Specification

Power Module, Method for Producing Same and Air Conditioner

TECHNICAL FIELD

The present invention relates to a power module that performs power conversion and to a method of producing the same. The present invention also relates to an air conditioner in which the power module is installed.

BACKGROUND ART

Typically, a power module is primarily configured by a power semiconductor mounting substrate on which is mounted a chip such as a power semiconductor whose heat emission is relatively large, a non-power semiconductor mounting substrate on which is mounted an IC chip such as a microcomputer whose heat emission is relatively small, and a cooling unit (e.g., a heat dissipating fin, etc.) for cooling primarily the power semiconductor (e.g., see Patent Document 1).

Patent Document 1: JP-A No. 2004-111619

DISCLOSURE OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

Incidentally, ordinarily a mounting substrate made of aluminium or a ceramic whose thermal conductivity is high is employed as the power semiconductor mounting substrate because it is necessary to release the large amount of heat arising from the power semiconductor to the outside. On the other hand, a mounting substrate made of a resin such as glass fiber reinforced epoxy resin is employed as the non-power semiconductor mounting substrate because a semiconductor whose heat emission amount is large like the power semiconductor is not mounted thereon. Ordinarily, a mounting substrate made of aluminium or a ceramic is more expensive than a mounting substrate made of a resin, and this is a large factor that leads to an increase in the cost of the power module. Further, separating and mounting the power semiconductor and the non-power semiconductor on two types of mounting substrates leads to an increase in labor costs and equipment costs during production of the power module.

It is an object of the present invention to provide a power module whose production cost can be kept low.

MEANS TO SOLVE THE PROBLEM

A power module pertaining to a first invention comprises a power semiconductor, a non-power semiconductor, one resin substrate, and cooling means. The "power semiconductor" referred to here is, for example, a diode, a power transistor, and the like.

Further, the "non-power semiconductor" referred to here is, for example, a microcomputer, a ROM (read-only memory), and the like. Further, the "resin substrate" referred to here is, for example, a substrate produced by only a resin, a substrate produced by a fiber reinforced plastic, or a substrate produced from a resin in which powder or the like is dispersed and at least on one side or the inside of which a circuit pattern is formed. Incidentally, among these resin substrates, a two-sided resin substrate on both sides of which a circuit pattern is formed or a laminate resin substrate comprising plural circuits laminated alternately with insulation layers (resin layers) in a board thickness direction are particularly preferable. The power semiconductor and the non-power semiconductor configure a power supply circuit for performing power conversion. Both the power semiconductor and the non-power semiconductor are mounted on the resin substrate. The cooling means is disposed in order to cool the power semiconductor.

In a power module of the type that uses a heat dissipating fin to discharge heat arising from a power semiconductor, ordinarily the heat arising from the power semiconductor is discharged to the outside of the power module as a result of wind at air temperature or a temperature several tens of Celsius degrees higher being supplied to the heat dissipating fin. When such a heat dissipating method is employed, a substrate whose thermal conductivity is high, such as an aluminium substrate or a ceramic substrate, is needed in the power module as the substrate on which the power semiconductor is mounted in order to ensure sufficient heat dissipation.

However, when a cooling medium (which may be a gas or a liquid) whose temperature is lower than ordinary, for example, is utilized in the cooling means of the power module pertaining to the present invention, the heat arising from the power semiconductor can be sufficiently discharged from the power module even when a resin substrate whose thermal conductivity is low is utilized as the mounting substrate of the power semiconductor. Of course, it is necessary for the temperature of the cooling medium in this case to be appropriately changed depending on the amount of heat arising from the power semiconductor and the thickness of the resin substrate. Under this assumption, in this power module, it becomes possible to mount the power semiconductor and the non-power semiconductor on one resin substrate. Consequently, in this power module, it is not necessary to employ an expensive aluminium substrate or ceramic substrate as the substrate on which the power semiconductor is mounted. As a result, the raw material cost of the substrate, the labor cost, and the equipment cost can be reduced in the production of this power module. For this reason, this power module can be produced

at a low production cost.

A power module pertaining to a second invention is the power module pertaining to the first invention, wherein the cooling means is a cooling fluid passage. A cooling fluid is passed through this cooling fluid passage. The "cooling fluid" referred to here is a fluid for cooling the power semiconductor and includes air, a gas, water or a liquid (e.g., a refrigerant enclosed in a refrigerant circuit of a refrigeration device), for example. Additionally, the cooling fluid passage is disposed on the opposite side of a mounting surface of the resin substrate on which the power semiconductor and the non-power semiconductor are mounted. The "mounting surface" referred to here may have a step.

In this power module, the heat arising from the power semiconductor is discharged to the outside of the power module by the cooling fluid flowing in the cooling fluid passage. Consequently, in this power module, as long as the cooling fluid is maintained at an appropriate temperature, the heat arising from the power semiconductor can be sufficiently discharged from the power module even when a resin substrate whose thermal conductivity is low is employed as the mounting substrate of the power semiconductor. Further, when this power module is installed in an air conditioner, the refrigerant flowing through the refrigerant circuit can be utilized as the cooling fluid, which is economical.

A power module pertaining to a third invention is the power module pertaining to the second invention, wherein the cooling fluid passage is disposed inside the resin substrate.

In this power module, the cooling fluid passage is disposed inside the resin substrate. For this reason, in this power module, the distance between the cooling fluid passage and the power semiconductor can be shortened. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

A power module pertaining to a fourth invention is the power module pertaining to the second invention or the third invention and further comprises temperature detecting means and temperature controlling means. The temperature detecting means detects the temperature of the power semiconductor or the vicinity thereof. The temperature controlling means controls the temperature of the cooling fluid such that the temperature detected by the temperature detecting means becomes a predetermined temperature.

In this power module, the temperature detecting means detects the temperature of the power semiconductor or the vicinity thereof. Additionally, the temperature

controlling means controls the temperature of the cooling fluid such that the temperature detected by the temperature detecting means becomes a predetermined temperature. For this reason, in this power module, the temperature of the cooling fluid can be appropriately maintained.

A power module pertaining to a fifth invention is the power module pertaining to any of the second invention to the fourth invention, wherein the shortest distance between the power semiconductor and the cooling fluid passage is shorter than the shortest distance between the non-power semiconductor and the cooling fluid passage.

In this power module, the shortest distance between the power semiconductor and the cooling fluid passage is shorter than the shortest distance between the non-power semiconductor and the cooling fluid passage. For this reason, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module more efficiently than the heat arising from the non-power semiconductor.

A power module pertaining to a sixth invention is the power module pertaining to any of the first invention to the fifth invention, wherein the thickness of the portion of the resin substrate on which the power semiconductor is mounted is thinner than the thickness of the portion of the resin substrate on which the non-power semiconductor is mounted.

In this power module, the thickness of the portion of the resin substrate on which the power semiconductor is mounted is thinner than the thickness of the portion of the resin substrate on which the non-power semiconductor is mounted. For this reason, in this power module, the power semiconductor is closer to the cooling fluid passage in comparison to the non-power semiconductor. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module more efficiently than the heat arising from the non-power semiconductor. Further, because the non-power semiconductor is disposed on a different level than the power semiconductor, it becomes difficult for the non-power semiconductor to be affected by the heat arising from the power semiconductor.

A power module pertaining to a seventh invention is the power module pertaining to the fifth invention or the sixth invention, wherein the resin substrate is configured by plural laminate units laminated in a board thickness direction. Further, the thickness of the portion on which the power semiconductor is mounted and the thickness of the portion on which the non-power semiconductor is mounted are adjusted depending on the shapes of the laminate units.

In this power module, the resin substrate is configured by plural laminate units

laminated in a board thickness direction. Further, the thickness of the portion on which the power semiconductor is mounted and the thickness of the portion on which the non-power semiconductor is mounted are adjusted depending on the shapes of the laminate units. For this reason, in this power module, a resin substrate with a complex shape can be produced without performing complex machining.

A power module pertaining to an eighth invention is the power module pertaining to any of the first invention to the seventh invention and further comprises a heat diffusing portion. The heat diffusing portion is for diffusing heat arising from at least the power semiconductor. The "heat diffusing portion" referred to here is, for example, a heat spreader, a thermal via, a thermally conductive filler, a thermally conductive sheet and the like.

In this power module, a heat diffusing portion is further comprised. For this reason, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

A power module pertaining to a ninth invention is the power module pertaining to the eighth invention and further comprises an electrical insulation layer. The electrical insulation layer is disposed between the heat diffusing portion and the cooling fluid passage. The "electrical insulation layer" referred to here may be an electrical insulation sheet, an adhesive, or part of a resin layer of a multilayer resin substrate.

In this power module, the electrical insulation layer is disposed between the heat diffusing portion and the cooling fluid passage. For this reason, in this power module, electrical discharge can be effectively prevented.

A power module pertaining to a tenth invention is the power module pertaining to the eighth invention or the ninth invention, wherein a heat spreader is included in the heat diffusing portion. The heat spreader is disposed between the power semiconductor and the mounting surface of the resin substrate.

In this power module, the heat spreader is disposed between the power semiconductor and the mounting surface of the resin substrate. For this reason, in this power module, the heat arising from the power semiconductor can be processed efficiently.

A power module pertaining to an eleventh invention is the power module pertaining to any of the eighth invention to the tenth invention, wherein a thermal via is included in the heat diffusing portion. The thermal via is disposed inside the resin substrate along a direction intersecting the board surface of the resin substrate. Further, it is preferable for the thermal via to be disposed in a direction orthogonal to the board

surface of the resin substrate.

In this power module, the thermal via is disposed inside the resin substrate along a direction intersecting the board surface of the resin substrate. For this reason, in this power module, the thermal conductivity of the inside of the resin substrate can be raised. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

A power module pertaining to a twelfth invention is the power module pertaining to any of the eighth invention to the eleventh invention, wherein a thermally conductive filler is included in the heat diffusing portion. The thermally conductive filler is dispersed and mixed in with the resin portion of the resin substrate. The "thermally conductive filler" referred to here is ceramic powder or the like having an insulating property, for example.

In this power module, the thermally conductive filler is dispersed and mixed in with the resin portion of the resin substrate. For this reason, the thermal conductivity of the inside of the resin substrate can be raised. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

A power module pertaining to a thirteenth invention is the power module pertaining to any of the fourth invention to the eighth invention, wherein a thermally conductive sheet is included in the heat diffusing portion. The thermally conductive sheet is embedded in the resin portion of the resin substrate. The "thermally conductive sheet" referred to here is a ceramic plate or the like having an insulating property, for example.

In this power module, the thermally conductive sheet is embedded in the resin portion of the resin substrate. For this reason, in this power module, the thermal conductivity of the inside of the resin substrate can be raised. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

A power module pertaining to a fourteenth invention comprises a power semiconductor, a non-power semiconductor, one mounting substrate, and cooling means. The "power semiconductor" referred to here is, for example, a diode, a power transistor, and the like. Further, the "non-power semiconductor" referred to here is, for example, a microcomputer, a ROM (read-only memory), and the like. Further, the "mounting substrate" referred to here is, for example, a substrate produced by only a resin, a substrate produced by a fiber reinforced plastic, or a substrate produced from a resin in which

powder or the like is dispersed and at least on one side or the inside of which a circuit pattern is formed. Incidentally, among these resin substrates, a two-sided resin substrate on both sides of which a circuit pattern is formed or a laminate resin substrate comprising plural circuits laminated alternately with insulation layers (resin layers) in a board thickness direction are particularly preferable. The power semiconductor and the non-power semiconductor configure a power supply circuit for performing power conversion. Both the power semiconductor and the non-power semiconductor are mounted on the mounting substrate. The thermal conductivity of the mounting substrate in a board thickness direction is 10 W/(m·K) or less. The cooling means is disposed in order to cool the power semiconductor.

In a power module of the type that uses a heat dissipating fin to discharge heat arising from a power semiconductor, ordinarily the heat arising from the power semiconductor is discharged to the outside of the power module as a result of wind at air temperature or a temperature several tens of Celsius degrees higher being supplied to the heat dissipating fin. When such a heat dissipating method is employed, a substrate whose thermal conductivity is high, such as an aluminium substrate or a ceramic substrate, is needed in the power module as the substrate on which the power semiconductor is mounted in order to ensure sufficient heat dissipation.

However, when a cooling medium (which may be a gas or a liquid) whose temperature is lower than ordinary, for example, is utilized in the cooling means of the power module pertaining to the present invention, the heat arising from the power semiconductor can be sufficiently discharged from the power module even when a mounting substrate whose thermal conductivity is low and 10 W/(m·K) or less is utilized as the mounting substrate of the power semiconductor. Of course, it is necessary for the temperature of the cooling medium in this case to be appropriately changed depending on the amount of heat arising from the power semiconductor and the thickness of the mounting substrate. Under this assumption, in this power module, it becomes possible to mount the power semiconductor and the non-power semiconductor on one mounting substrate whose thermal conductivity is low. Ordinarily, a mounting substrate whose thermal conductivity is low and 10 W/(m·K) or less is produced from a resin, a fiber reinforced plastic or the like, and inexpensive ones plentifully exist in comparison to aluminium substrates and ceramic substrates. Consequently, the raw material cost of the substrate, the labor cost, and the equipment cost can be reduced in the production of this power module. For this reason, this power module can be produced at a low production

cost.

An air conditioner pertaining to a fifteenth invention comprises a refrigerant circuit and a power module. The power module includes a power semiconductor, a non-power semiconductor, one resin substrate, and a refrigerant passage. The power semiconductor and the non-power semiconductor configure a power supply circuit for performing power conversion. Both the power semiconductor and the non-power semiconductor are mounted on the resin substrate. The refrigerant passage is a passage for allowing refrigerant flowing in the refrigerant circuit to pass therethrough and is disposed on the opposite side of a mounting surface of the resin substrate on which the power semiconductor and the non-power semiconductor are mounted.

Ordinarily, a power module of the type that uses a heat dissipating fin to discharge heat arising from a power semiconductor is employed in an air conditioner, and in this power module, typically the heat arising from the power semiconductor is discharged to the outside of the power module as a result of wind at air temperature or a temperature several tens of Celsius degrees higher being supplied to the heat dissipating fin. When such a heat dissipating method is employed, a substrate whose thermal conductivity is high, such as an aluminium substrate or a ceramic substrate, is needed in the power module as the substrate on which the power semiconductor is mounted in order to ensure sufficient heat dissipation.

However, in the refrigerant circuit of an air conditioner, there are places where the refrigerant temperature is sufficiently low, and as long as the refrigerant can be allowed to flow through the refrigerant passage of the power module, the heat arising from the power semiconductor can be sufficiently discharged from the power module even when a resin substrate whose thermal conductivity is low is utilized as the mounting substrate of the power semiconductor. Of course, the temperature of the cooling medium in this case is dependent on the amount of heat arising from the power semiconductor and the thickness of the resin substrate. Under this assumption, in the power module of this air conditioner, it becomes possible to mount the power semiconductor and the non-power semiconductor on one resin substrate. Consequently, in the power module of this air conditioner, it is not necessary to employ an expensive aluminium substrate or ceramic substrate as the substrate on which the power semiconductor is mounted. As a result, the raw material cost of the substrate, the labor cost, and the equipment cost can be reduced in the production of this power module. For this reason, this power module can be produced at a low production cost. Therefore, the production cost of the air conditioner can also be

reduced.

A method of producing a power module pertaining to a sixteenth invention is a method of producing a power module including a power semiconductor and a non-power semiconductor that configure a power supply circuit for performing power conversion, one resin substrate on which both the power semiconductor and the non-power semiconductor are mounted, and cooling means for cooling the power semiconductor, the method comprising: a power semiconductor fixing step; a wire connecting step, a non-power semiconductor connecting step; and a cooling means fixing step. In the power semiconductor fixing step, the power semiconductor is fixed to a prescribed position on the resin substrate. In the wire connecting step, the power semiconductor and a circuit disposed on the resin substrate are wire-connected. In the non-power semiconductor connecting step, the non-power semiconductor and the circuit are connected. In this non-power semiconductor connecting step, it is preferable for a reflow method to be employed. In the cooling means fixing step, the resin substrate is fixed to the cooling means. It will be noted that the power semiconductor fixing step, the wire connecting step, the non-power semiconductor connecting step, and the cooling means fixing step may be appropriately switched around.

In this power module producing method, the power semiconductor is fixed to a prescribed position on the resin substrate in the power semiconductor fixing step. Further, in the wire connecting step, the power semiconductor and the circuit disposed on the resin substrate are wire-connected. Further, in the non-power semiconductor connecting step, the non-power semiconductor and the circuit are connected. Further, in the cooling means fixing step, the resin substrate is fixed to the cooling means. For this reason, in this power module producing method, the power semiconductor and the non-power semiconductor are mounted on one resin substrate. Consequently, by utilizing this power module producing method, the raw material cost of the substrate, the labor cost, and the equipment cost can be reduced.

EFFECT OF THE INVENTION

The power module pertaining to the first invention can be produced at a low production cost.

In the power module pertaining to the second invention, as long as the cooling fluid can be maintained at an appropriate temperature, the heat arising from the power semiconductor can be sufficiently discharged from the power module even when a resin substrate whose thermal conductivity is low is employed as the mounting substrate of the

power semiconductor.

In the power module pertaining to the third invention, the distance between the cooling fluid passage and the power semiconductor can be shortened. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

In the power module pertaining to the fourth invention, the temperature of the cooling fluid can be appropriately maintained.

In the power module pertaining to the fifth invention, the heat arising from the power semiconductor can be discharged to the outside of the power module more efficiently than the heat arising from the non-power semiconductor.

In the power module pertaining to the sixth invention, the heat arising from the power semiconductor can be discharged to the outside of the power module more efficiently than the heat arising from the non-power semiconductor. Further, because the non-power semiconductor is disposed on a different level than the power semiconductor, it becomes difficult for the non-power semiconductor to be affected by the heat from the power semiconductor.

In the power module pertaining to the seventh invention, a resin substrate with a complex shape can be produced without performing complex machining.

In the power module pertaining to the eighth invention, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

In the power module pertaining to the ninth invention, electrical discharge can be effectively prevented.

In the power module pertaining to the tenth invention, the heat arising from the power semiconductor can be processed efficiently.

In the power module pertaining to the eleventh invention, the thermal conductivity of the inside of the resin substrate can be raised. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

In the power module pertaining to the twelfth invention, the thermal conductivity of the inside of the resin substrate can be raised. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

In the power module pertaining to the thirteenth invention, the thermal

conductivity of the inside of the resin substrate can be raised. Consequently, in this power module, the heat arising from the power semiconductor can be discharged to the outside of the power module even more efficiently.

The power module pertaining to the fourteenth invention can be produced at a low production cost.

The air conditioner pertaining to the fifteenth invention can be produced at a low production cost.

In the power module producing method pertaining to the sixteenth invention, the power semiconductor and the non-power semiconductor are mounted on one resin substrate. Consequently, by utilizing this power module producing method, the raw material cost of the substrate, the labor cost, and the equipment cost can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an external perspective view of an air conditioner pertaining to the present embodiment.

FIG. 2 is a diagram of a refrigerant circuit of the air conditioner pertaining to the present embodiment.

FIG. 3(a) is a longitudinal sectional view of a power module installed in the air conditioner pertaining to the present embodiment, and (b) is a top transparent view of a cooling jacket of the power module pertaining to the present embodiment.

FIG. 4 is a chart showing the relationship between thicknesses and thermal discharge characteristics of mounting substrates pertaining to the present embodiment.

FIG. 5 is a flow chart showing the steps of producing the power module pertaining to the present embodiment.

FIG. 6 is a partial longitudinal sectional view of a power module installed in an air conditioner pertaining to a modification (A).

FIG. 7 is a partial longitudinal sectional view of a power module installed in an air conditioner pertaining to a modification (B).

FIG. 8 is a partial longitudinal sectional view of a power module installed in an air conditioner pertaining to a modification (F).

FIG. 9 is a partial longitudinal sectional view of a power module installed in an air conditioner pertaining to a modification (F).

FIG. 10 is a partial longitudinal sectional view of a power module installed in an air conditioner pertaining to a modification (F).

FIG. 11 is a partial longitudinal sectional view of a power module installed in an air

conditioner pertaining to a modification (G).

DESCRIPTION OF THE REFERENCE SYMBOLS

1 Air Conditioner

5, 5A, 5B, 5C, 5D, 5E, 5F Power Module

51, 51A, 51B, 51C, 51D, 51E, 51F Mounting Substrate (Resin Substrate)

53a First Electronic Component (Power Semiconductor)

53b Second Electronic Component (Non-power Semiconductor)

54, 54C Heat Spreader (Heat Diffusing Portion)

54B Thermal Via (Heat Diffusing Portion)

54D Thermally Conductive Filler (Heat Diffusing Portion)

54E Thermally Conductive Sheet (Heat Diffusing Portion)

57C, 57D, 57E, 57F Electrical Insulation Layer

59, 59A, 59F Refrigerant Passage (Cooling Means)

DETAILED DESCRIPTION OF THE INVENTION

<Overall Configuration of Air Conditioner>

In FIG. 1, there is shown an external perspective view of an air conditioner 1 pertaining to the present embodiment.

The air conditioner 1 comprises a wall-mounted type indoor unit 2 that is attached to a wall surface inside a room and an outdoor unit 3 that is installed outdoors.

An indoor heat exchanger is housed inside the indoor unit 2, an outdoor heat exchanger is housed inside the outdoor unit 3, and the heat exchangers are interconnected by a refrigerant pipe 4 to configure a refrigerant circuit.

<Configural Schematics of Refrigerant Circuit of Air Conditioner>

The configuration of the refrigerant circuit of the air conditioner 1 is shown in FIG. 2. The refrigerant circuit is primarily configured by an indoor heat exchanger 20, an accumulator 31, a compressor 32, a four-way switch valve 33, an outdoor heat exchanger 30, and an electric-operated expansion valve 34.

The indoor heat exchanger 20 disposed in the indoor unit 2 performs heat exchange with air coming into contact therewith. Further, a cross flow fan 21 for sucking in room air and discharging, into the room, air with respect to which heat exchange has been performed through the indoor heat exchanger 20 is disposed in the indoor unit 2. The cross flow fan 21 is configured in a circular cylinder shape, includes a peripheral surface on which blades are disposed in a rotational axis direction, and generates an air flow in a direction orthogonal to its rotational axis. The cross flow fan 21 is driven to

rotate by an indoor fan motor 22 disposed inside the indoor unit 2.

Disposed in the outdoor unit 3 are the compressor 32, the four-way switch valve 33 connected to a discharge side of the compressor 32, the accumulator 31 connected to an intake side of the compressor 32, the outdoor heat exchanger 30 connected to the four-way switch valve 33, and the electric-operated expansion valve 34 connected to the outdoor heat exchanger 30. The electric-operated expansion valve 34 is connected to a pipe 41 via a filter 35 and a liquid close valve 36 and is connected to one end of the indoor heat exchanger 20 via the pipe 41. Further, the four-way switch valve 33 is connected to a pipe 42 via a gas close valve 37 and is connected to the other end of the indoor heat exchanger 20 via the pipe 42. The pipes 41 and 42 correspond to the refrigerant pipe 4 of FIG. 1. Further, a propeller fan 38 for discharging, to the outside, air after heat exchange by the outdoor heat exchanger 30 is disposed in the outdoor unit 3. The propeller fan 38 is driven to rotate by a fan motor 39. It will be noted that a cooling jacket 58 (see FIG. 3) disposed in a power module 5 (described later) that performs power conversion of the compressor 32, the fan motor 39, the electric-operated expansion valve 34 and the like is also connected to this refrigerant circuit.

<Configuration of Power Module>

In FIG. 3(a), there is shown a longitudinal sectional view of the power module 5 pertaining to the present embodiment.

The power module 5 pertaining to the present embodiment is primarily configured by a casing 50, a first electronic component 53a, a second electronic component 53b, a mounting substrate 51, and the cooling jacket 58.

The casing 50 is configured by a side wall 50a disposed upright on the mounting surface side of the electronic components 53a and 53b from the side edge of the mounting substrate 51 and by a cover 50b disposed so as to cover the upper portions of the electronic components 53a and 53b from the upper end of the side wall 50a.

The first electronic component 53a is a power semiconductor that generates a large amount of heat when it is powered (including a via chip and the like). In the present embodiment, "power semiconductor" refers to a diode, a power transistor, and the like, for example.

The second electronic component 53b is a non-power semiconductor and other electronic components (surface mounted components such as a condenser and a resistor). In the present embodiment, "non-power semiconductor" refers to a microcomputer, a ROM, and the like (including a via chip and the like) for example.

The mounting substrate 51 comprises an area (called a first mounting area below) on which the first electronic component 53a is mounted and an area (called a second mounting area below) on which the second electronic component 53b is mounted. The first mounting area is formed from a 1-ply sheet-like glass fiber reinforced epoxy resin (called "glass epoxy sheet" below) 51a, and the thickness thereof is around 100 μm. Incidentally, the thickness thereof is a value calculated in consideration of the amount of heat emitted from the first electronic component 53a being 40 W, the heat emission area being 4 cm^2, and keeping the first electronic component 53a at 100°C or less (see FIG. 4). In this first mounting area, the first electronic component 53a is mounted on the 1-ply glass epoxy sheet 51a via a heat spreader 54 and a conductor, and is sealed by a sealant such as silicone gel 56. On the other hand, the second mounting area is formed from a laminate resin substrate where a conductor pattern 52 and the glass epoxy sheet 51a are alternately laminated. In this second mounting area, the second electronic component 53b is mounted on the laminate resin substrate, and the second electronic component 53b is connected to the conductor pattern 52 disposed between the glass epoxy sheets 51a to form a three-dimensional complex control circuit. It will be noted that the first electronic component 53a is also connected to the conductor pattern 52 via a wire 55, whereby part of a power supply circuit is formed. A lead 57 is used for connection to an external circuit. Incidentally, in order to form the mounting substrate 51 pertaining to the present embodiment, (i) a method of making thin the thickness of the first mounting area of the mounting substrate 51 by machining after adjusting a uniform plate-like laminated mounting substrate (it is necessary for the circuit pattern to be formed in consideration of machining) or (ii) a method of forming each ply of glass fiber fabric such that the mounting substrate becomes a predesigned shape, heating/compressing these after impregnating the n^{th} layer of glass fiber fabric with an epoxy resin stock solution, thereafter forming a circuit pattern on both sides or one side thereof (This glass fiber reinforced epoxy resin is called circuit pattern holding glass epoxy sheet below.), thereafter interposing the glass fiber fabric of the $(n + 1)^{th}$ layer impregnated with the epoxy resin stock solution between circuit pattern holding glass epoxy sheets and again heating/compressing the same are conceivable. In the latter case, a mold following the design shape becomes necessary.

The cooling jacket 58 is a rectangular parallelepiped metal box and is disposed on the opposite side of the mounting surface of the mounting substrate 51 on which the electronic components 53a and 53b are mounted, such that the cooling jacket 58 contacts

the surface opposite the mounting surface of the mounting substrate 51. Plural hairpin-shaped passages (called "refrigerant passages" below) 59 are formed inside the cooling jacket 58 in the portion corresponding to the first mounting area (see FIG. 3(b)). As shown in FIG. 2, the refrigerant passages 59 are connected to the refrigerant circuit so as to sandwich the electric-operated expansion valve 34. For this reason, liquid refrigerant flows into the refrigerant passages 59 from the refrigerant circuit so that primarily the heat arising from the first electronic component 53a is discharged from the power module 5 by that liquid refrigerant. It will be noted that the temperature of the liquid refrigerant flowing into the refrigerant circuit is ordinarily about 30 to 60°C.

<Method of Producing Power Module>

Here, the method of producing the power module 5 pertaining to the embodiment of the present invention will be described using FIG. 5.

Turning now to FIG. 5, in step S1, the first electronic component 53a and the heat spreader 54 are bonded. In step S2, the bonding product of the first electronic component 53a and the heat spreader 54 obtained in step S1 is bonded to the first mounting area of the mounting substrate 51. At this time, the bonding product is bonded such that the heat spreader 54 tightly contacts the mounting substrate 51. In step S3, the first electronic component 53a and the conductor pattern 52 of the mounting substrate 51 are bonded via a wire. In step S4, the second electronic component 53b is heated to a predetermined temperature in a state where it has been placed in a prescribed position on the conductor pattern 52, and the second electronic component 53b is soldered by reflow to the conductor pattern 52. It will be noted that a reflowable substance (cream solder, etc.) is printed on, or applied to, the conductor pattern 52 beforehand. In step S5, a lead component 53c (included in the second electronic component 53b) is soldered by a reflow method to the conductor pattern 52.

<Characteristics of Power Module>

(1)

In the power module 5 pertaining to the present embodiment, both the first electronic component 53a and the second electronic component 53b are mounted on the same mounting substrate 51 formed by glass fiber reinforced epoxy resin. For this reason, this power module 5 can be produced at a lower cost than conventional power modules that have been produced using separate mounting substrates for the first electronic component 53a and for the second electronic component 53b.

(2)

In the power module 5 pertaining to the present embodiment, the thickness of the first mounting area of the mounting substrate 51 is sufficiently thin so that the first electronic component 53a is effectively cooled by refrigerant of about 50°C. For this reason, this power module 5 can be produced at a lower cost than conventional power modules that have employed aluminium substrates and ceramic substrates for mounting the first electronic component 53a. Further, in this power module 5, workability is superior to that of the conventional power modules because the mounting substrate 51 is formed by glass fiber reinforced epoxy resin. Further, in this power module 5, the mounting reliability of the first electronic component 53a is superior to that of the conventional power modules because the mounting substrate 51 is formed by glass fiber reinforced epoxy resin.

(3)

In the power module 5 pertaining to the present embodiment, the shortest distance between the first electronic component 53a and the refrigerant passages 59 is shorter than the shortest distance between the second electronic component 53b and the refrigerant passages 59. For this reason, in this power module 5, the heat arising from the power semiconductor can be discharged to the outside of the power module 5 more efficiently than the heat arising from the second electronic component 53b.

<Modifications>

(A)

In the power module 5 pertaining to the preceding embodiment, the cooling jacket 58 was disposed on the opposite side of the mounting surface of the mounting substrate 51 on which the electronic components 53a and 53b were mounted, such that the cooling jacket 58 contacted the surface opposite the mounting surface of the mounting substrate 51, and the cooling passages 59 were formed inside the cooling jacket 58. However, as shown in FIG. 6, cooling passages 59A may also be formed inside a mounting substrate 51A. By so doing, the distance between the first electronic component 53a and the cooling passages 59A can be shortened even more.

(B)

In the power module 5 pertaining to the preceding embodiment, the thickness of the first mounting area of the mounting substrate 51 was thinner than the thickness of the second mounting area, but the thickness of the first mounting area may also be the same as the thickness of the second mounting area. In this case, as shown in the chart of FIG. 4, there is the potential for the heat arising from the first electronic component 53a to not be

sufficiently discharged from the power module 5, so as shown in FIG. 7, it is preferable to dispose thermal vias 54B inside a mounting substrate 51B around the first electronic component 53a. Moreover, a contact heat transfer layer 57B may also be disposed between the cooling jacket 58 and the mounting substrate 51B. Furthermore, a heat spreader may be inserted between the first electronic component 53a and the mounting substrate 51B.

(C)

In the power module 5 pertaining to the preceding embodiment, the temperature of the refrigerant flowing into the refrigerant passages 59 was virtually determined by the flow of the refrigeration cycle. However, a temperature sensor may be disposed in the vicinity of the first electronic component 53a, an expansion valve may be disposed in the vicinity of the gateway of the refrigerant passages 59, and the evaporation temperature of the refrigerant may be controlled to maintain the temperature in the vicinity of the first electronic component 53a at a constant. By so doing, the first electronic component can be more reliably protected. In this case, the outlet of the refrigerant passages 59 may be connected to the intake pipe of the compressor 32.

(D)

In the power module 5 pertaining to the preceding embodiment, the thickness of the first mounting area of the mounting substrate 51 was set to around 100 μm, but the first mounting area may also be thicker than that depending on the temperature of refrigerant flowing into the refrigerant passages 59 (see FIG. 4). Conversely, the thickness of the first mounting area of the mounting substrate 51 may also be less than 100 μm, but in this case, it is necessary to consider dielectric breakdown strength.

(E)

In the power module 5 pertaining to the preceding embodiment, an epoxy resin was employed as the raw material of the mounting substrate 51, but an epoxy resin in which ceramic powder or the like having an insulating property are mixed may also be employed. By so doing, the thermal conductivity of the mounting substrate can be improved, and the heat arising from the first electronic component 53a can be efficiently discharged to the outside of the power module 5.

(F)

In the power module 5 pertaining to the preceding embodiment, a laminate resin substrate was employed as the mounting substrate 51, but instead of this, as shown in FIG. 8, FIG. 9, and FIG. 10, two-sided resin substrates 51C, 51D, 51E on just both sides of

which a conductor pattern is disposed may also be employed. In such power modules 5C, 5D, and 5E, it is preferable to dispose thermal vias 54C in the resin portions of the two-sided resin substrates 51C, 51D, and 51E in order to cause the heat arising from the first electronic component 53a to be diffused in the direction of the refrigerant passages 59, or to disperse a thermally conductive filler 54D in the resin portion, or to insert a thermally conductive sheet 54E into the resin portion. Further, it is even more effective to dispose the heat spreader 54 that causes the heat arising from the first electronic component 53a to be diffused along the mounting surface. In this case, it is preferable to dispose electrical insulation layers 57C, 57D, and 57E between the two-sided resin substrates 51C, 51D, and 51E and the cooling jacket 58 in order to ensure the insulating property of the two-sided resin substrates 51C, 51D, and 51E. However, when the thermally conductive filler 54D and the thermally conductive sheet 54E is made from a ceramic or the like and have an electrical insulation property, the electrical insulation layers 57C, 57D, and 57E can be omitted.

(G)

In the power module 5 pertaining to the preceding embodiment, the cooling jacket 58 was employed whose surface contacting the mounting substrate 51 had a flat shape, but instead of this, a stepped cooling jacket 58F as shown in FIG. 11 may also be employed. By so doing, the cooling jacket 58F contacts just the surface on the opposite side of the mounting surface on which the first electronic component 53a and the like are mounted, and it becomes possible to perform two-sided mounting at the other portion. Consequently, in such a power module 5F, unnecessary cooling (or heating) can be prevented, and at the same time further compactification becomes possible. Further, by so doing, it also becomes possible to accommodate instances where lead wires emerge from the surface on the opposite side of the mounting surface. Further, an electrical insulation layer 57F may also be disposed between the cooling jacket 58F and the mounting substrate 51F.

(H)

In the method of producing the power module 5 pertaining to the preceding embodiment, each process was performed in the order of step S1, step S2, step S3, step S4, and step S5, but this order may be switched around. For example, each process may be performed in the order of step S1, step S4, step S2, step S3, and step S5, or each process may be performed in the order of step S1, step S2, step S4, step S3, and step S5, or each process may be performed in the order of step S5, step S1, step S2, step S3, and step S4.

(I)

In the power module 5 pertaining to the preceding embodiment, an epoxy resin was employed as the raw material of the mounting substrate 51, but a resin other than this (e.g., a phenol resin, a bismaleimide resin, a polyimide resin) may also be employed.

INDUSTRIAL APPLICABILITY

The power module pertaining to the present invention has the characteristic that it can be produced at a lower production cost than conventional power modules and can contribute to reducing the cost of power modules.

CLAIMS

1. A power module (5, 5A, 5B, 5C, 5D, 5E, 5F) comprising:

a power semiconductor (53a) and a non-power semiconductor (53b) that configure a power supply circuit for performing power conversion;

one resin substrate (51, 51A, 51B, 51C, 51D, 51E, 51F) on which both the power semiconductor and the non-power semiconductor are mounted; and

cooling means (59, 59A) for cooling the power semiconductor.

2. The power module of claim 1, wherein the cooling means is a cooling fluid passage that is disposed on the opposite side of a mounting surface of the resin substrate on which the power semiconductor and the non-power semiconductor are mounted and is for allowing a cooling fluid that is a fluid for cooling the power semiconductor to pass therethrough.

3. The power module of claim 2, wherein the cooling fluid passage is disposed inside the resin substrate.

4. The power module of claim 2 or 3, further comprising

temperature detecting means that detects the temperature of the power semiconductor or the vicinity thereof, and

temperature controlling means that controls the temperature of the cooling fluid such that the temperature detected by the temperature detecting means becomes a predetermined temperature.

5. The power module of any of claims 2 to 4, wherein the shortest distance between the power semiconductor and the cooling fluid passage is shorter than the shortest distance between the non-power semiconductor and the cooling fluid passage.

6. The power module of any of claims 1 to 5, wherein the thickness of the portion of the resin substrate on which the power semiconductor is mounted is thinner than the thickness of the portion of the resin substrate on which the non-power semiconductor is mounted.

7. The power module of claim 5 or 6, wherein

the resin substrate is configured by plural laminate units laminated in a board thickness direction, and

the thickness of the portion on which the power semiconductor is mounted and the thickness of the portion on which the non-power semiconductor is mounted are adjusted depending on the shapes of the laminate units.

8. The power module of any of claims 1 to 7, further comprising a heat diffusing

portion (54, 54B, 54C, 54D, 54E) for diffusing heat arising from at least the power semiconductor.

9. The power module of claim 8, further comprising an electrical insulation layer (57C, 57D, 57E, 57F) disposed between the heat diffusing portion and the cooling fluid passage.

10. The power module of claim 8 or 9, wherein a heat spreader disposed between the power semiconductor and the mounting surface of the resin substrate is included in the heat diffusing portion.

11. The power module of any of claims 8 to 10, wherein a thermal via disposed inside the resin substrate along a direction intersecting the board surface of the resin substrate is included in the heat diffusing portion.

12. The power module of any of claims 8 to 11, wherein a thermally conductive filler dispersed and mixed in with the resin portion of the resin substrate is included in the heat diffusing portion.

13. The power module of any of claims 4 to 8, wherein a thermally conductive sheet embedded in the resin portion of the resin substrate is included in the heat diffusing portion.

14. A power module (5, 5A, 5B, 5C, 5D, 5E, 5F) comprising:

a power semiconductor (53a) and a non-power semiconductor (53b) that configure a power supply circuit for performing power conversion;

one mounting substrate (51, 51A, 51B, 51C, 51D, 51E, 51F) on which both the power semiconductor and the non-power semiconductor are mounted and whose thermal conductivity in a board thickness direction is 10 W/(m·K) or less; and

cooling means (59, 59A) for cooling the power semiconductor.

15. An air conditioner (1) comprising:

a refrigerant circuit; and

a power module (5, 5A, 5B, 5C, 5D, 5E, 5F) including a power semiconductor (53a) and a non-power semiconductor (53b) that configure a power supply circuit for performing power conversion, one resin substrate (51, 51A, 51B, 51C, 51D, 51E, 51F) on which both the power semiconductor and the non-power semiconductor are mounted, and a refrigerant passage (59, 59A) that is disposed on the opposite side of a mounting surface of the resin substrate on which the power semiconductor and the non-power semiconductor are mounted and is for allowing refrigerant flowing in the refrigerant circuit to pass therethrough.

16. A method of producing a power module (5, 5A, 5B, 5C, 5D, 5E, 5F) including a power semiconductor (53a) and a non-power semiconductor (53b) that configure a power supply circuit for performing power conversion, one resin substrate (51, 51A, 51B, 51C, 51D, 51E, 51F) on which both the power semiconductor and the non-power semiconductor are mounted, and cooling means (59, 59A) for cooling the power semiconductor, the method comprising:

a power semiconductor fixing step for fixing the power semiconductor to a prescribed position on the resin substrate;

a wire connecting step for wire-connecting the power semiconductor and a circuit disposed on the resin substrate;

a non-power semiconductor connecting step for connecting the non-power semiconductor and the circuit; and

a cooling means fixing step for fixing the resin substrate to the cooling means.