48**L in the plane defined by the X-direction and the Y-direction.

The facing surface of the upper arm side second heat sink **48**U facing the upper arm portion **10**U (terminal **46**U), and the side surface of the upper arm side second heat sink **48**U are covered by the resin molding **32**. On the other hand, the surface of the upper arm side second heat sink **48**U on the side opposite to the facing surface is exposed from the rear surface **32***b* of the resin molding **32**. Similarly, the facing surface of the second heat sink **48**L facing the lower arm portion **10**L (terminal **46**L), and the side surface of the lower arm side second heat sink **48**L are covered by the resin molding **32**. On the other hand, the surface of the upper arm side second heat sink **48**U on the side opposite to the facing surface is exposed from the rear surface **32***b* of the resin molding **32**. According to this structure, the surfaces of the second heat sinks **48**U and **48**L on the side opposite to the arm portions **10**U and **10**L constitute exposed portions **48**Ua and **48**La exposed from the resin molding **32**. In this case, the exposed portions **48**Ua and **48**La function as heat radiation surfaces. The exposed portions **48**Ua and **48**La are substantially flush with the rear surface **32***b*.

As illustrated in FIGS. **5** and **6**, each of the second heat sinks **48**U and **48**L has a substantially rectangular planar shape. Two sides of the rectangular shape extend substantially in parallel with the X-direction, while the other two sides extend substantially in parallel with the Y-direction. A protrusion portion **48**Ub protrudes in the Y-direction from one of the sides of the upper arm side second heat sink **48**U extending substantially in parallel with the X-direction. Similarly, a protrusion portion **48**Lb protrudes in the same direction as the protrusion direction of the protrusion portion **48**Ub from the lower arm side second heat sink **48**L. The protrusion portions **48**Ub and **48**Lb are portions electrically connected with a part of the plurality of main terminals **40**. Each of the protrusion portions **48**Ub and **48**Lb has a smaller thickness than each thickness of the second heat sinks **48**U and **48**L, and is sealed by the resin molding **32**.

The lower arm side first heat sink **36**L and the upper arm side second heat sink **48**U are electrically connected to each other via a relay portion **54**. According to this embodiment, a protrusion portion **54***a* protrudes toward the upper arm side from an upper arm side end of the first heat sink **36**L in the X-direction. On the other hand, a protrusion portion **54***b* protrudes toward the lower arm side from a lower arm side end of the second heat sink **48**U in the X-direction. The protrusion portions **54***a* and **54***b* are connected to each other via a solder **54***c* to constitute the relay portion **54**. The relay portion **54** electrically connects the emitter electrode **18**U of the IGBT element **12**U and the collector electrode **16**L of the IGBT element **12**L to form the substantially N-shaped upper and lower arms as illustrated in FIG. **3**.

The relay portion **54** is sealed by the resin molding **32**. Presented in this embodiment is a configuration example of the second heat sink **48**U side protrusion portion **54***b* extending in the X-direction. On the other hand, the first heat sink **36**L side protrusion portion **54***a* extends in the X-direction, and bends at an intermediate portion to extend in the Z-direction as well.

The main terminals **40** of the lead frame **34** extend to the outside of the resin molding **32** from a side surface **32***c* of the resin molding **32** forming a substantially rectangular planar shape. According to this structure, a part of the main terminals **40** is sealed by the resin molding **32**. The respective main terminals **40** are configured to extend in the Y-direction, and disposed in a line in the X-direction. The respective main terminals **40** are further bent at intermediate positions in the longitudinal direction to extend from positions between the one surface **32***a* and the rear surface **32***b*.

The main terminals **40** include a power supply terminal **40***p*, a ground terminal **40***n*, and output terminals **40***o***1** and **40***o***2**. The power supply terminal **40***p* is a terminal for connecting the collector electrode **16**U of the upper arm portion **10**U to the high potential power supply line **22** (so-called P-terminal). As illustrated in FIGS. **5** and **6**, the power supply terminal **40***p* is connected to the upper arm side first heat sink **36**U, and extends in the Y-direction from one side of the first heat sink **36**U having a substantially rectangular planar shape.

The ground terminal **40***n* is a terminal for connecting the emitter electrode **18**L of the lower arm portion **10**L to the low potential power supply line **24** (so-called N terminal).

The ground terminal **40***n* is disposed adjacent to the power supply terminal **40***p*. The ground terminal **40***n* is electrically connected to the protrusion portion **48**Lb of the lower arm side second heat sink **48**L via a not-shown solder.

The output terminal **40***o***1** is a terminal for connecting the emitter electrode **18**U of the upper arm portion **10**U to the output line **26** (so-called O terminal). The output terminal **40***o***1** is disposed adjacent to the power supply terminal **40***p* such that the power supply terminal **40***p* is sandwiched between the output terminal **40***o***1** and the ground terminal **40***n*. The output terminal **40***o***1** is electrically connected to the protrusion portion **48**Ub of the upper arm side second heat sink **48**U via a not-shown solder.

The output terminal **40***o***2** is a terminal for connecting the collector electrode **16**L of the lower arm portion **10**L to the output line **26** (so-called O terminal). The output terminal **40***o***2** is connected to the lower arm side first heat sink **36**L, and extends in the Y-direction from one side of the first heat sink **36**L forming a substantially rectangular planar shape.

The control terminals **42**U and **42**L extend to the outside of the resin molding **32** from a side surface **32***d* of the resin molding **32** on the side opposite to the side surface **32***c*. According to this structure, a part of the main terminals **40** is sealed by the resin molding **32**. The respective control terminals **42**U and **42**L are configured to extend in the Y-direction, and disposed in a line in the X-direction. The respective main terminals **40** are further bent at intermediate positions in the longitudinal direction to extend in the Z-direction from positions between the one surface **32***a* and the rear surface **32***b*.

The upper arm side control terminal **42**U includes terminals for temperature sensing, current sensing, Kelvin emitter, power supply, test mode setting, input for generating driving signals for the gate electrode **20**U by the driver IC **60**U, and error check, in addition to the upper arm side gate terminal **28**U. A part of the plurality of the control terminals **42**U are connected to the upper arm side island **38**U. According to this embodiment, the ten control terminals **42**U are provided in total. Two of the control terminals **42**U are connected to the island **38**U. More specifically, the second and ninth control terminals **42**U in the X-direction are connected such that the island **38**U is sandwiched between both ends of the second and ninth control terminals **42**U in the X-direction.

Similarly, the lower arm side control terminal **42**L includes terminals for temperature sensing, current sensing, Kelvin emitter, power supply, test mode setting, input for generating driving signals for the gate electrode **20**L by the driver IC **60**L, and error check, in addition to the upper and lower arm side gate terminal **28**L. A part of the plurality of control terminals **42**L are connected to the lower arm side island **38**L. According to this embodiment, the ten control terminals **42**L are provided in total. Two of the control terminals **42**L are connected to the island **38**L. More specifically, the second and ninth control terminals **42**L in the X-direction are connected such that the island **38**L is sandwiched between the second and ninth control terminals **42**L in the X-direction. The control terminals **42**U and **42**L connected to the islands **38**U and **38**L are hereinafter referred to as connection terminals **42***a*.

Each of the islands **38**U and **38**L and the control terminals **42**U and **42**L has a substantially the same thickness. A component indicated by a reference number **56** in FIGS. **2**, **5**, and **6** is a suspension lead. The suspension lead **56** is a portion for connecting the first heat sinks **36**U and **36**L to an outer circumferential frame of the lead frame **34**.

Each of the side surfaces **32***c* and **32***d* of the resin molding **32** includes a plurality of recesses **32***e*. Each of the recesses **32***e* of the side surface **32***c* is provided in a portion between an adjoining pair of the main terminals **40**. The recesses **32***e* of the side surface **32***d* are provided in a portion between the control terminals **42**U and **42**L, and each of portions between the control terminals **42**U and **42**L and the suspension leads **56**. The recesses **32***e* increase a creeping distance of insulation, for example.

The driver IC **60**U is mounted on the upper arm side island **38**U via a solder **58**, for example. Similarly, the driver IC **60**L is mounted on the lower arm side island **38**L via the not-shown solder **58**. The respective driver ICs **60**U and **60**L constitute the driver **104**. Each of the driver ICs **60**U and **60**L includes a single-side electrode element such as MOSFET on a semiconductor chip to control driving of an element provided on the corresponding arm portion **10**U or **10**L. Each thickness of the driver ICs **60**U and **60**L is larger than each thickness of the arm portions **10**U and **10**L. The driver ICs **60**U and **60**L correspond to second semiconductor chips.

Electrodes (pads) are provided on the surfaces of the driver ICs **60**U and **60**L on the side opposite to the islands **38**U and **38**L. The bonding wires **62** are connected to these electrodes. The control electrodes **30**U and **30**L of the arm portions **10**U and **10**L are connected to the driver ICs **60**U and **60**L, respectively, via the bonding wires **62**. The bonding wires **62** correspond to first bonding wires. The driver ICs **60**U and **60**L are connected to the control terminals **42**U and **42**L, respectively, via bonding wires **64**. The bonding wires **64** correspond to second bonding wires.

As illustrated in FIGS. **4** and **6**, the passive components **68** such as a chip resistance and a chip capacitor are mounted on the control terminals **42**U and **42**L via bonding materials **66**. Each of the passive components **68** is so mounted as to electrically connect the plurality of control terminals **42**U or **42**L on the corresponding arm. According to this embodiment, each of the passive components **68** is a two-terminal chip component, and so mounted as to bridge the adjoining two control terminals **42**U or **42**L as illustrated in FIG. **6**. More specifically, each of the passive components **68** is so mounted as to bridge a connection terminal **42***a* and the control terminal 42U or **42**L disposed adjacent to the connection terminal **42***a*.

The passive components **68** are mounted to reduce noise transmitted from the control terminals **42**U and **42**L to the driver ICs **60**U and **60**L, for example. Accordingly, it is preferable that the passive components **68** mounted on the control terminal **42**U and **42**L are located in the vicinity of the driver ICs **60**U and **60**L.

Each of the passive components **68** has a small coating area of the bonding material **66**. When a fluxless solder is used for the bonding material **66**, the solder is difficult to wet-spread through an electrode of the passive component **68**. Accordingly, the bonding material **66** may be made of a material providing bonding when heated in a second reflow step, such as a solder containing flux and Ag paste. The bonding material **66** of this type generates not a small amount of flux, outgas, fume, or other scatterings when heated. According to this embodiment, the bonding material **66** is constituted by a solder containing flux. On the other hand, the solders **44**, **50**, **52**, and **58** of the semiconductor device **10** bonded before wire bonding are constituted by fluxless solders.

The semiconductor device **10** thus constructed is cooled by coolers each of which includes a refrigerant flow path. More specifically, coolers are disposed on both sides of the semiconductor device **10** in the Z-direction to cool the semiconductor device **10** from both the surfaces **32***a* and **32***b* sides. An insulation sheet is attached to each of the one surface **32***a* and the rear surface **32***b* of the resin molding **32** in a manner covering the exposed portions **36**Ua, **36**La, **48**Ua, and **48**La. The semiconductor device **10** is sandwiched between the coolers via the insulation sheets.

A structure of an area around the islands **38**U and **38**L is hereinafter described with reference to FIGS. **4**, **7**, and **8**.

The lead frame **34** is formed by punching a metal plate into a predetermined shape, and bending a part of the punched shape. More specifically, the islands **38**U and **38**L are depressed to reduce a step formed between the control electrode surfaces of the arm portions **10**U and **10**L and the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction as much as possible.

According to a comparison made in view of the position of the rear surface **34***b* in the Z-direction, the islands **38**U and **38**L are depressed such that the portions of the islands **38**U and **38**L are located closer to the one surface **32***a* of the resin molding **32** than the portions of the first heat sinks **36**U and **36**L and the passive component mounting portions of the control terminals **42**U and **42**L are. More specifically, the portions of the islands **38**U and **38**L on the rear surface **34***b* are depressed toward the one surface **32***a* of the resin molding **32** with respect to the portions of the first heat sinks **36**U and **36**L and the passive component mounting portions of the control terminals **42**U and **42**L.

In particular, in this embodiment, the control electrode surfaces of the arm portions **10**U and **10**L are substantially flush with the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction as a result of bending as can be seen from illustration of the upper arm side in FIG. **4** by way of example. Moreover, each of the connection terminals **42***a* includes a bent portion **70** between the connection end of the connection terminal **42***a* connecting with the islands **38**U and **38**L and the passive component mounting portion of the connection terminal **42***a* to depress the islands **38**U and **38**L toward the one surface **32***a* as illustrated in FIGS. **7** and **8**.

The passive components **68** are mounted on the control terminals **42**U and **42**L on the one surface **34***a* of the lead frame **34**. The distance between the one surface **34***a* of the lead frame **34** and the one surface **32***a* of the resin molding **32** in the Z-direction is determined such that a distance L**1** at the passive component mounting portions of the control terminals **42**U and **42**L is longer than a distance L**2** at the islands **38**U and **38**L. In this case, a sufficient clearance is securable between the passive components **68** and the one surface **32***a* of the resin molding **32** even in the structure of the passive components **68** mounted on the one surface **34***a*.

A method for manufacturing the semiconductor device **10** described above is hereinafter described with reference to FIGS. **9** to **14**. FIG. **13** does not show the bonding wires **62** and **64**.

Initially, respective elements constituting the semiconductor device **10** are prepared. More specifically, the respective arm portions **10**U and **10**L, the lead frame **34**, the terminals **46**U and **46**L, the second heat sinks **48**U and **48**L, the driver ICs **60**U and **60**L, and the passive components **68** are prepared.

In this case, the lead frame **34** to be prepared includes the first heat sinks **36**U and **36**L, the islands **38**U and **38**L, the main terminals **40**, and the control terminals **42**U and **42**L as one piece body as illustrated in FIGS. **9** and **10**. In addition, the lead frame **34** to be prepared is bent such that the portions of the islands **38**U and **38**L are located closer to the one surface **32***a* of the resin molding **32** on the rear surface **34***b* than the portions of the first heat sinks **36**U and **36**L and the passive component mounting portions of the control terminals **42**U and **42**L are. In other words, the lead frame **34** to be prepared is bent such that steps in the Z-direction between the control electrode surfaces of the arm portions **10**U and **10**L and the electrode surfaces of the driver ICs **60**U and **60**L become the smallest possible lengths. In particular, in this embodiment, the lead frame **34** to be prepared is bent such that substantially no step is produced between these portions.

The lead frame **34** having this structure is formed by a bending process in which the islands **38**U and **38**L are pressed downward from the rear surface **34***b* with respect to the first heat sinks **36**U and **36**L and the passive component mounting portions of the control terminals **42**U and **42**L. According to this embodiment, the lead frame **34** having this structure is formed by bending the portions of the connection terminals **42***a* between the connection ends connected with the islands **38**U and **38**L and the passive component mounting portions. The bent portions of the connection terminals **42***a* become the bent portions **70** discussed above. A component indicated by a reference number **72** in FIG. **9** is an outer circumferential frame of the lead frame **34**, while a component indicated by a reference number **74** in FIG. **9** is a tie-bar.

Subsequently, a first reflow step is performed. In the first reflow step, reflow is carried out for the solders **44** interposed between the respective arm portions **10**U and **10**L and the corresponding first heat sinks **36**U and **36**L, and the solders **50** interposed between the respective arm portions **10**U and **10**L and the corresponding terminals **46**U and **46**L. In addition, reflow is also carried out for the solders **58** interposed between the respective driver ICs **60**U and **60**L and the corresponding islands **38**U and **38**L. As a result, a connection body **76** constituted by the lead frame **34**, the arm portions **10**U and **10**L, the terminals **46**U and **46**L, and the respective driver ICs **60**U and **60**L as one piece body is produced as illustrated in FIG. **9**.

According to this embodiment, the solders **50** and **52** are soldered beforehand (soldering beforehand) on both the surfaces of each of the terminals **46**U and **46**L in the preparatory step discussed above. A sufficiently large amount of the solders **52** are disposed to absorb tolerance variations in the height of the semiconductor device **10**.

Subsequently, the solder **44** having a foil shape, for example, is disposed on each of the portions of the first heat sinks **36**U and **36**L on the rear surface **34***b* of the lead frame **34**. The arm portions **10**U and **10**L are disposed on the solders **44** such that the collector electrodes **16**U and **16**L face the solders **44**. The terminals **46**U and **46**L are further disposed in such a condition as to face the emitter electrodes **18**U and **18**L of the arm portions **10**U and **10**L, respectively. On the other hand, the solder **58** having a foil shape, for example, is disposed on each of the portions of the islands **38**U and **38**L on the rear surface **34***b* of the lead frame **34**. The driver ICs **60**U and **60** are disposed on the solders **58**. Reflow is carried out for the solders **44**, **50**, **52**, and **58** in this laminated state. Each of the solders **52** has an elevated shape with a top located at the center of the terminal **46**U or **46**L by surface tension before the second heat sink **48**U or **48**L as a connection target is formed.

In this case, each or the solders **44**, **50**, **52**, and **58** is constituted by a fluxless solder. Accordingly, scattering such as flux, outgas, and fume are not generated during the first reflow step. It is preferable that each of the solders **58** is constituted by a solder not fused during a second reflow step described below. According to this structure, a drop of the driver ICs **60**U and **60**L is more securely avoidable at the time of reverse of the connection body **76**. However, each of the solders **58** may be constituted by a solder fused during the second reflow step similarly to the solders **44**, **50**, and **52**. Even fused, the solders **58** retain high viscosity. In addition, the solders **58** are supported by the bonding wires **62**. Accordingly, the solders **58** of this type similarly prevent a drop of the driver ICs **60**U and **60**L.

Subsequently, a wire bonding step is performed. As illustrated in FIGS. **11** and **12**, the control electrodes **30**U and **30**L of the arm portions **10**U and **10**L are connected to the respective electrodes of the driver ICs **60**U and **60**L via the bonding wires **62**. Similarly, the electrodes of the driver ICs **60**U and **60**L are connected to the respective control terminals **42**U and **42**L via the bonding wires **64**.

According to the structure including the lead frame **34** constructed as above, the steps between the control electrode surfaces of the arm portions **10**U and **10**L and the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction decrease. In particular, in this embodiment, the control electrode surfaces of the arm portions **10**U and **10**L are substantially flush with the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction. Accordingly, connection failure of the bonding wires **62** due to the steps decreases. Moreover, in a state of substantially no step produced in the Z-direction, the arm portions **10**U and **10**L are allowed to come close to the driver ICs **60**U and **60**L in the Y-direction even when a connection angle of each of the wires **62** is set to an ideal range approximately from 40° to 50°. Accordingly, the size of the semiconductor device **10** does not increase in the Y-direction.

Furthermore, scatterings such as flux, outgas, and fume are not produced during the first reflow step. Accordingly, connection failure of the bonding wires **62** and **64** also decreases in this point.

Subsequently, the second reflow step is performed. In the second reflow step, the connection body **76** is disposed on the second heat sinks **48**U and **48**L such that the terminals **46**U and **46**L face the respective second heat sinks **48**U and **48**L via the solders **52** as illustrated in FIGS. **13** and **14**. More specifically, the connection body **76** is reversed from the state of the first reflow step (and wire bonding step), and disposed on the second heat sinks **48**U and **48**L. In this case, a solder **54***c* is disposed on the protrusion portion **54***a* constituting the relay portion **54**, and the protrusion portion **54***b* is overlapped on the solder **54***c*. In addition, the bonding material **66** such as a solder containing flux is disposed at a predetermined value of each of the control terminals **42**U and **42**L, and the passive components **68** are disposed on the bonding materials **66**.

Thereafter, reflow is carried out for the solders **44**, **50**, **52**, and **54***c*. In this case, a not-shown jig may be used to connect the connection body **76** and the second heat sinks **48**U and **48**L while maintaining predetermined distances between the first heat sinks **36**U and **36**L and the exposed portions of the second heat sinks **48**U and **48**L. According to this embodiment, reflow is also carried out for the bonding materials **66** to mount the passive components **68** on the portions of the control terminals **42**U and **42**L on the one surface **34***a* of the lead frame **34**. This reflow may be carried out with pressure applied from the first heat sinks **36**U and **36**L side.

Subsequently, a molding step is performed to mold the resin molding **32**. While not shown in the figures, a connection structure obtained in the second reflow step is disposed in a not-shown metal mold. Thereafter, resin is injected into a cavity of the metal mold to mold the resin molding **32**. According to this embodiment, the resin molding **32** is molded from epoxy resin by transfer molding.

After the molding step, a cutting step is performed as necessary. Thereafter, the outer circumferential frame **72** and the tie-bar **74** of the lead frame **34** are removed to produce the semiconductor device **10**. The unnecessary portions may be removed before the cutting step. The cutting step may include cutting the one surface **32***a* and the rear surface **32***b* of the resin molding **32** to smooth the surfaces **32***a* and **32***b*, or cutting the heat sinks **36**U, **36**L, **48**U, and **48**L as well as the resin molding **32** to smooth the one surface **32***a* and the rear surface **32***b* together with the exposed portions **36**Ua, **36**La, **48**Ua, and **48**La.

According to this embodiment, the cutting step is performed after the molding step. In this case, the heat sinks **36**U, **36**L, **48**U, and **48**L are cut simultaneously with the cutting of the resin molding **32** to smooth the one surface **32***a* and the rear surface **32***b* together with the exposed portions **36**Ua, **36**La, **48**Ua, and **48**La. Accordingly, the exposed portions **36**Ua and **36**La become substantially flush with the one surface **32***a*, while the exposed portions **48**Ua and **48**La become substantially flush with the rear surface **32***b*.

Advantageous effects of the semiconductor device **10** and the method for manufacturing the semiconductor device **10** are hereinafter described.

There are shape limitations to the bonding wires **62**. Connection failure decreases when the connection angle is set in a range approximately from 40° to 50°. When a large step is produced between the control electrode surfaces of the arm portions **10**U and **10**L and the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction, the control electrode surfaces and the electrode surfaces need to be disposed away from each other in the Y-direction for connection at a predetermined connection angle. In this case, the size of the semiconductor device **10** in the Y-direction increases.

According to this embodiment, however, the lead frame **34** is bent such that the portions of the islands **38**U and **38**L on the rear surface **34***b* of the lead frame **34** are located closer to the one surface **32***a* of the resin molding **32** than the portions of the heat sinks **36**U and **36**L are. This structure positions the connection surfaces of the bonding wires **62** close to the arm portions **10**U and **10**L and the driver ICs **60**U and **60**L in the Z-direction. In other words, the steps produced between the control electrode surfaces of the arm portions **10**U and **10**L and the electrode surfaces of the driver ICs **60**U and **60**L decrease. Accordingly, the size of the semiconductor device **10** in the Y-direction does not increase.

In addition, the control electrode surfaces of the arm portions **10**U and **10**L are located close to the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction, and thus failure at the time of connection of the bonding wires **62** also decreases. Furthermore, the control electrode surfaces of the arm portions **10**U and **10**L are located close to the electrode surfaces of the driver ICs **60**U and **60**L in both the Z-direction and the Y-direction, and thus the connection length of the bonding wires **62** decreases. Accordingly, failure caused when the bonding wires **62** are pressed by resin during the forming step decreases.

The driver ICs **60**U and **60**L are mounted on the rear surface **34***b* of the lead frame **34**, while the passive components **68** are mounted on the one surface **34***a*. Accordingly, connection failure of the bonding wires **62** and **64** caused by scatterings such as flux decreases even when the bonding materials **66** of the passive components **68** are made of solder containing flux, Ag paste or the like.

The lead frame **34** used herein is bent such that the portions of the islands **38**U and **38**L on the rear surface **34***b* of the lead frame **34** are located closer to the one surface **32***a* of the resin molding **32** than the passive component mounting portions of the control terminals **42**U and **42**L are. In this case, the distance between the one surface **34***a* of the lead frame **34** and the one surface **32***a* of the resin molding **32** in the Z-direction is determined such that the length L**1** at the passive component mounting portions of the control terminals **42**U and **42**L becomes longer than the distance L**2** at the islands **38**U and **38**L. According to this structure, a predetermined clearance is securable between the one surface **32***a* and the passive components **68**. Accordingly, exposure of the passive components **68** from the resin molding **32**, and generation of entrainment voids or the like resulting from decrease in the thickness of resin covering the passive components **68** decrease. This structure therefore allows mounting of the passive components **68** on the one surface **34***a* side of the lead frame **34**.

Particularly in case of this embodiment, the one surface **34***a* of the lead frame **34** is positioned above the rear surface **34***b* by reverse of the connection body **76** in the second reflow step. This structure allows positioning of the passive components **68** on the control terminals **42**U and **42**L of the reversed connection body **76** on the one surface **34***a* via the bonding materials **66**. Mounting of the passive components **68** is executed by heating during the second reflow step. Accordingly, mounting of the passive components **68** is achievable in the second reflow step without the necessity of an additional manufacturing step. Moreover, the passive components **68** are mounted after the wire bonding step, and thus connection failure of the bonding wires **62** and **64** caused by scatterings such as flux is more securely avoidable.

The control electrode surfaces of the arm portions **10**U and **10**L are substantially flush with the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction. In this case, substantially no step is produced between the connection surfaces of the bonding wires **62**, and thus increase in size is more effectively avoidable. Moreover, connection failure of the bonding wires **62** caused by steps between these portions more effectively decreases. Furthermore, failure caused when the bonding wires **62** are pressed by resin during the molding step more effectively decreases.

When the electrode surfaces of the driver ICs **60**U and **60**L are located closer to the second heat sinks **48**U and **48**L than the control electrode surfaces of the arm portions **10**U and **10**L are with large steps produced between these surfaces, the bonding wires **62** may contact the second heat sinks **48**U and **48**L and cause connection failure. For avoiding this difficulty, large clearances between the second heat sinks **48**U and **48**L and the arm portions **10**U and **10**L are needed. In this case, size reduction in the Z-direction becomes difficult. According to this embodiment, however, the control electrode surfaces of the arm portions **10**U and **10**L are substantially flush with the electrode surfaces of the driver ICs **60**U and **60**L in the Z-direction. Accordingly, the size in the Z-direction decreases while avoiding contact between the bonding wires **62** and the second heat sinks **48**U and **48**L.

According to this embodiment, the exposed portions **36**Ua and **36**La of the first heat sinks **36**U and **36**L are exposed from the one surface **32***a* of the resin molding **32**. Accordingly, heat generated from the arm portions **10**U and **10**L is efficiently radiated to the outside of the semiconductor device **10**, Particularly in case of this embodiment, the exposed portions **36**Ua and **36**La are substantially flush with the one surface **32***a*, while the exposed portions **48**Ua and **48**La are substantially flush with the rear surface **32***b*. Moreover, the exposed portions **36**Ua and **36**La are substantially in parallel with the exposed portions **48**Ua and **48**La. Accordingly, efficient heat radiation is achievable for the coolers disposed on both sides of the semiconductor device **10**.

According to this embodiment, only a part of the connection terminals **42***a* of the plurality of control terminals **42**U and **42**L are connected to the islands **38**U and **38**L. Each of the connection terminals **42***a* includes the bent portion **70** between the connection end of the connection terminal **42***a* connecting with the island **38**U or **38**L and the passive component mounting portion for mounting the passive component **68** to depress the island **38**U or **38**L. For example, when bent portions are formed in portions different from the control terminals **42**U and **42**L of the lead frame **34**, such as suspension leads, the control terminals **42**U and **42**L and the first heat sinks **36**U and **36**L are required to be disposed in portions other than the suspension leads. According to this embodiment, however, the foregoing structure of the semiconductor device **10** decreases the size of the semiconductor device **10**.

While a preferred embodiment of the present disclosure has been described, the present disclosure is not limited to this embodiment in any sense. Various modifications may be made without departing from the scope of the present disclosure.

According to this embodiment, the semiconductor device **10** includes the terminals **46**U and **46**L. However, the terminals **46**U and **46**L may be eliminated. For example, protrusions corresponding to the terminals may be provided on the second heat sinks **48**U and **48**L.

According to this embodiment, the main terminals **40** include the two output terminals **40***o***1** and **40***o***2**. However, the main terminals **40** may include only either the output terminal **40***o***1** or **40***o***2**, i.e., only a single output terminal.

Discussed in this embodiment has been an example of a two-in-one package which seals the two arm portions **10**U and **10**L of the six arm portions **10**U and **10**L of the three-phase inverter by using the resin molding **32**. However, a one-in-one package which seals the single arm portion **10**U or **10**L by the resin molding **32**, or a six-in-one package which seals the six arm portions **10**U and **10**L by the resin molding **32** may be adopted.

According to this embodiment, the heat sinks **36**U, **36**L, **48**U, and **48**L include the exposed portions **36**Ua, **36**La, **48**Ua, and **48**La, respectively. However, a structure in which the heat sinks **36**U, **36**L, **48**U, and **48**L are completely sealed by the resin molding **30**, i.e., a structure in which the exposed portions **36**Ua, **36**La, **48**Ua, and **48**La are covered with the resin molding **32** may be adopted.

The invention claimed is:

1. A semiconductor device comprising:

a single lead frame that includes

one surface and a rear surface opposite to the one surface, and further includes

a first heat sink, an island, and a control terminal, the island and the control terminal being separated from the first heat sink;

a first semiconductor chip that includes

a first main electrode arranged at a facing surface of the first semiconductor chip facing the rear surface, and further includes a control electrode and a second main electrode, the second main electrode paired with the first main electrode, the control electrode and the second main electrode being arranged at a surface of the first semiconductor chip opposite to the facing surface, the first main electrode being connected to the first heat sink;

a second heat sink arranged opposed to the surface of the first semiconductor chip at which the control electrode is arranged, the second heat sink being connected to the second main electrode;

a second semiconductor chip fixed to the island at the rear surface to control driving of the first semiconductor chip, the second semiconductor chip being connected to the control electrode through a first bonding wire, and connected to the control terminal through a second bonding wire;

a passive component mounted on a passive component mounting portion of the control terminal through a bonding material; and

a resin molding that includes a surface at the first heat sink side, and a surface at the second heat sink side in a lamination direction of the first heat sink, the second heat sink, and the first semiconductor chip, the resin molding integrally sealing the first semiconductor chip, the second semiconductor chip, the passive component, at least a part of the first heat sink and the second heat sink, the first bonding wire, the second bonding wire, the island, and a part of the control terminal including the passive component mounting portion, wherein:

a part of the single lead frame is bent with respect to a remaining part of the single lead frame such that a surface of the island on which the second semiconductor chip is mounted is located closer to the first heat sink side surface of the resin molding at the rear surface than a surface of the first heat sink on which the first semiconductor chip is mounted and the passive component mounting portion of the control terminal; and

the passive component is mounted on the passive component mounting portion of the control terminal at the one surface.

2. The semiconductor device according to claim **1**, wherein:

the control terminal is included in a plurality of control terminals;

a part of the plurality of control terminals are connected to the island; and

the control terminal connected to the island includes a bent portion between a connection end of the control terminal connected to the island, and the passive component mounting portion.

3. The semiconductor device according to claim **1**, wherein a connection surface of the first semiconductor chip connected to the first bonding wire and a connection surface of the second semiconductor chip connected to the first bonding wire are located in an identical plane.

4. The semiconductor device according to claim **1**, wherein a part of the first heat sink at the one surface is exposed from the resin molding.

5. A method for manufacturing a semiconductor device, the semiconductor device including:

a lead frame that includes

one surface and a rear surface opposite to the one surface, and further includes

a first heat sink, an island, and a control terminal, the island and the control terminal being separated from the first heat sink;

a first semiconductor chip that includes

a first main electrode arranged at a facing surface of the first semiconductor chip facing the rear surface, and further includes

a control electrode and a second main electrode, the second main electrode paired with the first main electrode, the control electrode and the second main electrode being arranged at a surface of the first semiconductor chip opposite to the facing surface, the first main electrode being connected to the first heat sink through solder;

a second heat sink arranged opposed to the surface of the first semiconductor chip at which the control electrode is arranged, the second heat sink being connected to the second main electrode through solder;

a second semiconductor chip fixed to the island at the rear surface to control driving of the first semiconductor chip, the second semiconductor chip connected to the control electrode through a first bonding wire, and connected to the control terminal through a second bonding wire;

a passive component mounted on a passive component mounting portion of the control terminal through a bonding material; and

a resin molding that includes a front surface at the first heat sink side, and a rear surface at the second heat sink side in a lamination direction of the first heat sink, the second heat sink, and the first semiconductor chip, the resin molding integrally sealing the first semiconductor chip, the second semiconductor chip, the passive component, at least a part of the first heat sink and the second heat sink, the first bonding wire, the second bonding wire, the island, and a part of the control terminal including the passive component mounting portion,

the method comprising:

using the lead frame, which is bent, such that a surface of the island on which the second semiconductor chip is mounted is located closer to the first heat sink side front surface of the resin molding at the rear surface than a surface of the first heat sink on which the first semiconductor chip is mounted and the passive component mounting portion of the control terminal;

forming a connection body that integrates the lead frame and the first semiconductor chip by reflow of the solder between the first heat sink and the first semiconductor chip, and fixing the second semiconductor chip at the island;

connecting the control electrode and the second semiconductor chip through the first bonding wire after fixing the second semiconductor chip, and further connecting the second semiconductor chip and the control terminal through the second bonding wire;

reversing the connection body and positioning the reversed connection body at the second heat sink after connecting the second semiconductor chip through the first bonding wire and the second bonding wire, carrying out reflow of the solder between the second heat sink and the connection body, and mounting the passive component on the passive component mounting portion of the control terminal at the one surface through the bonding material; and

molding the resin molding after mounting the passive component.

6. The method for manufacturing the semiconductor device according to claim **5**,

wherein the lead frame is bended such that connection surface of the first semiconductor chip connected to the first bonding wire and connection surface of the second semiconductor chip connected to the first bonding wire are located in an identical plane.

7. The method for manufacturing the semiconductor device according to claim **5**, further comprising:

exposing a part of the first heat sink at the one surface from the resin molding.

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