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(54) **SEMICONDUCTOR DEVICE, HIGH-FREQUENCY POWER AMPLIFIER, AND METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE**

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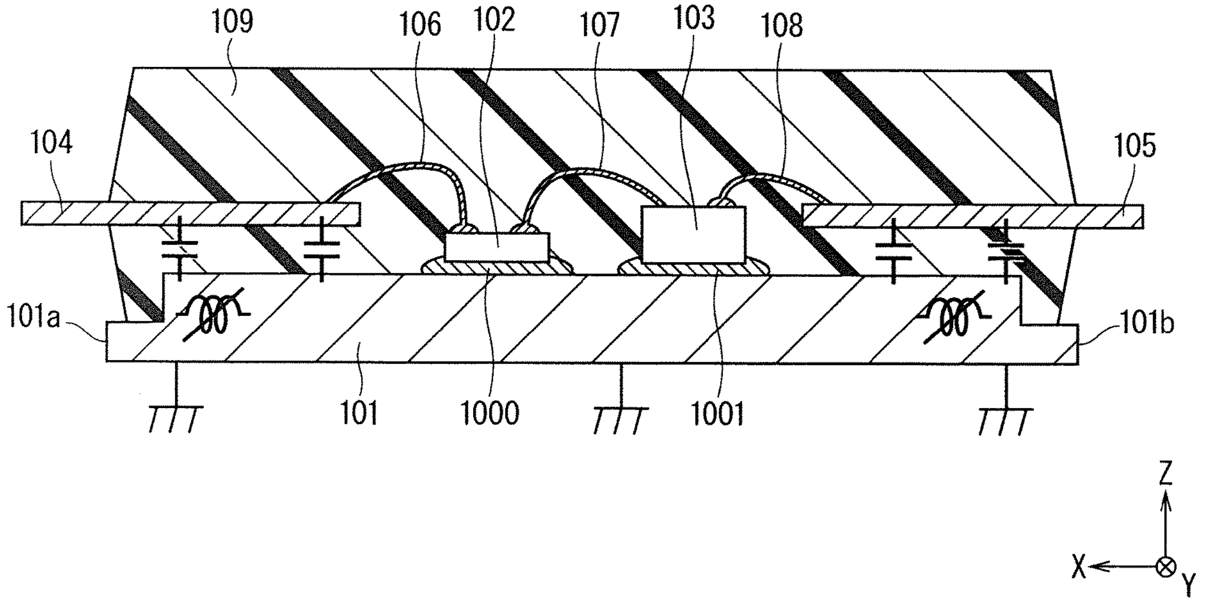
(57) **ABSTRACT**

Reduction in impedance in a lead connected to a semiconductor element is achieved while achieving anchor effect. The semiconductor device includes a heatsink, a semiconductor element, a lead disposed on an upper side of the heatsink, and a molding material formed to cover the lead, the heatsink, and the semiconductor element. Formed on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view is a first convex portion protruding more than an edge portion of an upper surface in the position, and formed on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view is a second convex portion protruding more than an edge portion of a lower surface in the position.



F I G. 1

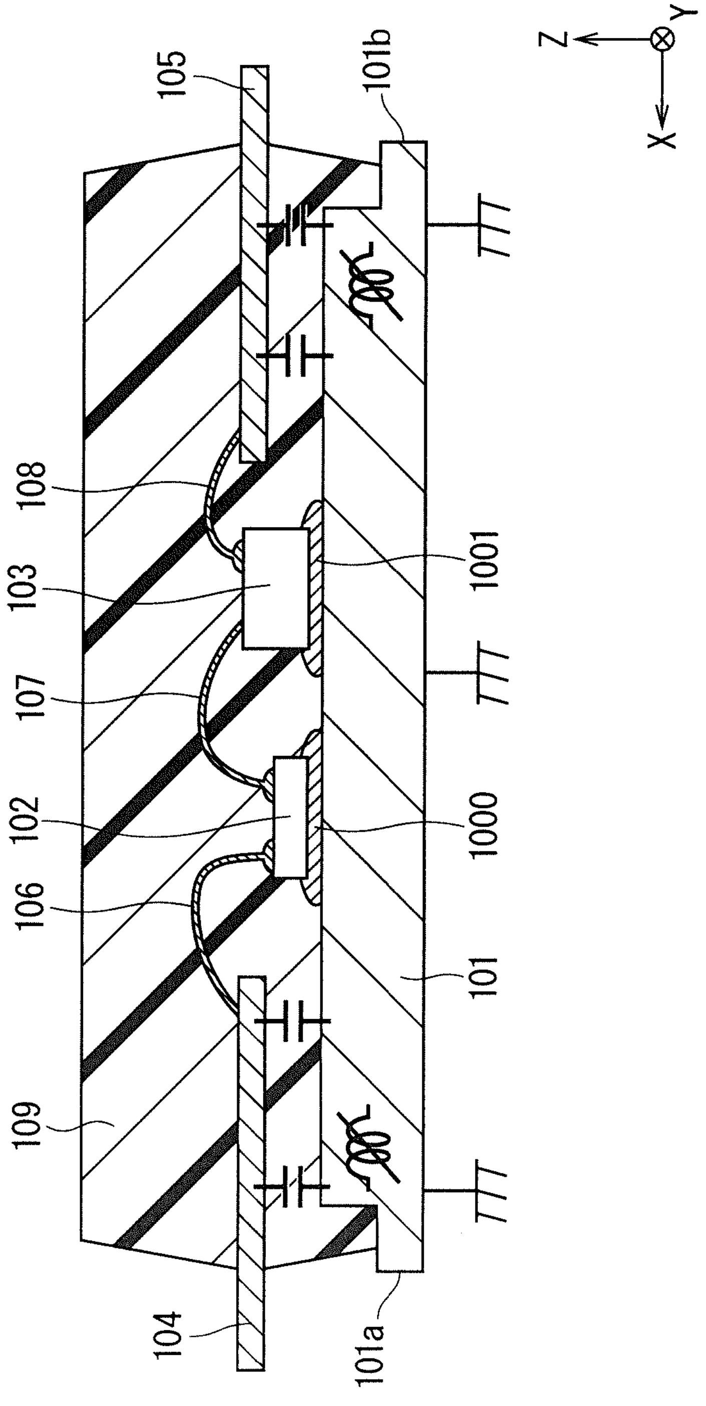


FIG. 2

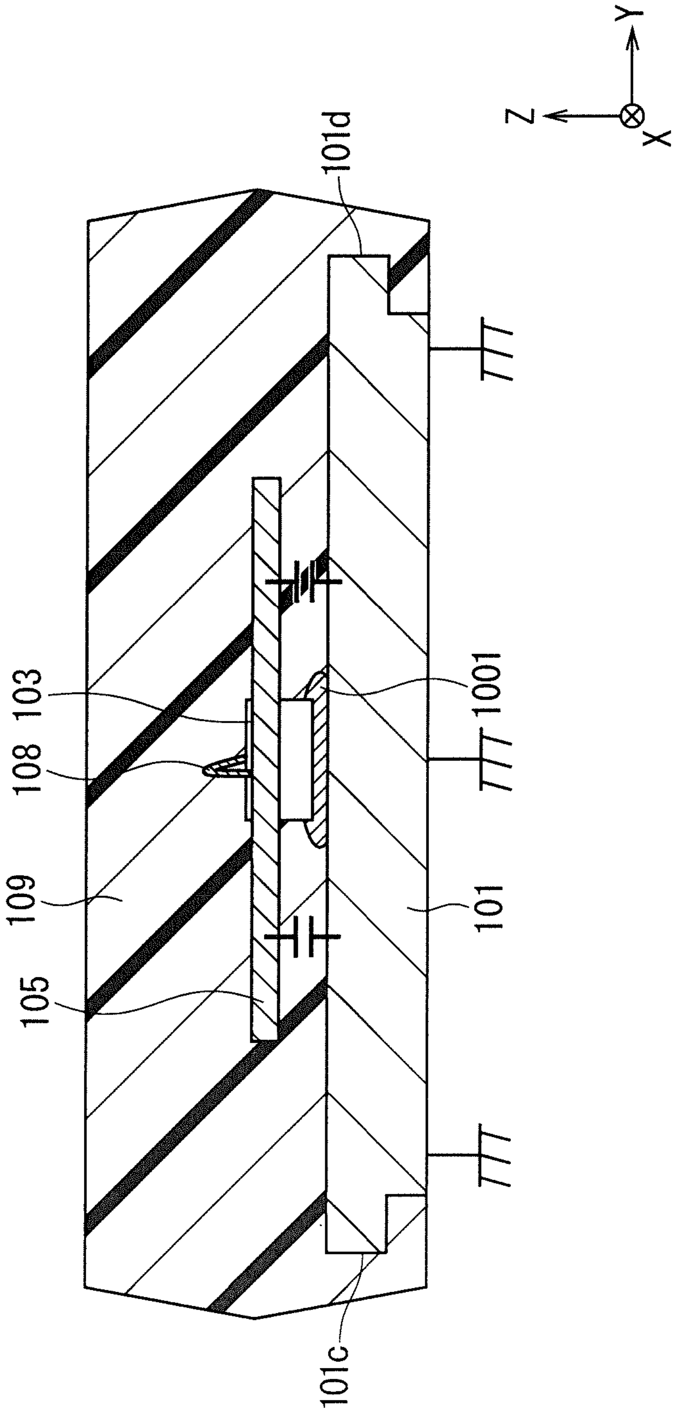


FIG. 3

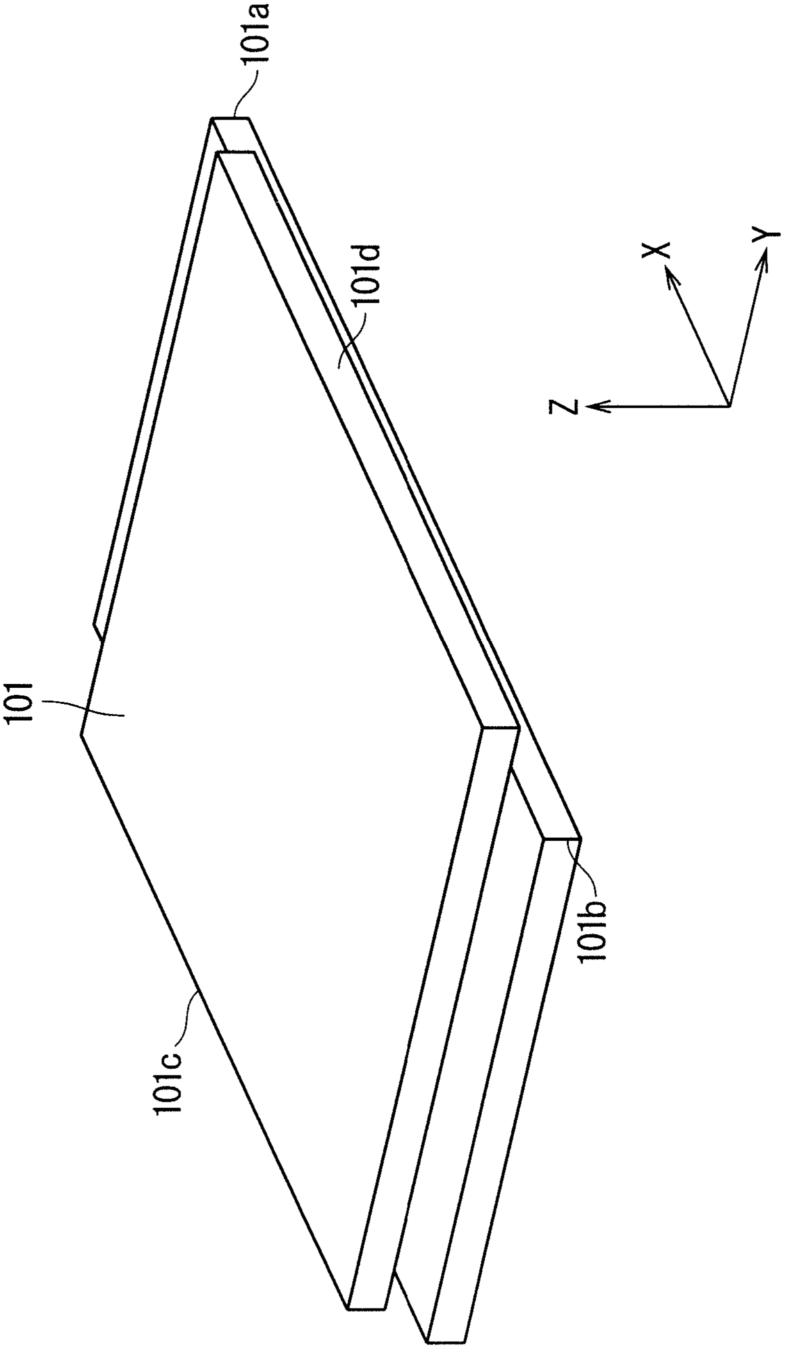
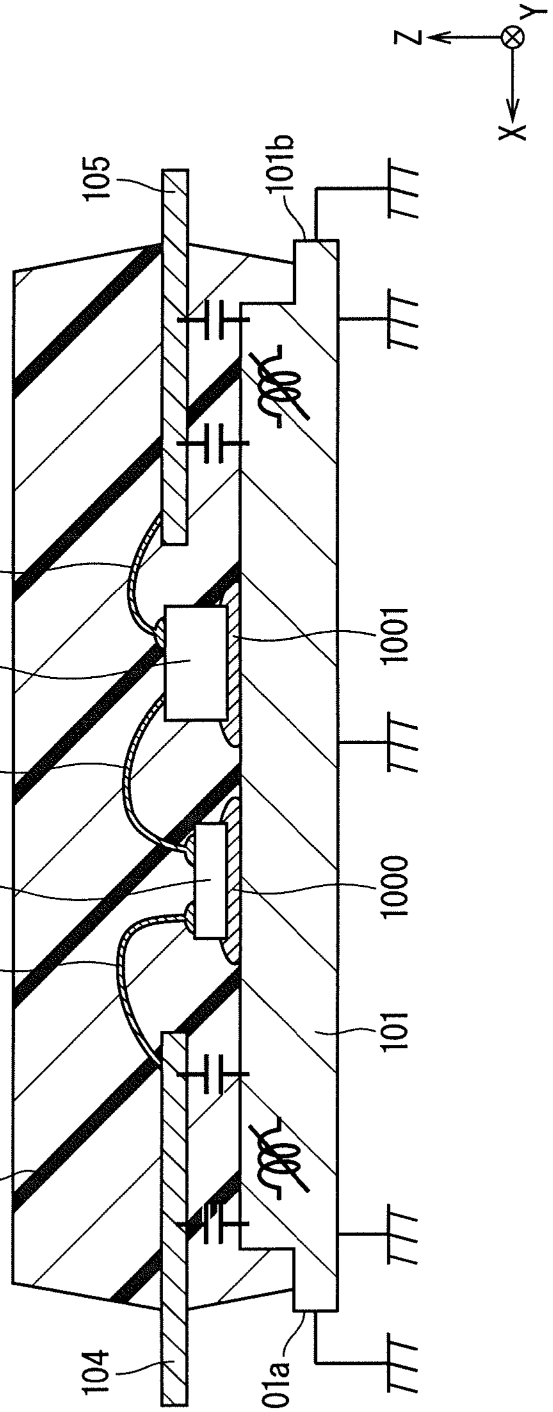
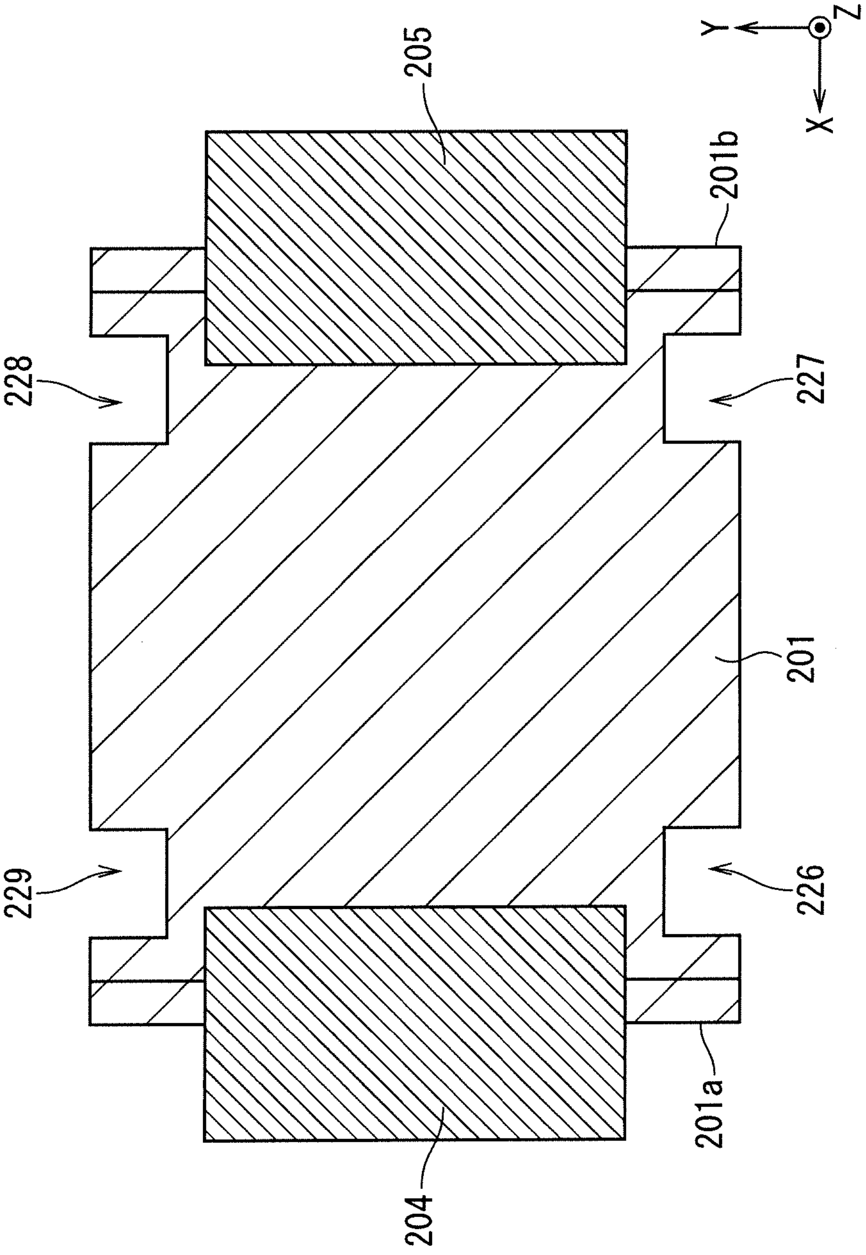


FIG. 4



F I G. 5



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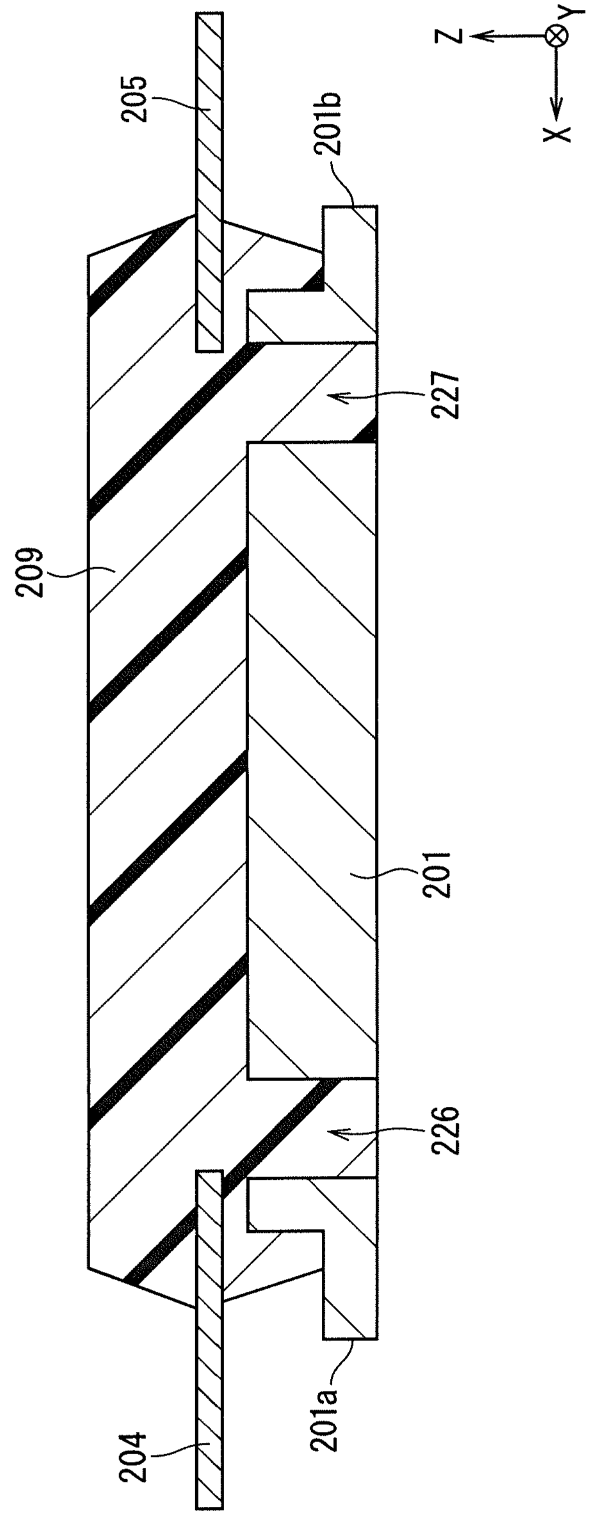


F I G. 7

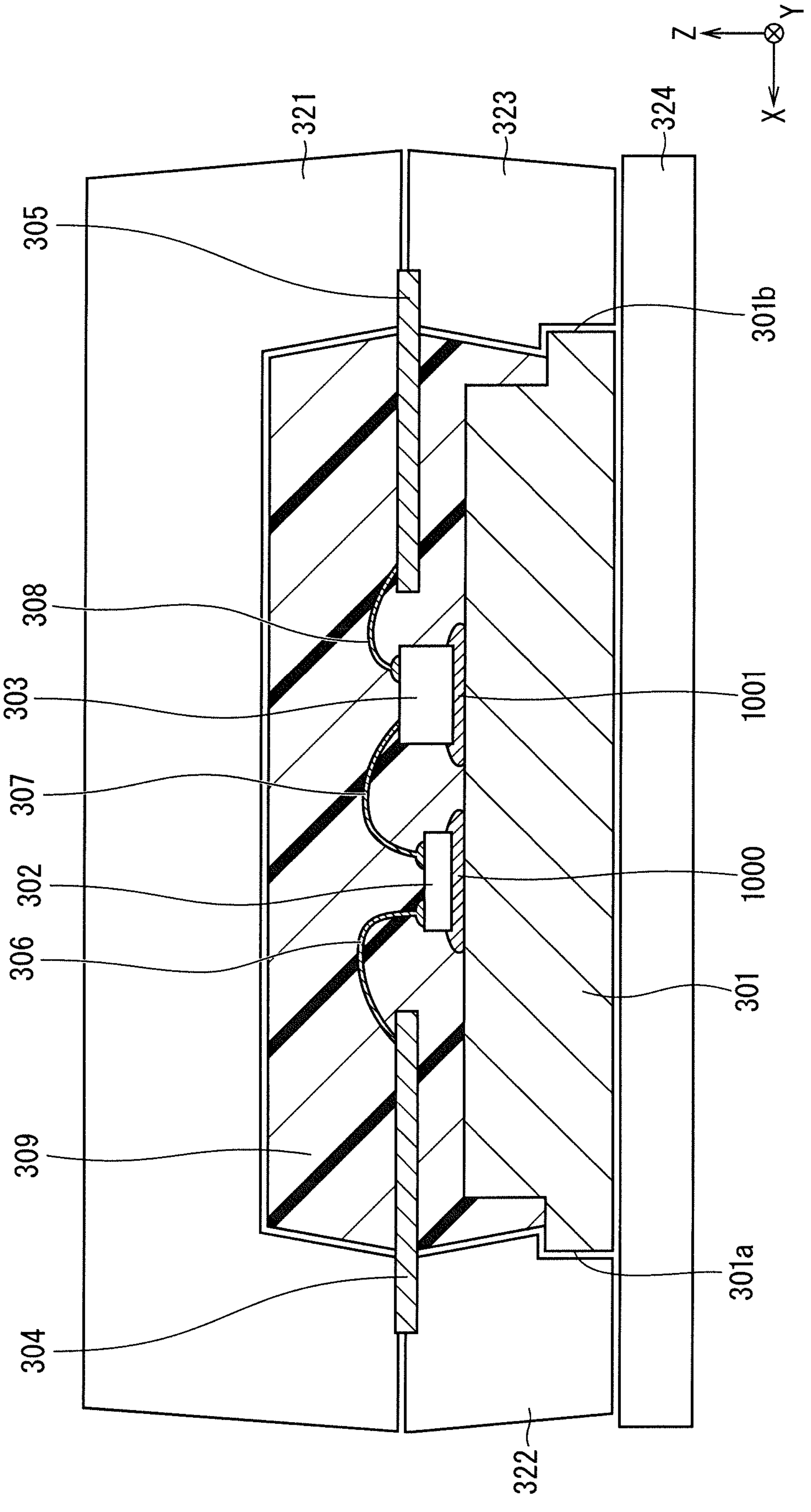

Z
Y
X
321
323
324
305
301b
308
303
1001
307
302
1000
306
301
309
301a
304
322

FIG. 8

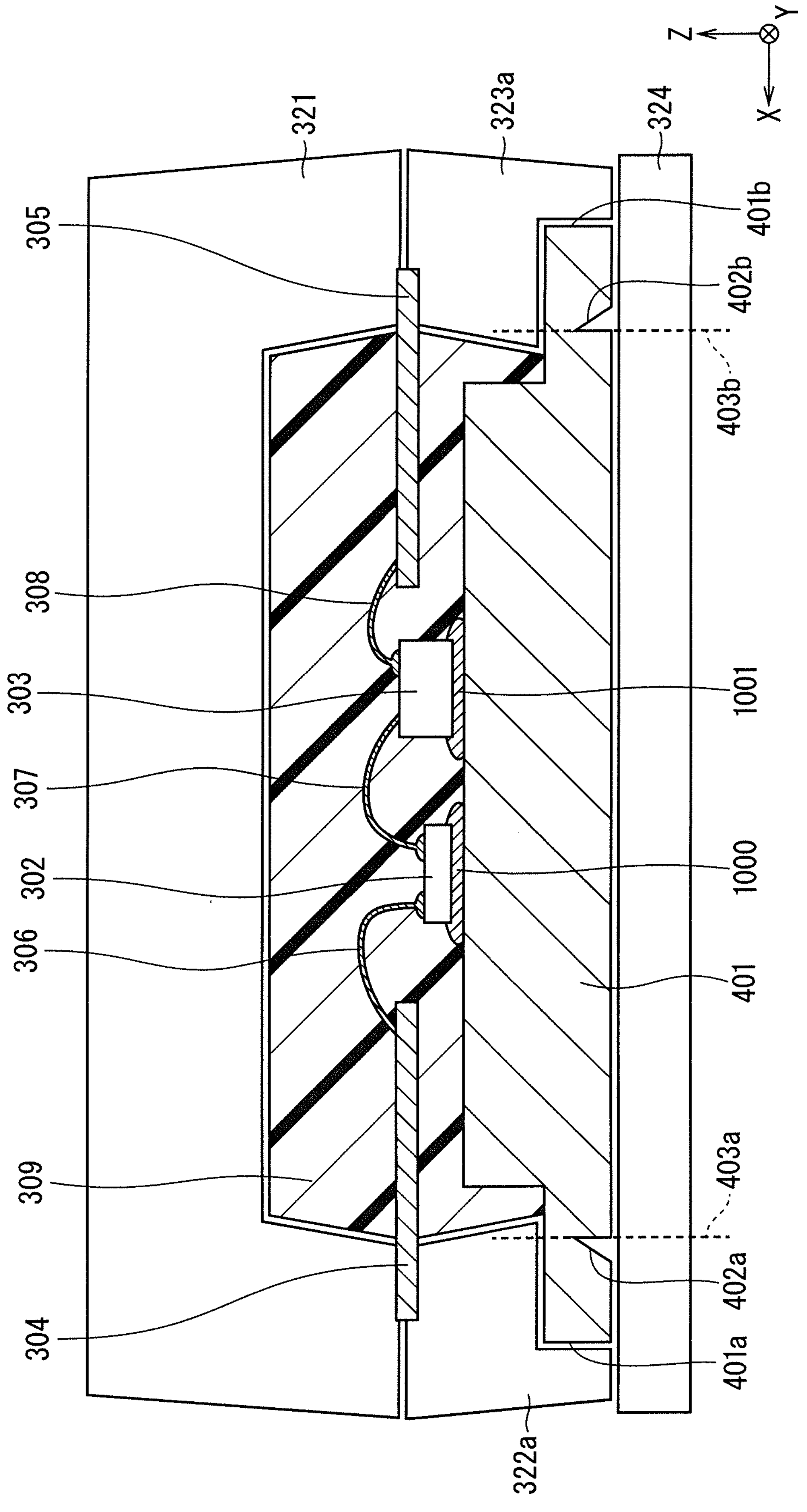

Z
Y
X
321
323a
324
305
401b
402b
403b
308
303
1001
307
302
1000
306
401
309
403a
402a
304
401a
322a

FIG. 9

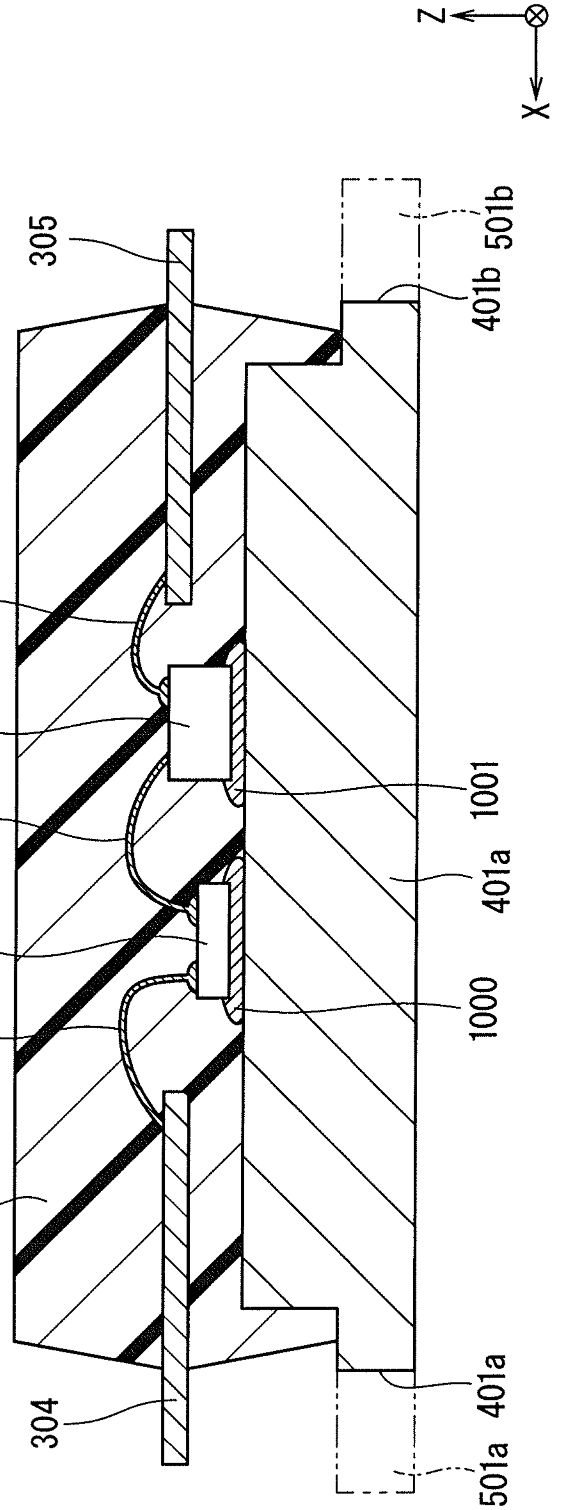
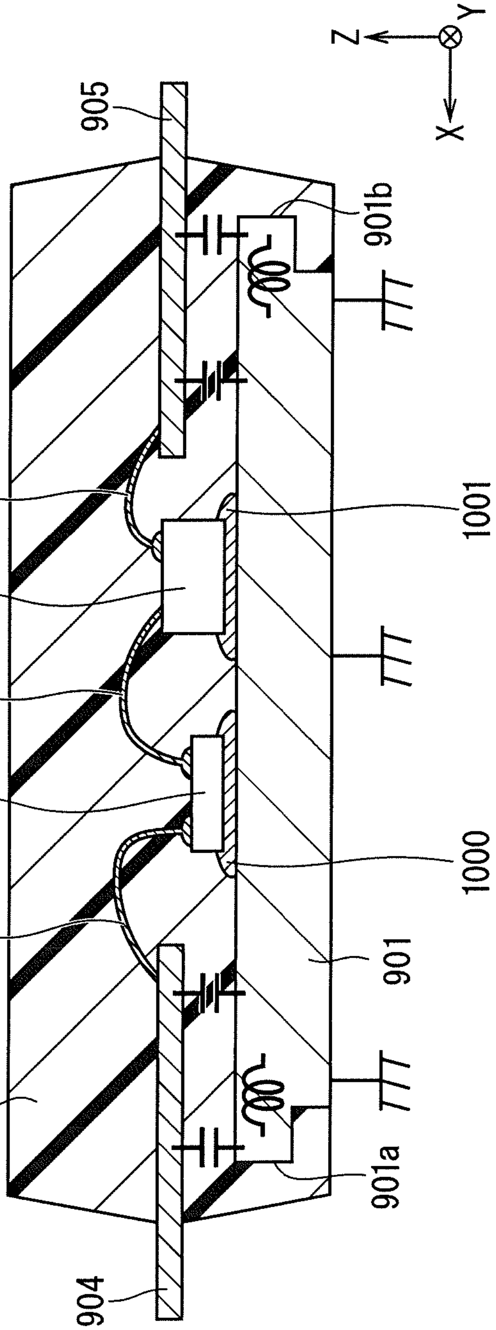

Z
Y
X
305
501b
401b
308
303
1001
307
401a
302
1000
306
309
304
401a
501a

FIG. 10



SEMICONDUCTOR DEVICE, HIGH-FREQUENCY POWER AMPLIFIER, AND METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE

TECHNICAL FIELD

[0001] The technique disclosed in the specification of the present application relates to a semiconductor device, a high-frequency power amplifier including the semiconductor device, and a method of manufacturing the semiconductor device.

BACKGROUND ART

[0002] In a conventional package structure that a semiconductor element disposed on an upper surface of a heatsink is covered by a molding material, used for purpose of anchoring the molding material to the heatsink, that is to say, producing anchor effect is a heatsink with a shape having a convex portion on an edge portion of the upper surface covered by the molding material so that the convex portion protrudes more than an edge portion of a lower surface exposed from the molding material (refer to Patent Document 1, for example).

PRIOR ART DOCUMENTS

Patent Documents

[0003] Patent Document 1: International Publication No. 2013/094101

SUMMARY

Problem to be Solved by the Invention

[0004] However, in the case where the heatsink having the shape described above is used, a parasitic inductance component on a heatsink side becomes redundant in a region where a lead connected to the semiconductor element via a wire and the heatsink overlap with each other in an up-down direction when the heatsink is grounded. Thus, there is a problem that impedance in the lead cannot be reduced to a desired level. In this case, the impedance in the lead is high, so that a high performance is obstructed in a case where a semiconductor device is used as a high-frequency amplifier, for example.

[0005] The technique disclosed in the specification of the present application is therefore has been made to solve the above problems, and it is an object of the technique to provide a technique capable of reducing impedance in a lead connected to a semiconductor element while producing an effect of anchoring a molding material.

Means to Solve the Problem

[0006] A first embodiment of a technique disclosed in the specification of the present application includes: a heatsink at least whose lower surface is grounded; semiconductor element which is disposed on an upper surface of the heatsink and a high-frequency signal is input to or output from; at least one lead electrically connected to the semiconductor element via a wire and disposed on an upper side of the heatsink; and a molding material formed to cover part of the lead, at least an upper surface of the heatsink, and the semiconductor element, wherein the heatsink is disposed to partially overlap with the lead in a plan view, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position is formed, and on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, at least one second convex portion protruding more than an edge portion of a lower surface in the position is formed.

[0007] A second embodiment of a technique disclosed in the specification of the present application includes: a heatsink at least whose lower surface is grounded; a semiconductor element which is disposed on an upper surface of the heatsink and a high-frequency signal is input to or output from; at least one lead electrically connected to the semiconductor element via a wire and disposed on an upper side of the heatsink; and a molding material formed to cover part of the lead, at least an upper surface of the heatsink, and the semiconductor element, wherein the heatsink is disposed to partially overlap with the lead in a plan view, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position is formed, at least one cutting portion is formed in an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, and the cutting portion is filled with the molding material.

[0008] A third embodiment of a technique disclosed in the specification of the present application includes: preparing a heatsink at least whose lower surface is grounded; locating, on an upper surface of the heatsink, a semiconductor element which a high-frequency signal is input to or output from; locating at least one lead electrically connected to the semiconductor element via a wire on an upper side of the heatsink; locating the heatsink to partially overlap with the lead in a plan view; forming, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position; forming, on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, at least one second convex portion protruding more than an edge portion of a lower surface in the position; forming a molding material covering part of the lead, part of the heatsink, and the semiconductor element; exposing at least an end portion of the first convex portion in the heatsink to form the molding material; and cutting the end portion of the first convex portion after forming the molding material.

Effects of the Invention

[0009] A first embodiment of a technique disclosed in the specification of the present application includes: a heatsink at least whose lower surface is grounded; a semiconductor element which is disposed on an upper surface of the heatsink and a high-frequency signal is input to or output from; at least one lead electrically connected to the semiconductor element via a wire and disposed on an upper side of the heatsink; and a molding material formed to cover part of the lead, at least an upper surface of the heatsink, and the semiconductor element, wherein the heatsink is disposed to partially overlap with the lead in a plan view, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position is formed, and on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, at least one second convex portion protruding more than an edge portion of a lower surface in the position is formed. According to such a configuration, the parasitic inductance component in the lateral direction of the heatsink is reduced in the position where the heatsink overlaps with the lead in a plan view. Reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead and the heatsink is grounded via the heatsink. Accordingly, the impedance in the lead can be reduced. That is to say, the impedance in the lead connected to the semiconductor element can be reduced while achieving the effect of anchoring the molding material by the second convex portion.

[0010] A second embodiment of a technique disclosed in the specification of the present application includes: a heatsink at least whose lower surface is grounded; a semiconductor element which is disposed on an upper surface of the heatsink and a high-frequency signal is input to or output from; at least one lead electrically connected to the semiconductor element via a wire and disposed on an upper side of the heatsink; and a molding material formed to cover part of the lead, at least an upper surface of the heatsink, and the semiconductor element, wherein the heatsink is disposed to partially overlap with the lead in a plan view, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position is formed, at least one cutting portion is formed in an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, and the cutting portion is filled with the molding material. According to such a configuration, the cutting portion in the heatsink is filled with the molding material, thus the effect of anchoring the heatsink and the molding material, that is to say, the anchor effect can be achieved. The parasitic inductance component in the lateral direction of the heatsink is reduced in the position where the heatsink overlaps with the lead in a plan view. Reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead and the heatsink is grounded via the heatsink. Accordingly, the impedance in the lead can be reduced. That is to say, the impedance in the lead connected to the semiconductor element can be reduced while achieving the effect of anchoring the molding material by the cutting portion.

[0011] A third embodiment of a technique disclosed in the specification of the present application includes: preparing a heatsink at least whose lower surface is grounded; locating, on an upper surface of the heatsink, a semiconductor element which a high-frequency signal is input to or output from; locating at least one lead electrically connected to the semiconductor element via a wire on an upper side of the heatsink; locating the heatsink to partially overlap with the lead in a plan view; forming, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position; forming, on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, at least one second convex portion protruding more than an edge portion of a lower surface in the position; forming a molding material covering part of the lead, part of the heatsink, and the semiconductor element; exposing at least an end portion of the first convex portion in the heatsink to form the molding material; and cutting the end portion of the first convex portion after forming the molding material. According to such a configuration, the projection length of the lower side of the heatsink, that is to say, the lateral protrusion length of first convex portion is set to be long enough to be able to prevent the intrusion of the molding material, thus the intrusion of the molding resin around the side surface of the first convex portion or the lower surface of the heatsink can be suppressed. Accordingly, the semiconductor device capable of reducing the impedance in the lead while suppressing the intrusion of the molding resin can be manufactured.

[0012] These and other objects, features, aspects and advantages of the technique disclosed in the specification of the present application will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0013] FIG. **1** A cross-sectional view along an X axis direction for schematically illustrating a configuration for achieving a semiconductor device according to an embodiment.

[0014] FIG. **2** A cross-sectional view along a Y axis direction for schematically illustrating a configuration for achieving the semiconductor device according to an embodiment.

[0015] FIG. **3** A perspective view illustrating a configuration of a heatsink according to an embodiment.

[0016] FIG. **4** A cross-sectional view along the X axis direction for schematically illustrating the configuration for achieving the semiconductor device according to an embodiment.

[0017] FIG. **5** A plan view illustrating a shape of the heatsink according to an embodiment.

[0018] FIG. **6** A cross-sectional view illustrating a structure of covering and fixing the heatsink and a lead illustrated in FIG. **5** by a molding material.

[0019] FIG. **7** A cross-sectional view along the X axis direction for schematically illustrating the configuration for achieving the semiconductor device according to an embodiment.

[0020] FIG. **8** A cross-sectional view along the X axis direction for schematically illustrating the configuration for achieving the semiconductor device according to an embodiment.

[0021] FIG. **9** A drawing illustrating an outer shape of a package after being cut in a process subsequent to a formation of a molding material resin according to an embodiment.

[0022] FIG. **10** A cross-sectional view illustrating a package structure including s heatsink with a shape having a convex portion on an edge portion of an upper surface covered by the molding material so that the convex portion protrudes more than an edge portion of a lower surface exposed from the molding material according to an embodiment.

DESCRIPTION OF EMBODIMENT(S)

[0023] Embodiments are described with reference to the appended drawings hereinafter.

[0024] The drawings a schematically illustrated, thus a configuration is appropriately omitted or simplified for convenience of explanation. A mutual relationship of sizes and positions of constituent elements respectively illustrated in the different drawings is not necessarily illustrated accurately, but may be appropriately changed.

[0025] In the description hereinafter, the same reference numerals will be assigned to the similar constituent elements in the drawings, and the constituent elements having the same reference numeral have the same name and function. Accordingly, the detailed description on them may be omitted to avoid a repetition in some cases.

[0026] In the following description, even when terms indicating a specific position and direction such as "upper", "lower", "left", "right", "side", "bottom", "front" or "rear" are stated, the terms are used to facilitate understanding of embodiments for convenience, and therefore, irrelevant to directions in practical implementation.

[0027] Further, in the following description, even when ordinal numbers such as "first" or "second" are stated, the terms are used to facilitate understanding of embodiments, and therefore, the usage of the ordinal numbers does not limit the indication of the ordinal numbers to ordering.

First Embodiment

[0028] Described hereinafter are a semiconductor device, a high-frequency power amplifier including the semiconductor device, and a method of manufacturing the semiconductor device according to the present embodiment. Described firstly for convenience of explanation is a package structure including a heatsink with a shape having a convex portion on an edge portion of an upper surface covered by a molding material so that the convex portion protrudes more than an edge portion of a lower surface exposed from the molding material.

[0029] FIG. **10** is a cross-sectional view illustrating a package structure including a heatsink with a shape having a convex portion on an edge portion of an upper surface covered by the molding material so that the convex portion protrudes more than an edge portion of a lower surface exposed from the molding material.

[0030] As illustrated in FIG. **10**, the package structure includes a heatsink **901** made of metal, a semiconductor element **902** disposed on an upper surface of the heatsink **901** via a bonding material **1000**, a matching element **903** disposed on the upper surface of the heatsink **901** via a bonding material **1001**, a wire **907** electrically connecting the semiconductor element **902** and the matching element **903**, a lead **904** electrically connected to the semiconductor element **902** via a wire **906** and also electrically connected to an external circuit (not shown herein), a lead **905** electrically connected to the matching element **903** via a wire **908** and also electrically connected to an external circuit (not shown herein), and a molding material **909** formed to cover the upper surface of the heatsink **901**, the semiconductor element **902**, the matching element **903**, part of the lead **904**, and part of the lead **905**. The molding material **909** also has a function of protecting the semiconductor element **902** and the matching element **903** in the package structure from contact with an external circuit, for example.

[0031] A lower surface of the heatsink **901** is exposed from the molding material **909**, and radiates heat generated from the semiconductor element **902** and the matching element **903**.

[0032] The semiconductor element **902** is a high-frequency power amplifying element which a high-frequency signal is input to or output from, for example. The matching element **903** is an output matching circuit element of the semiconductor element **902**, for example.

[0033] The heatsink **901** has a shape with a convex portion **901***a* and a convex portion **901***b* laterally protruding on an edge portion of the upper surface covered by the molding material **909**, that is to say, a shape in which an upper side is longer than a lower side in FIG. **10** for purpose of anchoring the molding material **909** to the heatsink **901**, that is to say, producing anchor effect.

[0034] In such a structure, a parasitic inductance component on a heatsink **901** side becomes redundant in a region where the lead **904** and the heatsink **901** overlap with each other in an up-down direction and a region where the lead **905** and the heatsink **901** overlap with each other in the up-down direction when the package structure is mounted on an external structure and the lower surface of the heatsink **901** is grounded. Thus, there is a problem that impedance in the lead **904** and the lead **905** cannot be reduced to a desired level.

[0035] <Configuration of Semiconductor Device>

[0036] FIG. **1** is a cross-sectional view along an X axis direction for schematically illustrating a configuration for achieving a semiconductor device according to the present embodiment.

[0037] As illustrated in FIG. **1**, the semiconductor device includes a heatsink **101** made of metal, a semiconductor element **102** disposed on an upper surface of the heatsink **101** via a bonding material **1000**, a matching element **103** disposed on the upper surface of the heatsink **101** via a bonding material **1001**, a wire **107** electrically connecting the semiconductor element **102** and the matching element **103**, a lead **104** electrically connected to the semiconductor element **102** via a wire **106** and also electrically connected to an external circuit (not shown herein), a lead **105** electrically connected to the matching element **103** via a wire **108** and also electrically connected to an external circuit (not shown herein), and a molding material **109** formed to cover the upper surface of the heatsink **101**, the semiconductor element **102**, the matching element **103**, part of the lead **104**, and part of the lead **105**. The molding material **109** also has a function of protecting the semiconductor element **102** and the matching element **103** in the package structure from contact with an external circuit, for example.

[0038] As illustrated in FIG. **1**, the heatsink **101** has a convex portion **101***a* and a convex portion **101***b* laterally protruding on an edge portion of a lower surface of the heatsink **101** in a region where the heatsink **101** overlaps with the lead **104** or the lead **105** in an up-down direction, that is to say, in a position having the overlap in a plan view, and has a shape in which an upper side thereof is shorter than a lower side thereof. Thus, a parasitic inductance component on a heatsink **101** side hardly becomes redundant when the semiconductor device is mounted on an external structure and the lower surface of the heatsink **101** is grounded.

[0039] In the convex portion **101***a* in FIG. **1**, an upper end and a lower end of the convex portion **101***a* protrude in the similar manner, however, a degree of protrusion of the upper end and the lower end of the convex portion **101**_a_ is not limited to be similar to each other. That is to say, it is also applicable that a protrusion amount of the upper end of the convex portion **101**_a_ is small and a protrusion amount of the lower end thereof is large, thus the convex portion **101**_a_ has an inclined shape (a tapered shape) in whole. In the similar manner, the convex portion **101**_b_ may also have an inclined shape (a tapered shape) in whole.

[0040] FIG. **2** is a cross-sectional view along a Y axis direction for schematically illustrating a configuration for achieving the semiconductor device according to the present embodiment.

[0041] As illustrated in FIG. **2**, the heatsink **101** has a shape with a convex portion **101**_c_ and a convex portion **101**_d_ laterally protruding on the edge portion of the upper surface covered by the molding material **109**, that is to say, a shape in which the upper side is longer than the lower side in FIG. **2** for purpose of anchoring the molding material **109** to the heatsink **101**, that is to say, producing the anchor effect.

[0042] In the convex portion **101**_c_ in FIG. **2**, an upper end and a lower end of the convex portion **101**_c_ protrude in the similar manner, however, a degree of protrusion of the upper end and the lower end of the convex portion **101**_c_ is not limited to be similar to each other. In the similar manner, a degree of protrusion of an upper end and a lower end of the convex portion **101**_d_ is not limited to be similar to each other.

[0043] However, the convex portion **101**_c_ and the convex portion **101**_d_ in the heatsink **101** do not overlap with the lead **104** and the lead **105** in the up-down direction, thus do not prevent the lead **104** and the lead **105** from reducing the impedance.

[0044] The convex portion **101**_c_ and the convex portion **101**_d_ in the heatsink **101** illustrated in FIG. **2** are also formed in the similar manner in a cross-sectional view along the Y axis direction in a configuration in the other embodiment described hereinafter as an example unless otherwise mentioned.

[0045] FIG. **3** is a perspective view illustrating a configuration of the heatsink according to the present embodiment. Herein, a cross-sectional view along the X axis direction in FIG. **3** corresponds to FIG. **1**. A cross-sectional view along the Y axis direction in FIG. **3** corresponds to FIG. **2**.

[0046] According to the configuration illustrated in FIG. **1**, the parasitic inductance component in a lateral direction of the heatsink **101** is reduced in a region where the heatsink **101** overlaps with the lead **104** or the lead **105** in the up-down direction. Reduced is the parasitic inductance component at a time when a parasitic capacitance between the lead **104** and the heatsink **101** and a parasitic capacitance between the lead **105** and the heatsink **101** are grounded via the heatsink **101**. Accordingly, the impedance in the lead **104** and the lead **105** can be reduced.

[0047] As illustrated in FIG. **2**, the heatsink **101** has the shape in which the upper side is longer than the lower side in the region where the heatsink **101** does not overlap with the lead **104** and the lead **105** in the up-down direction, thus the anchor effect can be achieved without preventing the reduction in the impedance in the lead **104** and the lead **105**.

[0048] As described above, according to the present embodiment, achievable is both the reduction in the impedance in the lead **104** and the lead **105** and the effect of anchoring the heatsink **101** and the molding material **109**, that is to say, the anchor effect.

Second Embodiment

[0049] Described are a semiconductor device, a high-frequency power amplifier including the semiconductor device, and a method of manufacturing the semiconductor device according to the present embodiment. In the description hereinafter, the same reference numerals as those described in the above embodiment will be assigned to the similar constituent elements in the drawings, and detailed description thereof is appropriately omitted.

[0050] <Configuration of Semiconductor Device>

[0051] FIG. **4** is a cross-sectional view along the X axis direction for schematically illustrating a configuration for achieving the semiconductor device according to the present embodiment.

[0052] As illustrated in FIG. **4**, the semiconductor device includes the heatsink **101**, the semiconductor element **102**, the matching element **103**, the wire **106**, the wire **107**, the wire **108**, the lead **104**, the lead **105**, and the molding material **109**.

[0053] Herein, when the semiconductor device is mounted on an external structure, in the heatsink **101**, the lower surface and the convex portions **101**_a_ and **101**_b_ which are the convex portions laterally protruding on the edge portion of the lower surface are grounded.

[0054] According to the structure illustrated in FIG. **4**, not only the lower surface of the heatsink **101** but also the convex portion **101**_a_ and the convex portion **101**_b_ are grounded, thus further reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead **104** and the heatsink **101** and the parasitic capacitance between the lead **105** and the heatsink **101** are grounded via the heatsink **101**.

[0055] The configuration of grounding the convex portion **101**_a_ and the convex portion **101**_b_ in the heatsink **101** illustrated in FIG. **4** are also formed in the similar manner in a configuration in the other embodiment described hereinafter as an example unless otherwise mentioned.

Third Embodiment

[0056] Described are a semiconductor device, a high-frequency power amplifier including the semiconductor device, and a method of manufacturing the semiconductor device according to the present embodiment. In the description hereinafter, the same reference numerals as those described in the above embodiment will be assigned to the similar constituent elements in the drawings, and detailed description thereof is appropriately omitted.

[0057] <Configuration of Semiconductor Device>

[0058] FIG. **5** is a plan view illustrating a shape of the heatsink in a semiconductor device according to the present embodiment. As illustrated in FIG. **5**, in a heatsink **201**, a cutting portion **226**, a cutting portion **227**, a cutting portion **228**, and a cutting portion **229** are provided in regions which do not overlap with a lead **204** and a lead **205** in a plan view.

[0059] In FIG. **5**, the convex portion **201**_a_ and the convex portion **201**_b_ are laterally formed on an edge portion of a lower surface of the heatsink **201**, and the cutting portion **226**, the cutting portion **227**, the cutting portion **228**, and the cutting portion **229** are formed in sides where the convex portion **201**_a_ and the convex portion **201**_b_ are not formed.

[0060] The convex portion **101**_c_ and the convex portion **101**_d_ illustrated in FIG. **2** are not formed in the heatsink **201**

illustrated in FIG. **5**, however, the convex portion **101***c* and the convex portion **101***d* illustrated in FIG. **2** may further be formed therein.

[0061] FIG. **6** is a cross-sectional view illustrating a structure of covering and fixing the heatsink **201**, the lead **204**, and the lead **205** illustrated in FIG. **5** by a molding material **209**. An illustration of a semiconductor element and a matching element covered by the molding material **209** is omitted for simplifying the drawing.

[0062] According to the structure illustrated in FIG. **5** and FIG. **6**, the cutting portion **226**, the cutting portion **227**, the cutting portion **228**, and the cutting portion **229** in the heatsink **201** are filled with the molding material **209**, thus the effect of anchoring the heatsink **201** and the molding material **209**, that is to say, the anchor effect can be achieved.

[0063] In the convex portion **201***a* in FIG. **6**, an upper end and a lower end of the convex portion **201***a* protrude in the similar manner, however, a degree of protrusion of the upper end and the lower end of the convex portion **201***a* is not limited to be similar to each other. That is to say, it is also applicable that a protrusion amount of the upper end of the convex portion **201***a* is small and a protrusion amount of the lower end thereof is large, thus the convex portion **201***a* has an inclined shape (a tapered shape) in whole. In the similar manner, the convex portion **201***b* may also have an inclined shape (a tapered shape) in whole.

Fourth Embodiment

[0064] Described are a semiconductor device, a high-frequency power amplifier including the semiconductor device, and a method of manufacturing the semiconductor device according to the present embodiment. In the description hereinafter, the same reference numerals as those described in the above embodiment will be assigned to the similar constituent elements in the drawings, and detailed description thereof is appropriately omitted.

[0065] <Configuration of Semiconductor Device>

[0066] FIG. **7** is a cross-sectional view along the X axis direction for schematically illustrating a configuration for achieving the semiconductor device according to the present embodiment. FIG. **7** illustrates a mold shape used in a process of sealing with the molding material in the semiconductor device.

[0067] As illustrated in FIG. **7**, the semiconductor device includes a heatsink **301**, a semiconductor element **302**, a matching element **303**, a wire **306**, a wire **307**, a wire **308**, a lead **304**, a lead **305**, and a molding material **309**.

[0068] In FIG. **7**, a convex portion **301***a* and a convex portion **301***b* are laterally formed on an edge portion of a lower surface of the heatsink **301**.

[0069] An upper surface side mold **321**, a lower surface side mold **322**, and a lower surface side mold **323** are used in the process of sealing with the molding material **309**. A support substrate **324** is a substrate supporting the heatsink **301**.

[0070] In a case illustrated in FIG. **7**, the heatsink **301** whose lower surface is grounded is prepared firstly. Then, the semiconductor element **302** and the matching element **303** are disposed on an upper surface of the heatsink **301** via a bonding material. Then, the lead **304** electrically connected to the semiconductor element **302** via the wire **306** and the lead **305** electrically connected to the matching element **303** via the wire **308** are disposed on an upper side of the heatsink **301**.

[0071] Herein, the heatsink **301** are disposed to partially overlap with the lead **304** and the lead **305** in a plan view. Formed on an edge portion of a lower surface in a position, in the heatsink **301**, overlapping with the lead **304** in a plan view is a convex portion **301***a* protruding more than an edge portion of an upper surface in the position. Formed on the edge portion of the lower surface in a position, in the heatsink **301**, overlapping with the lead **305** in a plan view is a convex portion **301***b* protruding more than the edge portion of the upper surface in the position.

[0072] Formed on the edge portion of the upper surface in a position, in the heatsink **301**, not overlapping with the lead **304** in a plan view is the convex portion **101***c* protruding more than the edge portion of the lower surface in the position (refer to FIG. **2**). Formed on the edge portion of the upper surface in a position, in the heatsink **301**, not overlapping with the lead **305** in a plan view is the convex portion **101***d* protruding more than the edge portion of the lower surface in the position (refer to FIG. **2**).

[0073] Formed then is the molding material **309** covering part of the lead **304**, part of the heatsink **301**, and the semiconductor element **302**. Herein, the molding material **309** is formed in such a manner as to expose at least an end portion of each of the convex portion **301***a* and the convex portion **301***b* in the heatsink **301**.

[0074] The support substrate **324** supporting the upper surface side mold **321**, the lower surface side mold **322**, the lower surface side mold **323**, and the heatsink **301** are used, thus the semiconductor device according to the present embodiment, for example, a high-frequency power amplifier can be manufactured.

Fifth Embodiment

[0075] Described are a semiconductor device, a high-frequency power amplifier including the semiconductor device, and a method of manufacturing the semiconductor device according to the present embodiment. In the description hereinafter, the same reference numerals as those described in the above embodiment will be assigned to the similar constituent elements in the drawings, and detailed description thereof is appropriately omitted.

[0076] <Configuration of Semiconductor Device>

[0077] FIG. **8** is a cross-sectional view along the X axis direction for schematically illustrating a configuration for achieving the semiconductor device according to the present embodiment. FIG. **8** illustrates a mold shape used in a process of sealing with the molding material in the semiconductor device.

[0078] As illustrated in FIG. **8**, the semiconductor device includes a heatsink **401**, the semiconductor element **302**, the matching element **303**, the wire **306**, the wire **307**, the wire **308**, the lead **304**, the lead **305**, and the molding material **309**.

[0079] The upper surface side mold **321**, a lower surface side mold **322***a*, and a lower surface side mold **323***a* are used in the process of sealing with the molding material **309**. The support substrate **324** is the substrate supporting the heatsink **401**.

[0080] In FIG. **8**, a convex portion **401***a* and a convex portion **401***b* are laterally formed on an edge portion of a lower surface of the heatsink **401**.

[0081] A shape of the mold and the heatsink **401** in FIG. **8** suppresses an intrusion of the molding material **309** around a side surface of the convex portion **401***a*, a side surface of the convex portion **401***b*, or a lower surface of the heatsink **401** in the process of sealing with the molding material **309**.

[0082] Specifically, the heatsink **401** includes a notch **402***a* formed in a lower surface of the convex portion **401***a* and a notch **402***b* formed in a lower surface of the convex portion **401***b*. A projection length of the lower surface of the heatsink **401**, that is to say, a lateral protrusion length of each convex portion is set to be long enough to be able to prevent the intrusion of the molding material **309**.

[0083] After the sealing with a molding resin of the molding material **309**, the upper surface side mold **321**, the lower surface side mold **322***a*, the lower surface side mold **323***a*, and the support substrate **324** used in the process of sealing with the molding material **309** are removed, and subsequently, part of the heatsink **401** is cut at a position **403***a* and a position **403***b*, starting from the notch **402***a* and the notch **402***b*. Specifically, part of the convex portion **401***a* and part of the convex portion **401***b* are cut.

[0084] FIG. **9** is a drawing illustrating an outer shape of a package after being cut in the process subsequent to the formation of the molding material resin. In FIG. **9**, a region **501***a* and a region **501***b* correspond to the parts of the heatsink which has been cut, specifically to portions where the part of the convex portion **401***a* and the part of the convex portion **401***b* used to be, respectively.

[0085] The projection length of the lower side of the heatsink **401**, that is to say, the lateral protrusion length of each convex portion is set to be long enough to be able to prevent the intrusion of the molding material **309**, thus the intrusion of the molding resin around the side surface of the convex portion **401***a*, the side surface of the convex portion **401***b*, or the lower surface of the heatsink **401** can be suppressed.

[0086] Accordingly, the impedance in the lead **304** and the lead **305** in FIG. **8** can be reduced while suppressing the intrusion of the molding resin.

Effects Generated by Embodiments Described Above

[0087] Effects generated by the above described embodiments are described next. It should be noted that, in the following description, the effects are described based on the specific configurations illustrated in the above described embodiments, however, other specific configurations may be applied in place of the configurations illustrated in the specification, within the scope of producing the similar effects.

[0088] Also, the replacement may be implemented with a plurality of embodiments. That is to say, each of the configurations illustrated in the corresponding embodiments may be combined with one another to produce the similar effects.

[0089] According to the embodiment described above, the semiconductor device includes the heatsink **101**, the semiconductor element **102**, at least one lead **104**, and the molding material **109**. At least the lower surface of the heatsink **101** is grounded. The semiconductor element **102** is disposed on the upper surface of the heatsink **101**. The high-frequency signal is input to or output from the semiconductor element **102**. The lead **104** is electrically connected to the semiconductor element **102** via the wire **106**. The lead **104** is disposed on the upper side of the heatsink **101**. Formed is the molding material **109** covering the part of the lead **104**, at least the upper surface of the heatsink **101**, and the semiconductor element **102**. Herein, the heatsink **101** is disposed to partially overlap with the lead **104** in a plan view. Formed on the edge portion of the lower surface in the position, in the heatsink **101**, overlapping with the lead **104** in a plan view is at least first convex portion protruding more than the edge portion of the upper surface in the position. Formed on the edge portion of the upper surface in the position, in the heatsink **101**, not overlapping with the lead **104** in a plan view is at least second convex portion protruding more than the edge portion of the lower surface in the position. Herein, the first convex portion corresponds to at least one of the convex portion **101***a*, the convex portion **201***a*, the convex portion **101***b*, and the convex portion **201***b*, for example. The second convex portion corresponds to at least one of the convex portion **101***c* and the convex portion **101***d*, for example.

[0090] According to such a configuration, the parasitic inductance component in the lateral direction of the heatsink **101** is reduced in the region where the heatsink **101** overlaps with the lead **104** in the up-down direction. Reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead **104** and the heatsink **101** is grounded via the heatsink **101**. Accordingly, the impedance in the lead **104** can be reduced. That is to say, the impedance in the lead connected to the semiconductor element **102** can be reduced while achieving the effect of anchoring the molding material by the convex portion **101***c* and the convex portion **101***d*.

[0091] It should be noted that the description of the other configurations other than the configurations illustrated in the specification of the present application can be appropriately omitted. That is to say, as long as the described configurations are provided, the above described effects can be produced.

[0092] However, even in the case where at least one of the other configurations other than the configurations illustrated in the specification of the present application is appropriately added to the configuration described above, that is to say, other configurations other than the configurations illustrated in the specification of the present application, which are not referred to as configurations described above are appropriately added, the similar effects can be produced.

[0093] According to the embodiment described above, the convex portion **101***a* in the heatsink **101** is exposed from the molding material **109**. The lower surface and the convex portion **101***a* in the heatsink **101** are grounded. According to such a configuration, not also the lower surface but also the convex portion **101***a* in the heatsink **101** are grounded, thus further reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead **104** and the heatsink **101** is grounded via the heatsink **101**.

[0094] According to the embodiments described above, at least one cutting portion **226** is formed in the edge portion of the upper surface in the position, in the heatsink **201**, which does not overlap with the lead **204** in a plan view. Then, the cutting portion **226** is filled with the molding material **209**. According to such a configuration, the cutting portion **226** in the heatsink **201** is filled with the molding material **209**, thus the effect of anchoring the heatsink **201** and the molding material **209**, that is to say, the anchor effect can be achieved.

[0095] According to the embodiment described above, the semiconductor device includes the heatsink **201**, the semiconductor element **102**, at least one lead **204**, and the molding material **209**. At least the lower surface of the heatsink **201** is grounded. The semiconductor element **102** is disposed on the upper surface of the heatsink **201**, and the high-frequency signal is input to or output from the semiconductor element **102**. The lead **204** is electrically connected to the semiconductor element **102** via the wire **106**. The lead **204** is disposed on the upper side of the heatsink **201**. Formed is the molding material **209** covering the part of the lead **204**, at least the upper surface of the heatsink **201**, and the semiconductor element **102**. Herein, the heatsink **201** is disposed to partially overlap with the lead **204** in a plan view. Formed on the edge portion of the lower surface in the position, in the heatsink **201**, overlapping with the lead **204** in a plan view is at least one convex portion **201***a* protruding more than the edge portion of the upper surface in the position. At least one cutting portion **226** is formed in the edge portion of the upper surface in the position, in the heatsink **201**, which does not overlap with the lead **204** in a plan view. Then, the cutting portion **226** is filled with the molding material **209**.

[0096] According to such a configuration, the cutting portion **226** in the heatsink **201** is filled with the molding material **209**, thus the effect of anchoring the heatsink **201** and the molding material **209**, that is to say, the anchor effect can be achieved. The parasitic inductance component in the lateral direction of the heatsink **201** is reduced in the region where the heatsink **201** overlaps with the lead **204** in the up-down direction. Reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead **204** and the heatsink **201** is grounded via the heatsink **201**. Accordingly, the impedance in the lead **204** can be reduced. That is to say, the reduction in the impedance in the lead connected to the semiconductor element **102** can be achieved while achieving the effect of anchoring the molding material by the cutting portion **226**.

[0097] It should be noted that the description of the other configurations other than the configurations illustrated in the specification of the present application can be appropriately omitted. That is to say, as long as the described configurations are provided, the above described effects can be produced.

[0098] However, even in the case where at least one of the other configurations other than the configurations illustrated in the specification of the present application is appropriately added to the configuration described above, that is to say, other configurations other than the configurations illustrated in the specification of the present application, which are not referred to as configurations described above are appropriately added, the similar effects can be produced.

[0099] According to the embodiment described above, the convex portion **201***a* in the heatsink **201** is exposed from the molding material **209**. The lower surface and the convex portion **201***a* in the heatsink **201** are grounded. According to such a configuration, not also the lower surface but also the convex portion **201***a* in the heatsink **201** are grounded, thus further reduced is the parasitic inductance component at the time when the parasitic capacitance between the lead **204** and the heatsink **201** is grounded via the heatsink **201**.

[0100] According to the embodiment described above, the high-frequency power amplifier includes the semiconductor device described above. According to such a configuration, the impedance in the lead can be reduced, thus the high-frequency performance can be enhanced.

[0101] According to the embodiments described above, the heatsink **401** at least whose lower surface is grounded is prepared in the method of manufacturing the semiconductor device. Then, disposed on the upper surface of the heatsink **401** is the semiconductor element **302** which the high-frequency signal is input to or output from. Then, at least one lead **304** electrically connected to the semiconductor element **302** via the wire **306** is disposed on the upper side of the heatsink **401**. Herein, the heatsink **401** is disposed to partially overlap with the lead **304** in a plan view. Formed on the edge portion of the lower surface in the position, in the heatsink **401**, overlapping with the lead **304** in a plan view is at least one first convex portion protruding more than the edge portion of the upper surface in the position. Formed on the edge portion of the upper surface in the position, in the heatsink **403**, which does not overlap with the lead **304** in a plan view is at least one second convex portion protruding more than the edge portion of the lower surface in the position. Formed then is the molding material **309** covering the part of the lead **304**, the part of the heatsink **401**, and the semiconductor element **302**. Herein, the molding material **309** is formed in such a manner as to expose at least the end portion of the first convex portion in the heatsink **401**. Then, the end portion of the first convex portion is cut after forming the molding material **309**. Herein, the first convex portion corresponds to at least one of the convex portion **401***a* and the convex portion **401***b*, for example. The second convex portion corresponds to at least one of the convex portion **101***c* and the convex portion **101***d*, for example.

[0102] According to such a configuration, the projection length of the lower side of the heatsink **401**, that is to say, the lateral protrusion length of each of the convex portion **401***a* and the convex portion **401***b* is set to be long enough to be able to prevent the intrusion of the molding material **309**, thus the intrusion of the molding resin around the side surface of the convex portion **401***a*, the side surface of the convex portion **401***b*, or the lower surface of the heatsink **401** can be suppressed. Accordingly, the semiconductor device capable of reducing the impedance in the lead **304** and the lead **305** while suppressing the intrusion of the molding resin can be manufactured.

[0103] It should be noted that the description of the other configurations other than the configurations illustrated in the specification of the present application can be appropriately omitted. That is to say, as long as the described configurations are provided, the above described effects can be produced.

[0104] However, even in the case where at least one of the other configurations other than the configurations illustrated in the specification of the present application is appropriately added to the configuration described above, that is to say, other configurations other than the configurations illustrated in the specification of the present application, which are not referred to as configurations described above are appropriately added, the similar effects can be produced.

[0105] The order of performing each processing can be changed unless there is a specific limitation.

[0106] According to the embodiments described above, the end portion of the convex portion **401***a* is cut from the notch **402***a* in the convex portion **401***a*. According to such a configuration, a tip portion of the convex portion **401***a* can be easily cut from a predetermined position.

Modification Example in Embodiments Described Above

[0107] In the embodiments described above, material properties, materials, dimensions, shapes, relative arrangement relations, conditions for implementation, and so forth for the respective constituent elements may be described, however, these represent a mare example in all aspects, and are not limited to the description in the specification of the present application.

[0108] Accordingly, it is understood that numerous other modifications variations, and equivalents can be devised without departing from the scope of the technique disclosed in the specification of the present application. For example, the following cases where at least one of the constituent elements is to be modified, added, or omitted, further, at least one of the constituent elements of at least one of the embodiments is extracted and then combined with constituent elements of the other embodiment, are involved.

[0109] The "one" constituent element described in the above embodiments may be "one or more" constituent elements so far as consistent with the embodiments.

[0110] Further, individual constituent elements are conceptual units. Thus, within the range of the technique disclosed in the specification of the present application, one constituent element may include multiple structures, one constituent element may correspond to part of some structure, and multiple constituent elements may be included in one structure.

[0111] Each constituent element includes a structure having a different configuration or a different shape as long as the structure of the different configuration or the different shape achieves the same function.

[0112] What has been described in the specification of the present application is referred for all purposes regarding the present technique. It is thus not an admission that any of the descriptions provided herein are conventional techniques.

[0113] Further, in the embodiments described above, when names of materials are stated unless otherwise specified, an alloy of the material and other additives, and so forth are included, so far as consistent with the embodiments.

EXPLANATION OF REFERENCE SIGNS

[0114] **101**, **201**, **301**, **401**, and **901** heatsink, **101***a*, **101***b*, **101***c*, **101***d*, **201***a*, **201***b*, **301***a*, **301***b*, **401***a*, **401***b*, **901***a*, and **901***b* convex portion, **102**, **302**, and **902** semiconductor element, **103**, **303**, and **903** matching element, **104**, **105**, **204**, **205**, **304**, **305**, **904**, and **905** lead, **106**, **107**, **108**, **306**, **307**, **308**, **906**, **907**, and **908** wire, **109**, **209**, **309**, and **909** molding material, **226**, **227**, **228**, and **229** cutting portion, **321** upper surface side mold, **322**, **322***a*, **323**, and **323***a* lower surface side mold, **324** support substrate, **402***a* and **402***b* notch, **403***a* and **403***b* position, **501***a* and **501***b* region, **1000** and **1001** bonding material

1. A semiconductor device, comprising:

a heatsink at least whose lower surface is grounded;

a semiconductor element which is disposed on an upper surface of the heatsink and a high-frequency signal is input to or output from;

at least one lead electrically connected to the semiconductor element via a wire and disposed on an upper side of the heatsink; and

a molding material formed to cover part of the lead, at least an upper surface of the heatsink, and the semiconductor element, wherein

the heatsink is disposed to partially overlap with the lead in a plan view,

on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position is formed, and

on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, at least one second convex portion protruding more than an edge portion of a lower surface in the position is formed.

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

the first convex portion in the heatsink is exposed from the molding material, and

a lower surface and the first convex portion in the heatsink are grounded.

3. The semiconductor device according to claim **1**, wherein

at least one cutting portion is formed in an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, and

the cutting portion is filled with the molding material.

4. A high-frequency power amplifier, comprising

the semiconductor device according to claim **1**.

5.-**7**. (canceled)

8. A method of manufacturing a semiconductor device, comprising:

preparing a heatsink at least whose lower surface is grounded;

locating, on an upper surface of the heatsink, a semiconductor element which a high-frequency signal is input to or output from;

locating at least one lead electrically connected to the semiconductor element via a wire on an upper side of the heatsink;

locating the heatsink to partially overlap with the lead in a plan view;

forming, on an edge portion of a lower surface in a position, in the heatsink, overlapping with the lead in a plan view, at least one first convex portion protruding more than an edge portion of an upper surface in the position;

forming, on an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, at least one second convex portion protruding more than an edge portion of a lower surface in the position;

forming a molding material covering part of the lead, part of the heatsink, and the semiconductor element;

exposing at least an end portion of the first convex portion in the heatsink to form the molding material; and

cutting the end portion of the first convex portion after forming the molding material.

9. The method of manufacturing the semiconductor device according to claim **8**, wherein

an end portion of the first convex portion is cut from a notch in the first convex portion.

10. The semiconductor device according to claim **2**, wherein at least one cutting portion is formed in an edge portion of an upper surface in a position, in the heatsink, which does not overlap with the lead in a plan view, and

the cutting portion is filled with the molding material.

11. The high-frequency power amplifier, comprising the semiconductor device according to claim **2**.

12. The high-frequency power amplifier, comprising the semiconductor device according to claim **3**.

* * * * *