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

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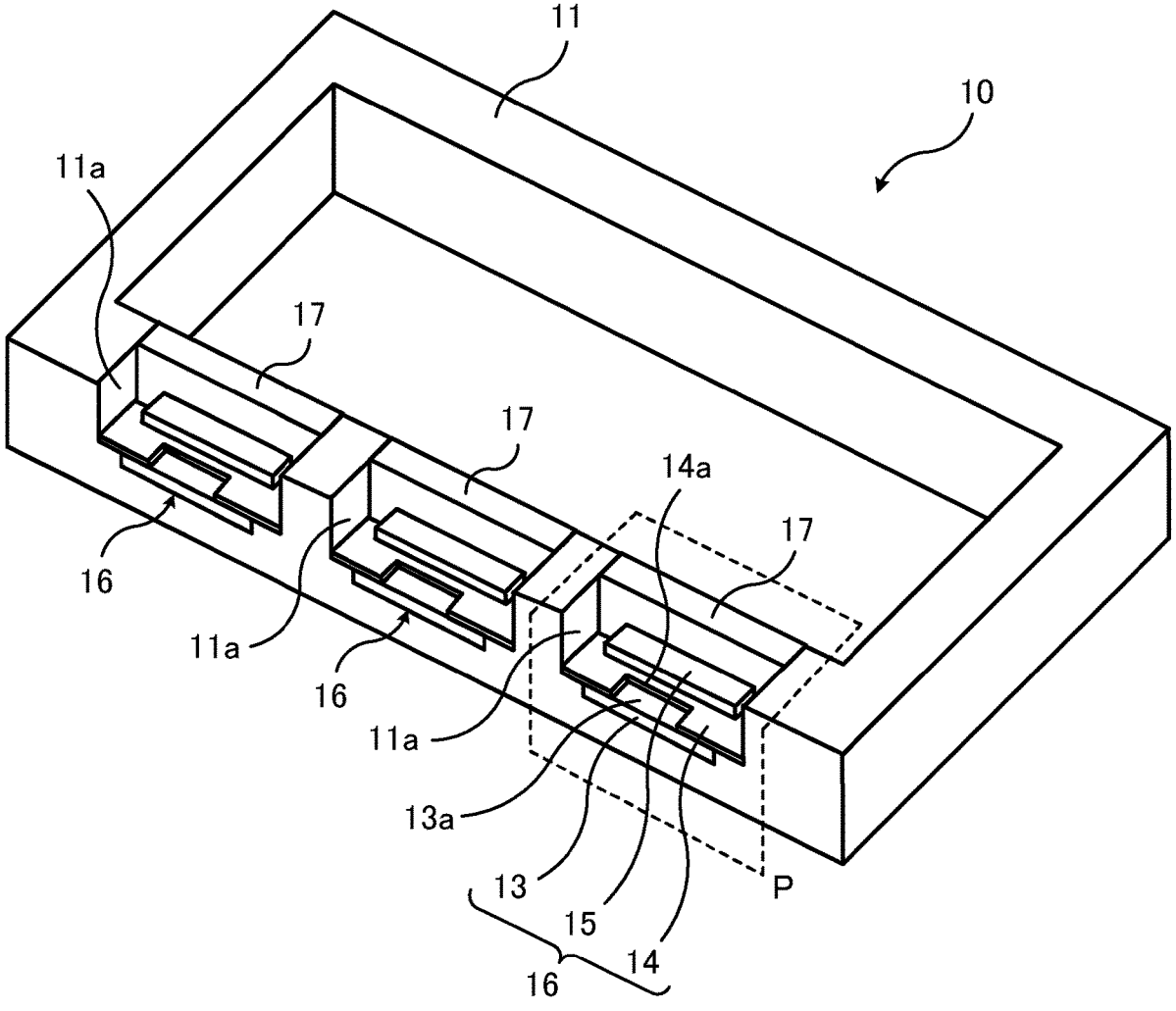
(57) **ABSTRACT**

A semiconductor module (semiconductor device) includes a case that has a side wall to form a frame, the side wall having a concave portion, a multi-layer structure in which a first terminal, an insulating sheet, and a second terminal are stacked in that order and which is disposed on the concave portion, and a beam member that is attached to the concave portion of the case to fix the multi-layer structure disposed on the concave portion.



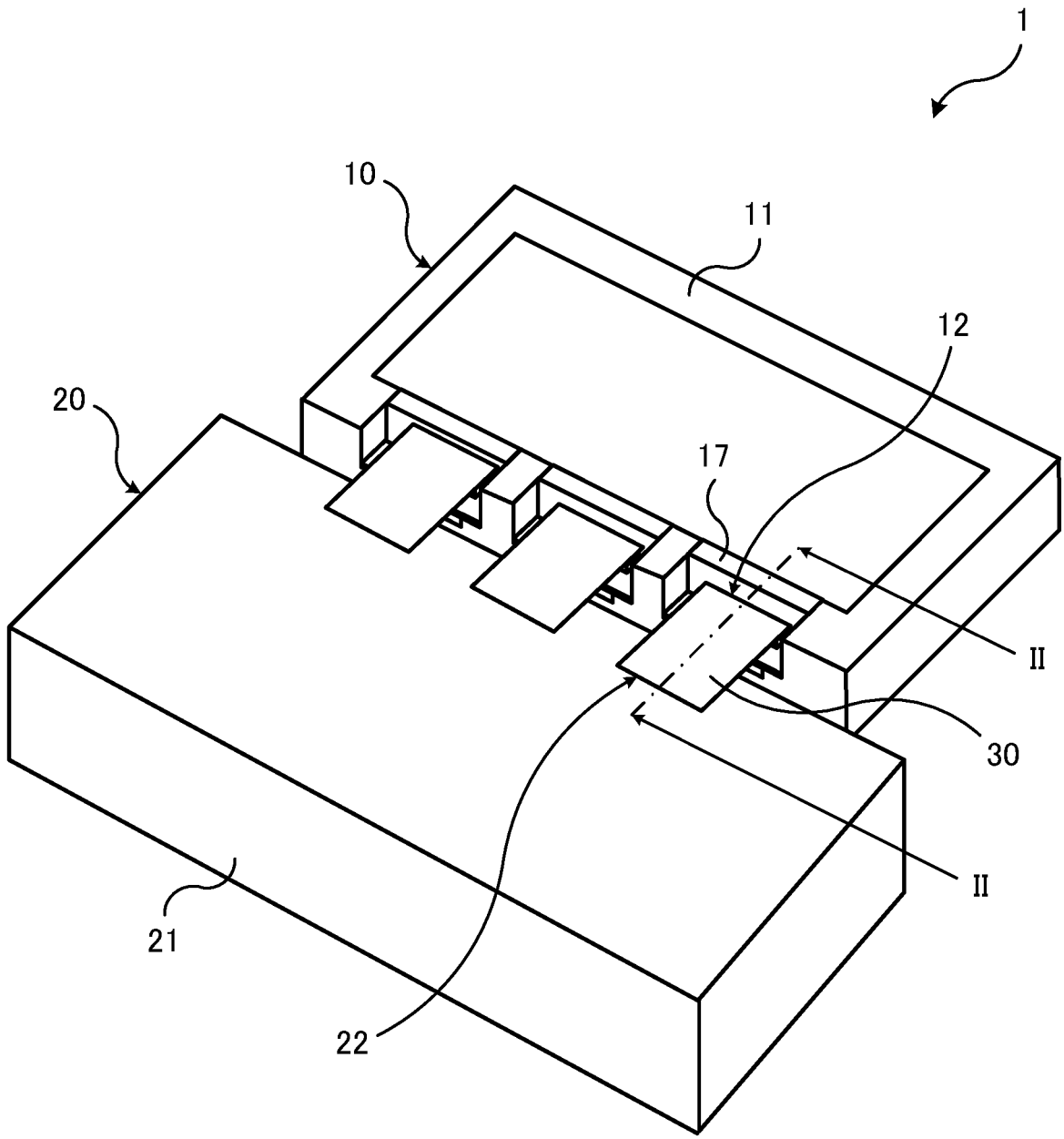


FIG. 1

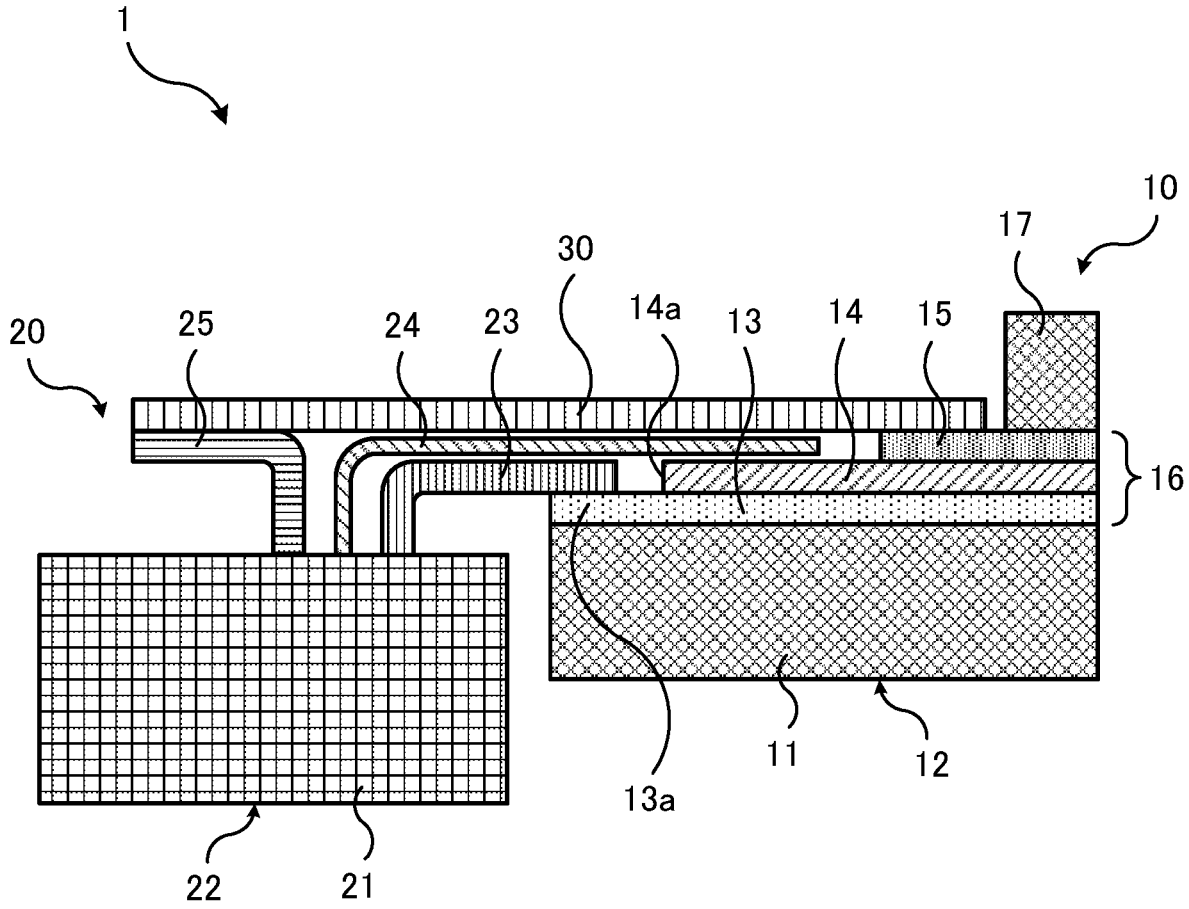


FIG. 2

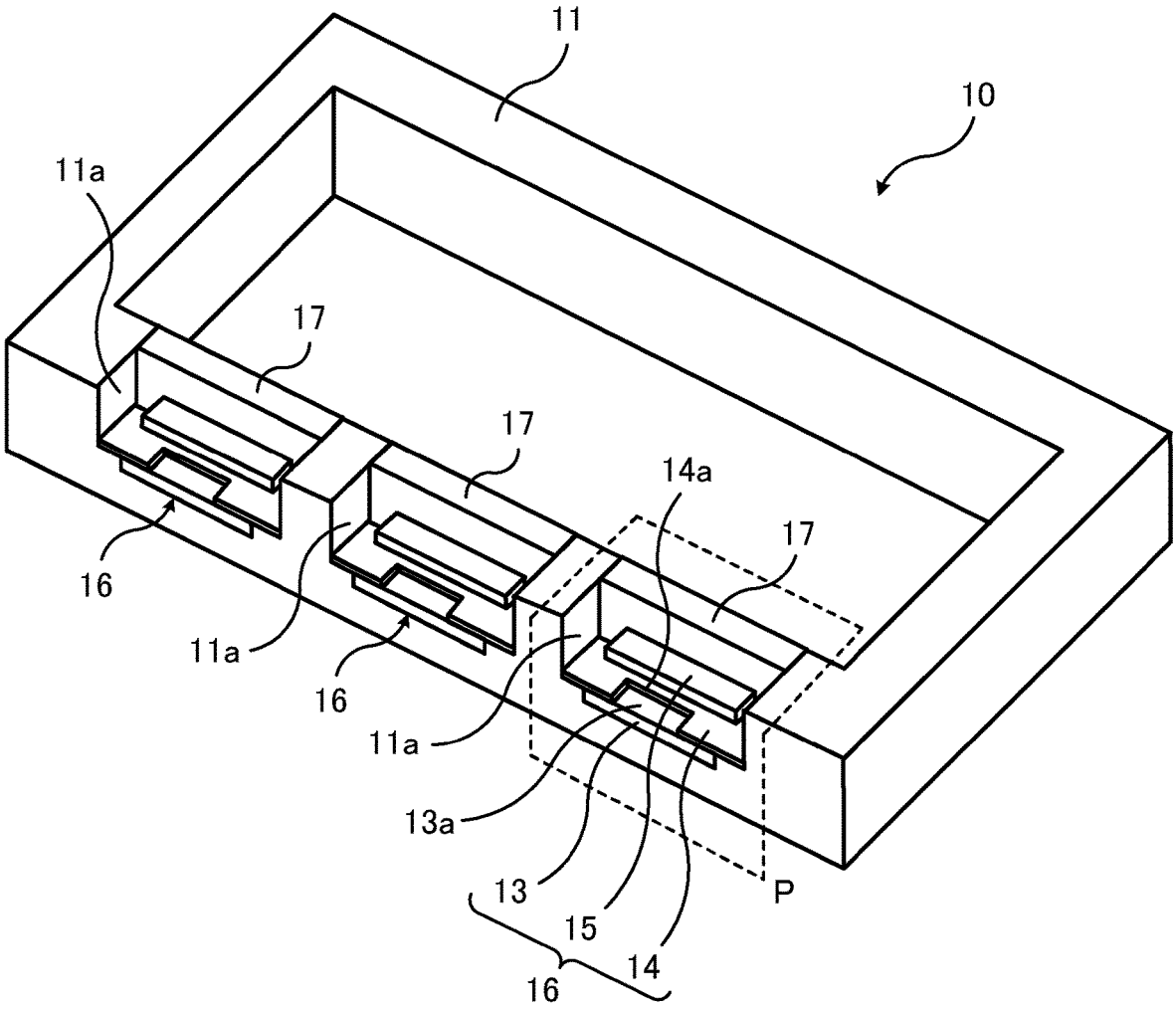


FIG. 3

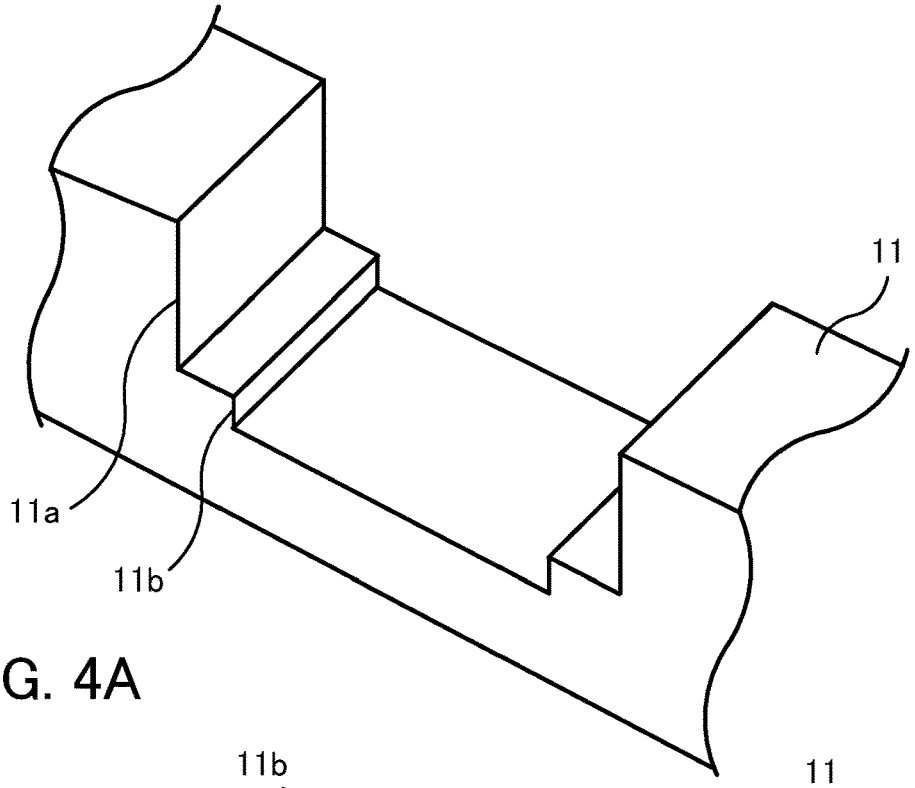


FIG. 4A

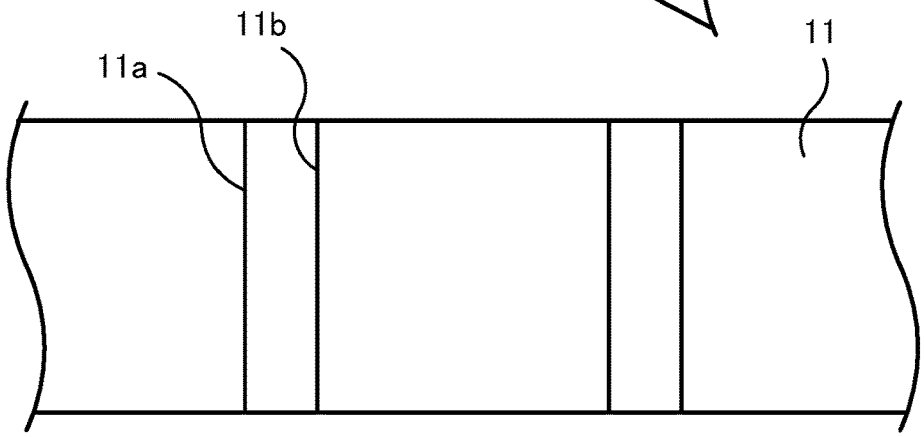


FIG. 4B

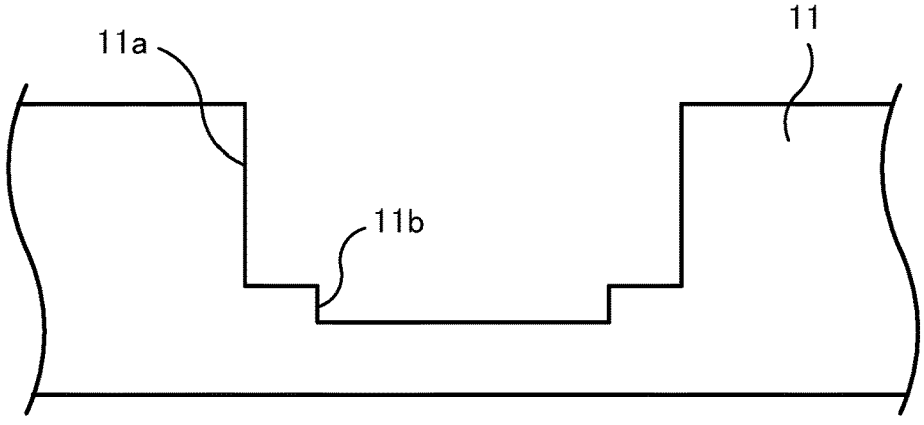


FIG. 4C

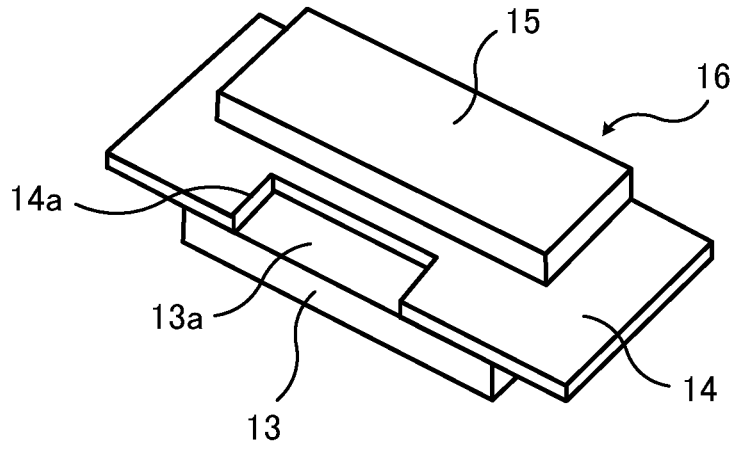


FIG. 5A

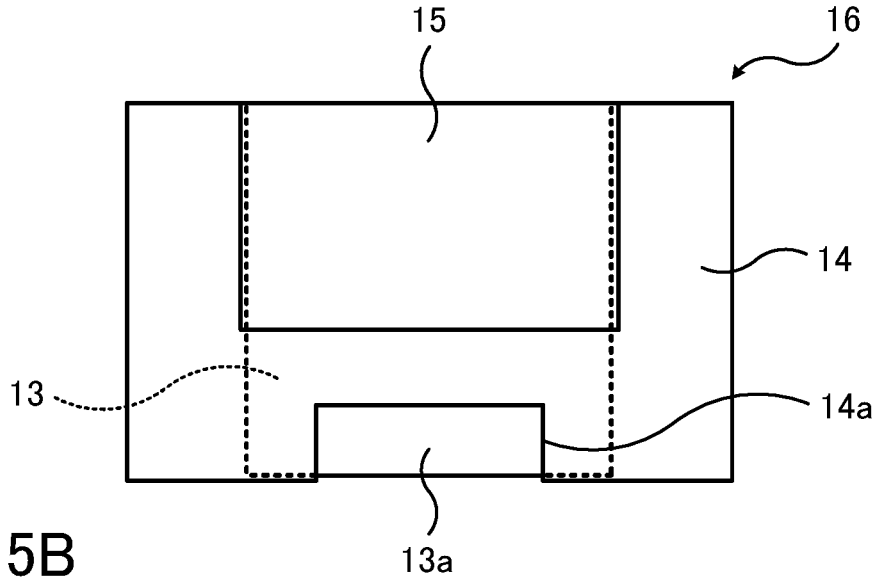


FIG. 5B

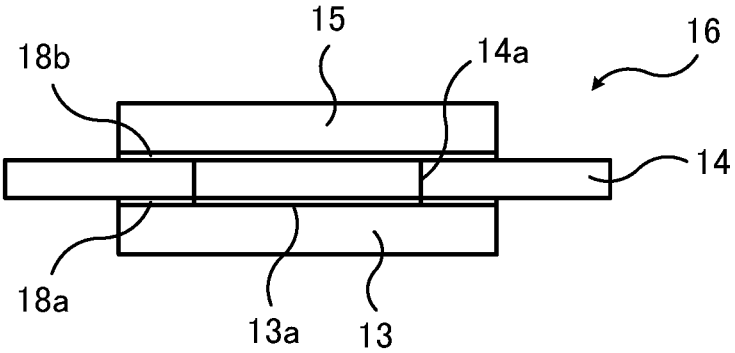


FIG. 5C

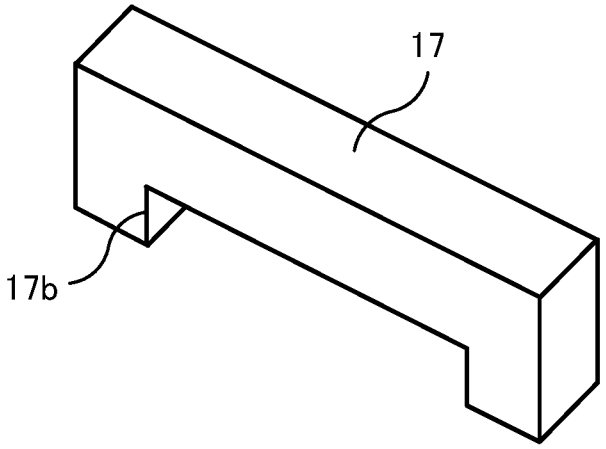


FIG. 6A

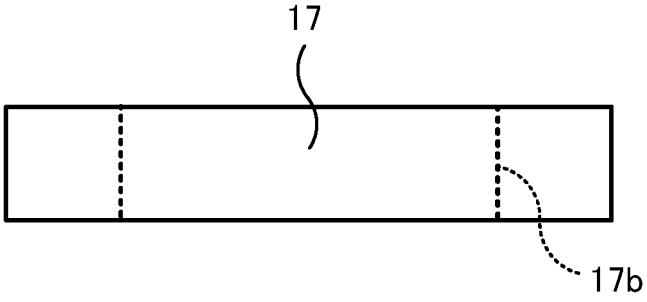


FIG. 6B

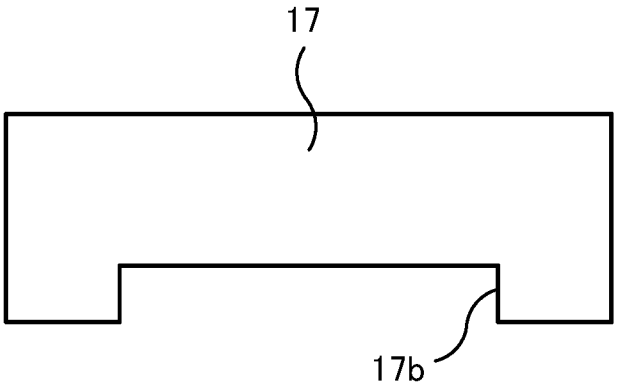


FIG. 6C

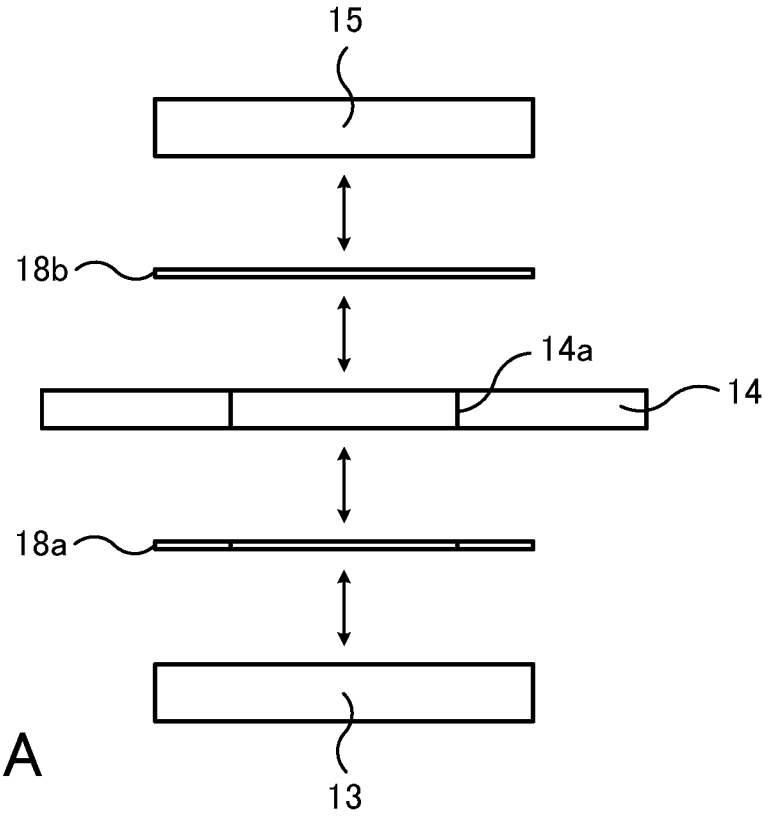


FIG. 7A

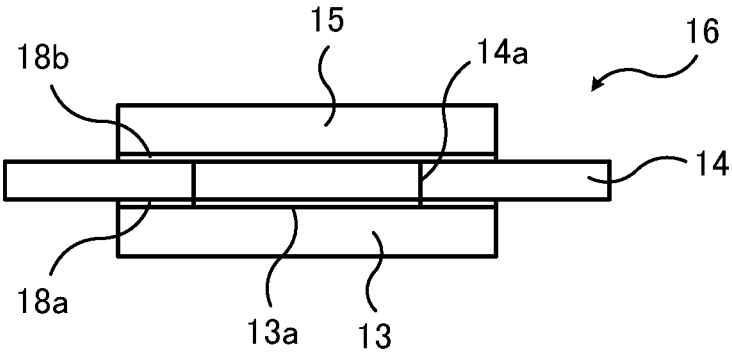


FIG. 7B

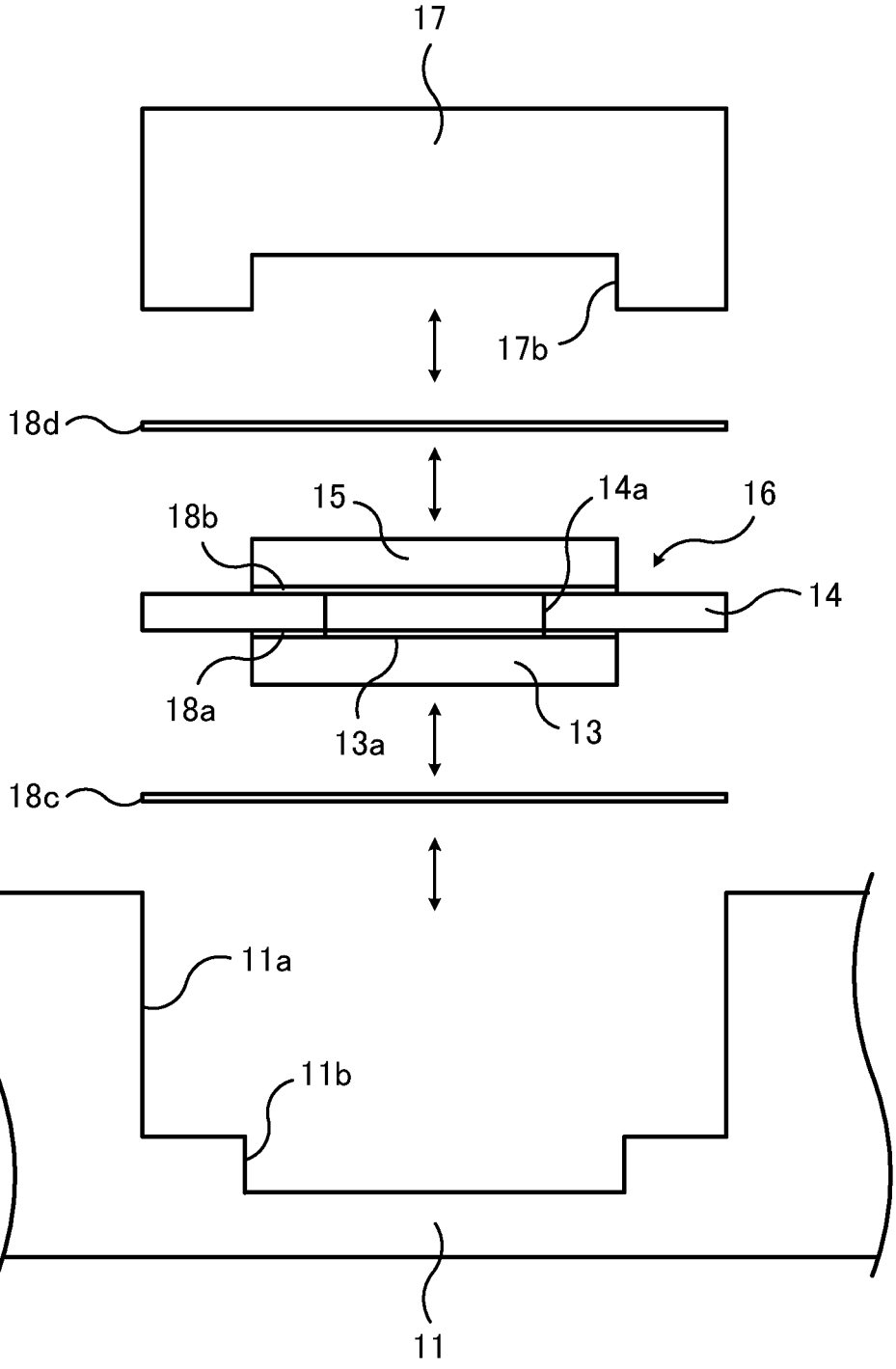


FIG. 8

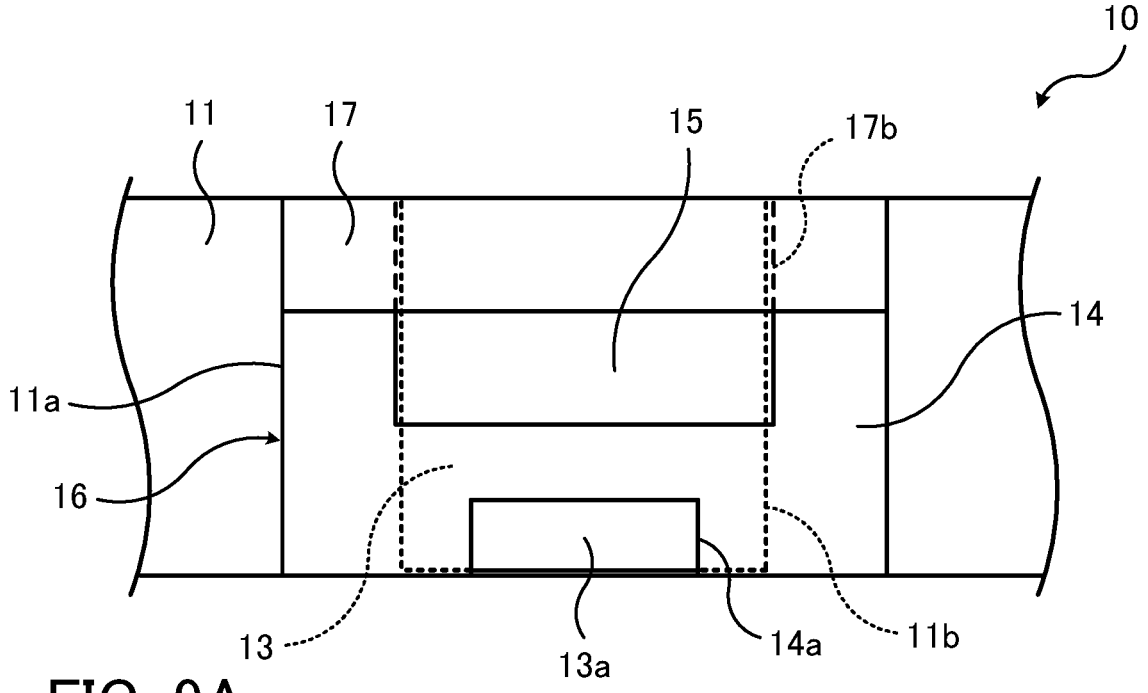

10
11
17
15
17b
14
11a
16
13
13a
14a
11b

FIG. 9A

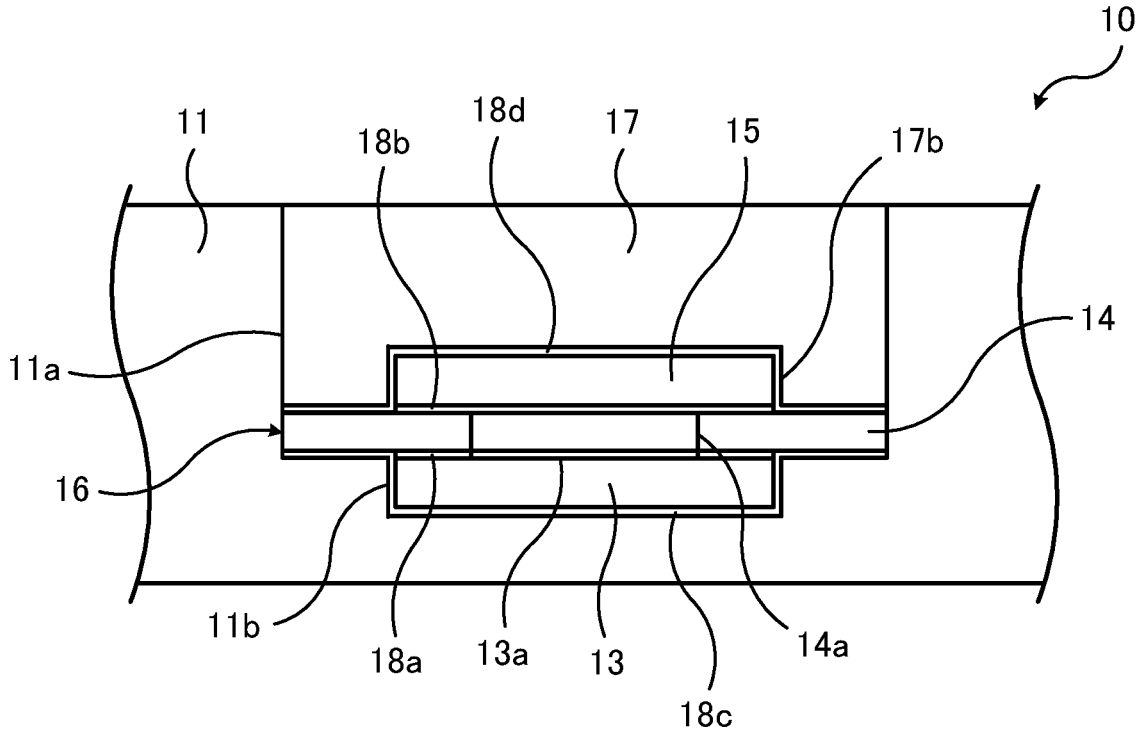

10
11
18b
18d
17
15
17b
14
11a
16
11b
18a
13a
13
18c
14a

FIG. 9B

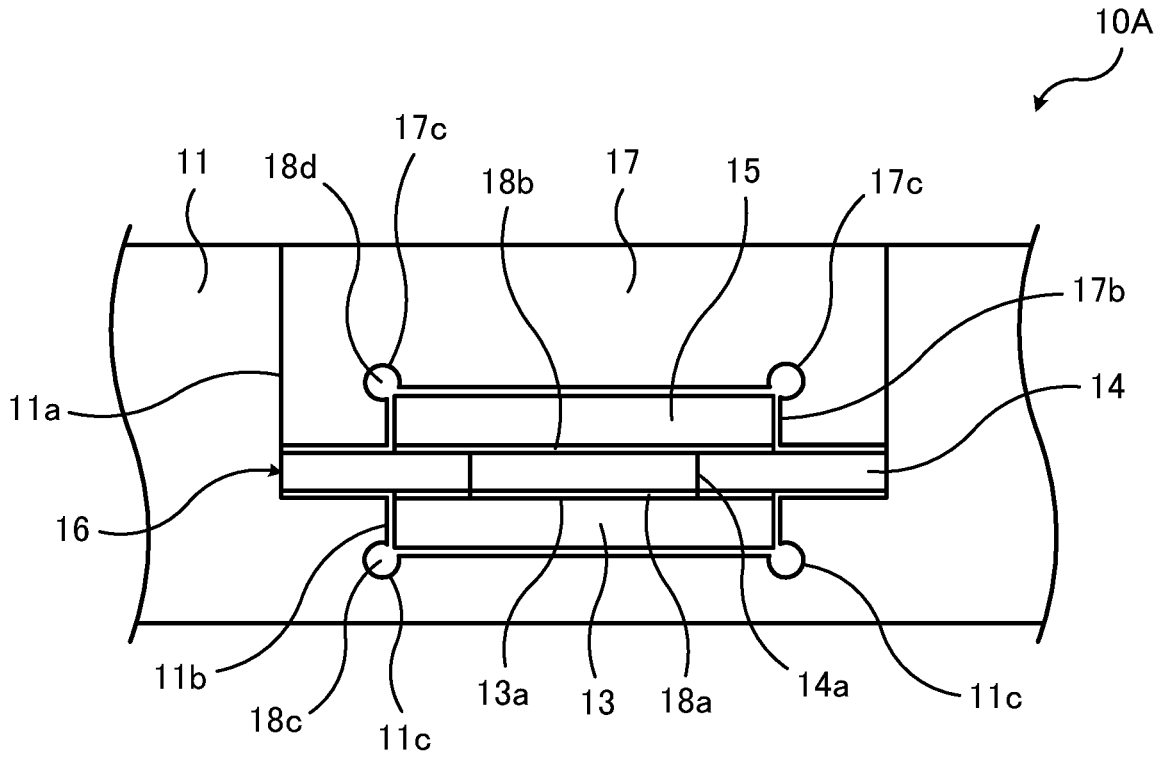

10A
11
18d
17c
18b
17
15
17c
17b
14
11a
16
11b
18c
11c
13a
13
18a
14a
11c

FIG. 10

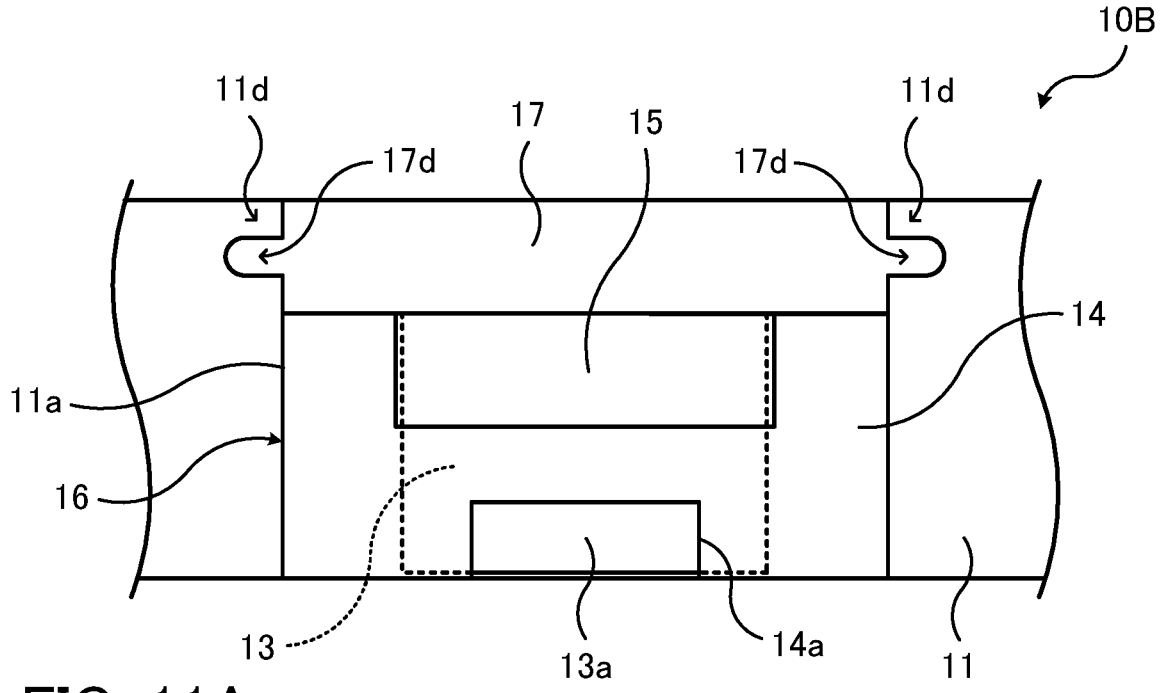


FIG. 11A

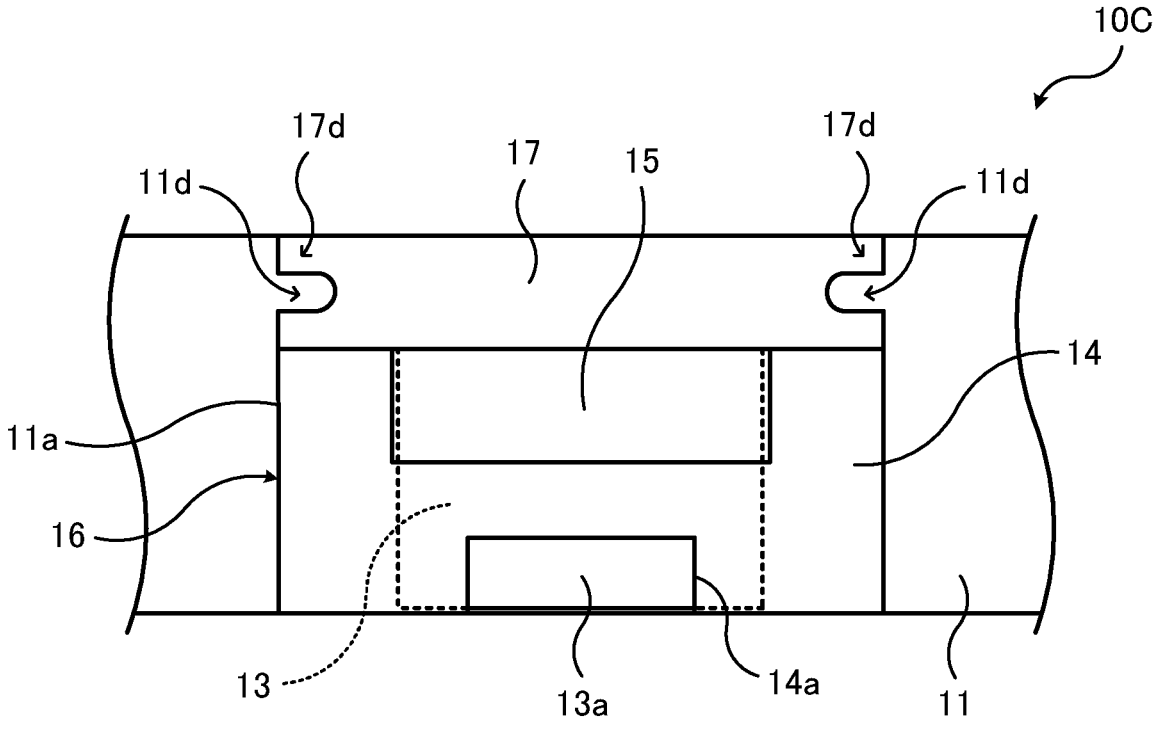


FIG. 11B

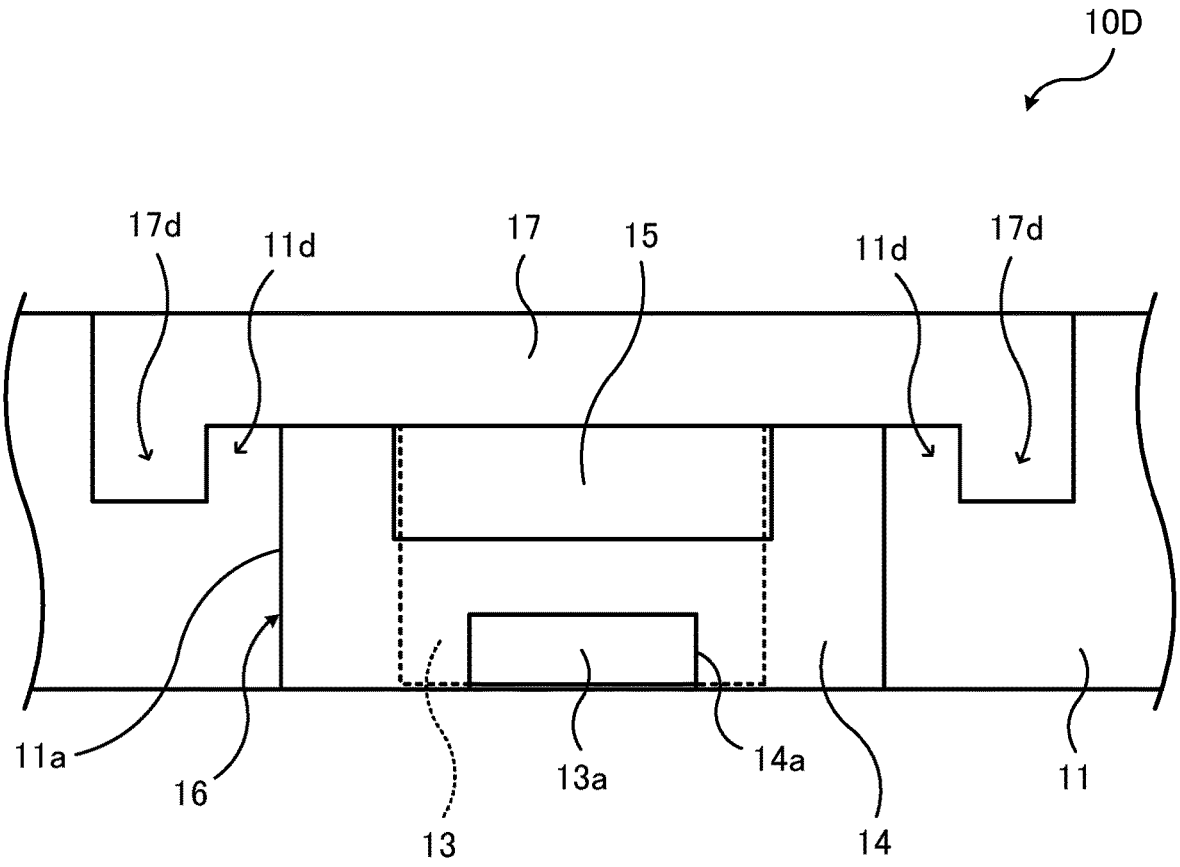


FIG. 12

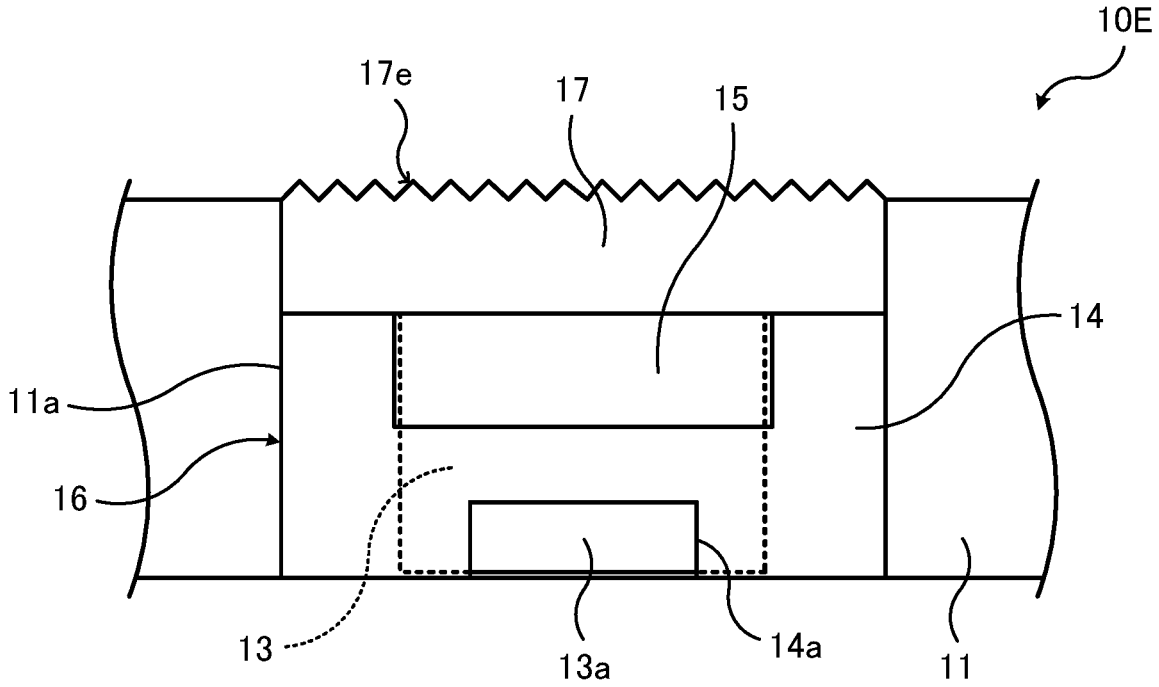


FIG. 13A

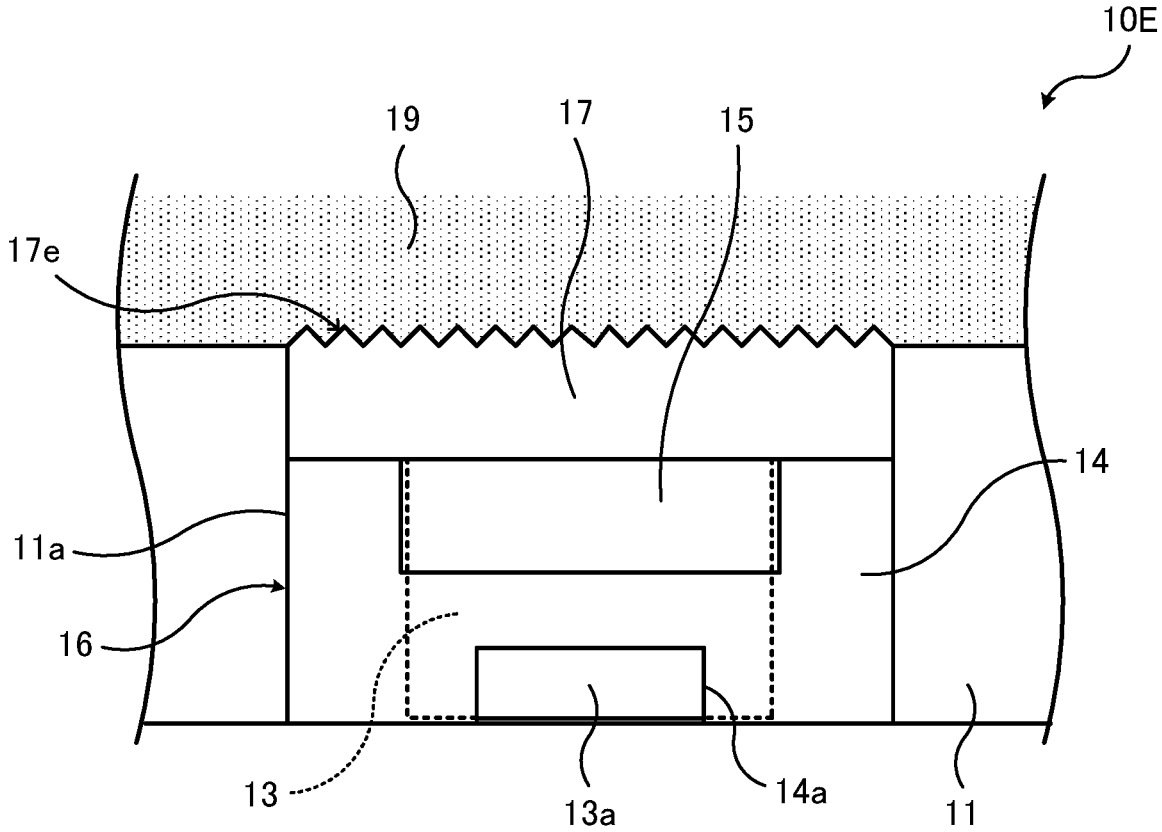


FIG. 13B

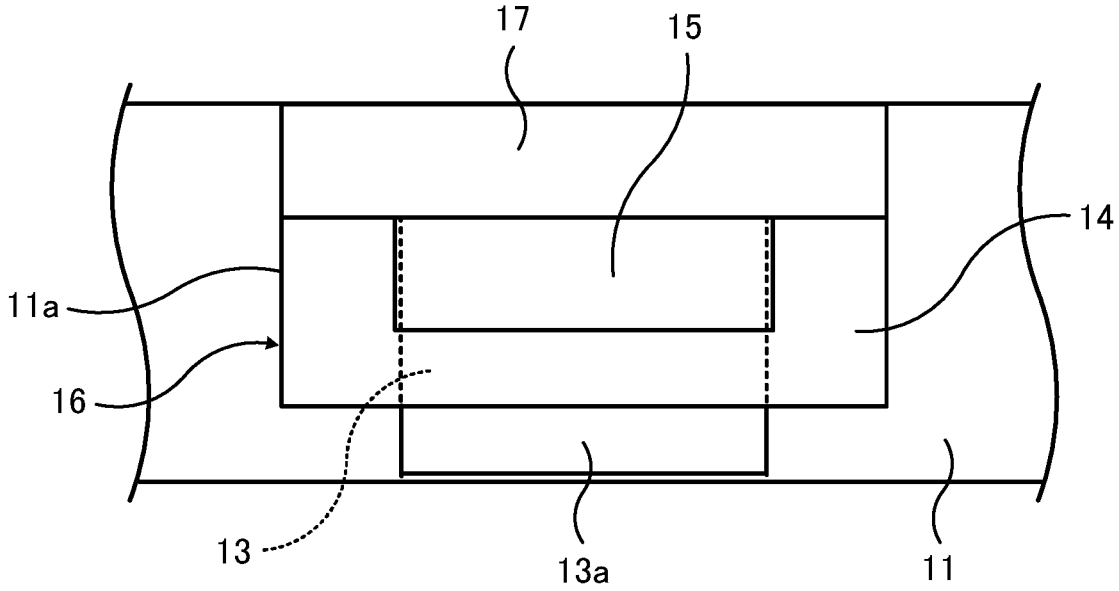


FIG. 14A

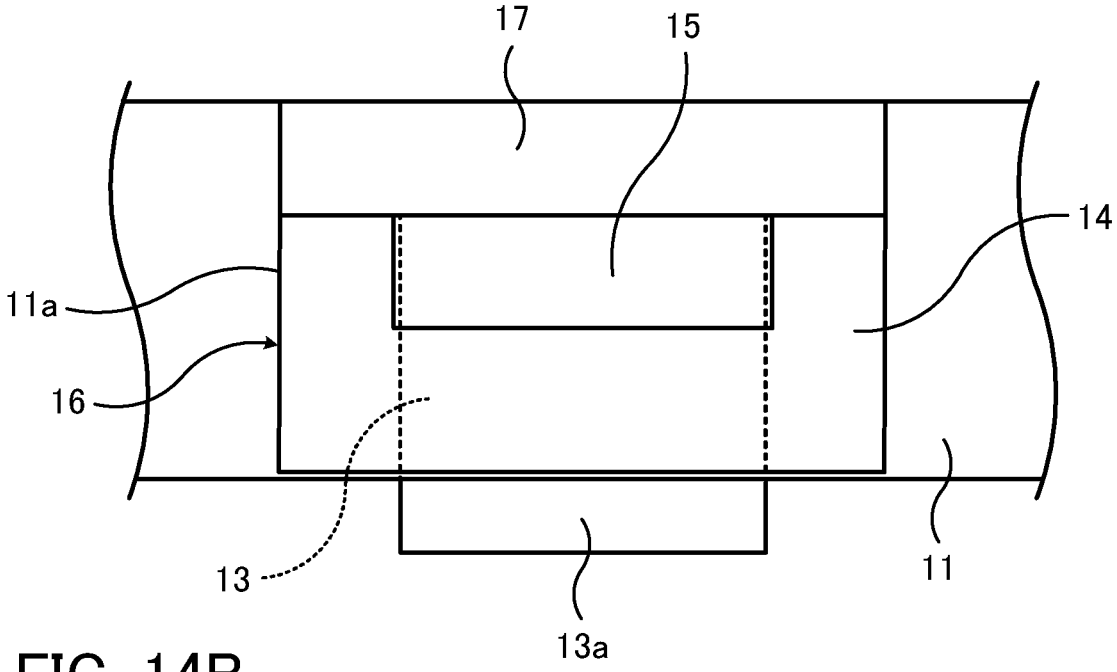


FIG. 14B

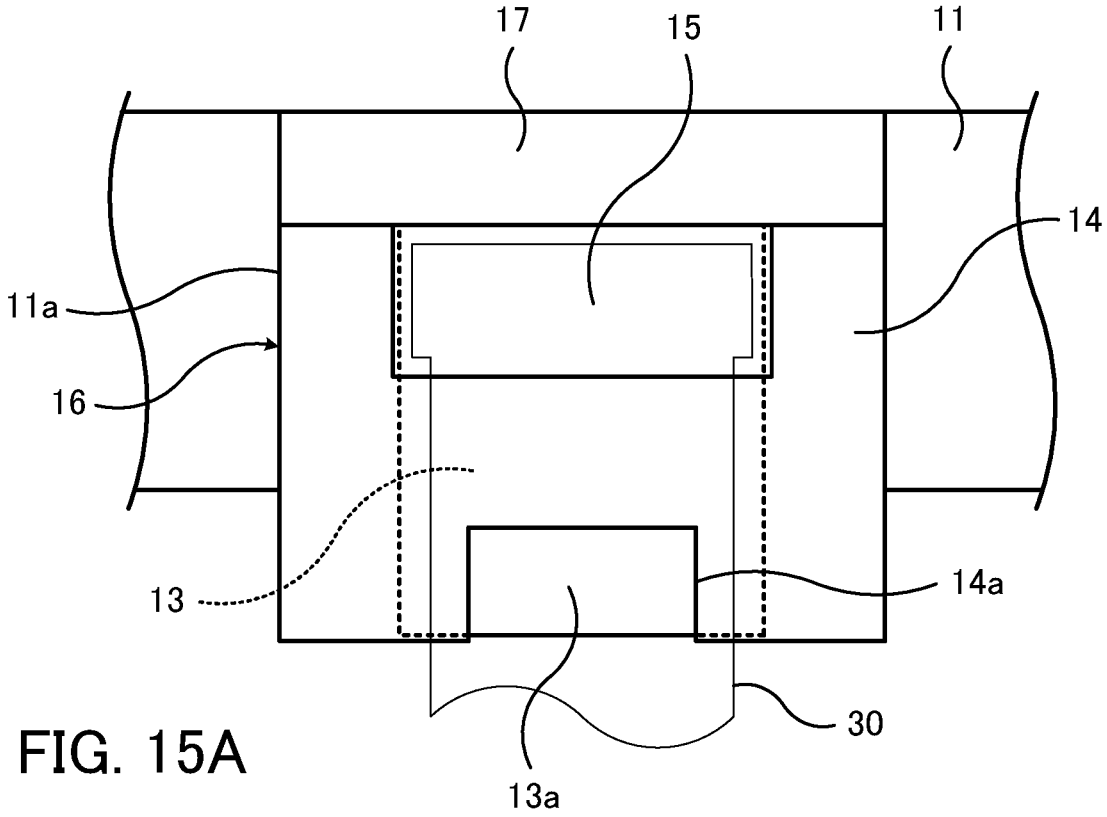


FIG. 15A

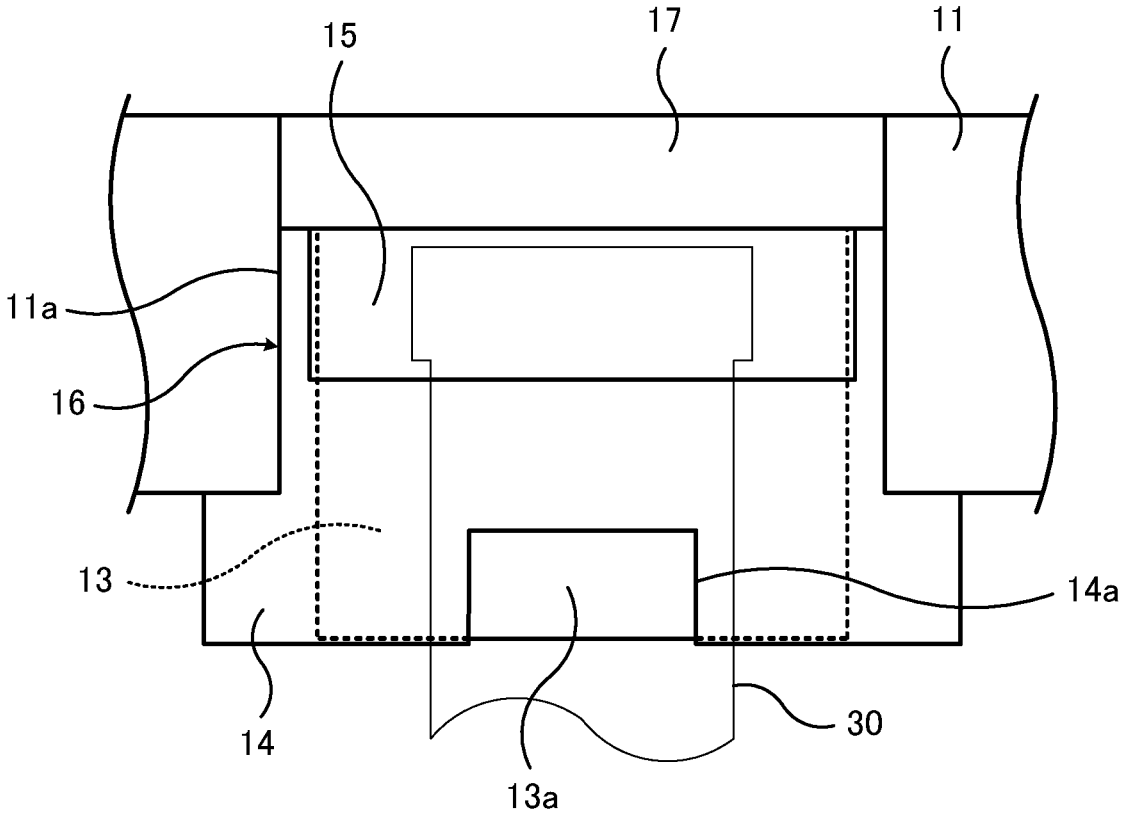


FIG. 15B

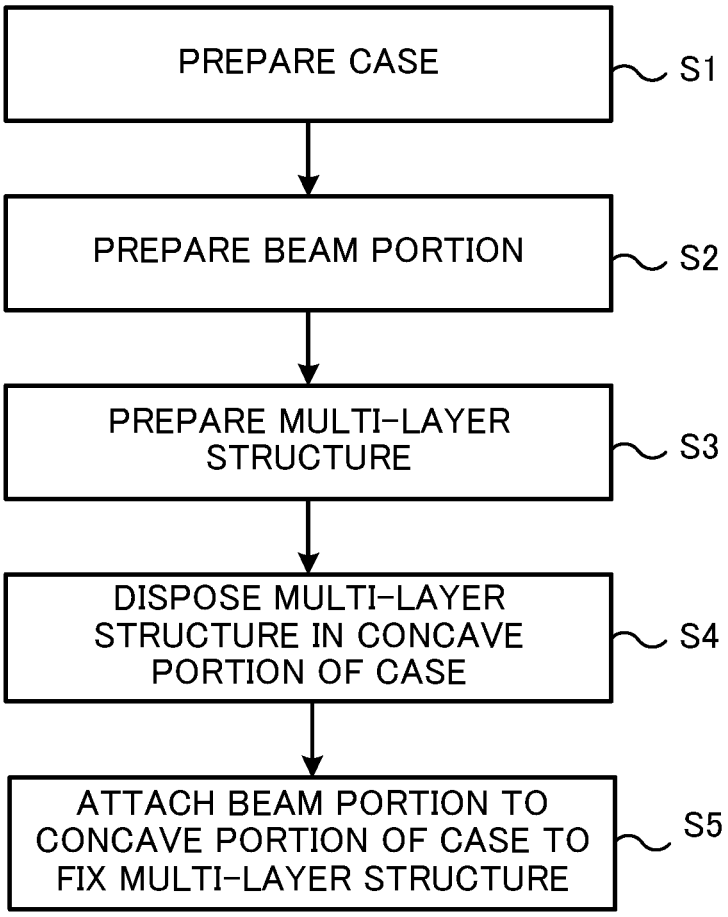

PREPARE CASE
S1
PREPARE BEAM PORTION
S2
PREPARE MULTI-LAYER STRUCTURE
S3
DISPOSE MULTI-LAYER STRUCTURE IN CONCAVE PORTION OF CASE
S4
ATTACH BEAM PORTION TO CONCAVE PORTION OF CASE TO FIX MULTI-LAYER STRUCTURE
S5

FIG. 16

SEMICONDUCTOR DEVICE AND METHOD FOR MANUFACTURING SEMICONDUCTOR DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2021-171319, filed on Oct. 20, 2021, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The embodiments discussed herein relate to a semiconductor device and a method for manufacturing a semiconductor device.

2. Background of the Related Art

[0003] One known technology relating to semiconductor devices houses a semiconductor unit, which includes a ceramic circuit board and a semiconductor chip mounted on the circuit board, in a case made of a resin material such as polyphenylene sulfide (PPS) resin, the case being provided with a multi-layer terminal portion in which a first power terminal, an insulating material, and a second power terminal are stacked in that order (see the specification of U.S. Patent Application Publication No. 2021/0202372).

[0004] In another known technology, a terminal block where a plurality of main terminals and insulating paper inserted between the respective main terminals are fixed to a resin line is provided inside the case of a semiconductor device. The terminal block is formed by forming holes in the main terminals and the insulating paper and by fixing the main terminals and the insulating paper to the resin line by integrated molding with resin that enters the holes during molding of the resin line using a mold (see Japanese Laid-open Patent Publication No. 2004-153243).

[0005] One known semiconductor device includes a multi-layer terminal portion in which a first power terminal, a first insulating sheet, and a second power terminal are stacked in that order, where the first power terminal has a first bonding region that is conductively connected to a first connection terminal of a capacitor, the second power terminal has a second bonding region that is conductively connected to a second connection terminal of the capacitor, and the first insulating sheet has a terrace part that extends in a direction from the second bonding region toward the first bonding region in plan view (see Japanese Laid-open Patent Publication No. 2021-106235).

[0006] In a semiconductor device with a case provided with a multi-layer structure where a first terminal, an insulating sheet, and a second terminal are stacked in that order, as one example, the multi-layer structure may be insertion molded when molding with the case resin material. However, with this method, when an insulating material with a low withstand temperature compared to the molding temperature of the case resin material is used for the insulating sheet included in the multi-layer structure, there is the risk of the insulating sheet deteriorating due to contact with the case resin material that reaches a comparatively high temperature during molding. When the insulating sheet deteriorates, this may result in problems in achieving sufficient insulation between the first terminal and the second terminal provided on both sides of the insulating sheet. This makes it difficult to ensure the reliability of a semiconductor device where a multi-layer structure formed of the first terminal, the insulating sheet, and the second terminal is provided on the case.

SUMMARY OF THE INVENTION

[0007] According to one aspect, there is provided a semiconductor device including: a case that has a side wall to form a frame, the side wall having a concave portion; a multi-layer structure in which a first terminal, an insulating sheet, and a second terminal are stacked in that order and which is disposed on the concave portion; and a beam member that is attached to the concave portion of the case to fix the multi-layer structure disposed on the concave portion.

[0008] The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

[0009] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** depicts one example of a semiconductor device according to a first embodiment;

[0011] FIG. **2** depicts one example of connected parts of the semiconductor module and a capacitor according to the first embodiment;

[0012] FIG. **3** depicts one example of the semiconductor module according to the first embodiment;

[0013] FIGS. **4**A to **4**C depict one example of a case of the semiconductor module according to the first embodiment;

[0014] FIGS. **5**A to **5**C depict one example of a multi-layer structure of a semiconductor module according to the first embodiment;

[0015] FIGS. **6**A to **6**C depict one example of a beam member of a semiconductor module according to the first embodiment;

[0016] FIGS. **7**A and **7**B depict one example of a process that prepares a multi-layer structure according to the first embodiment;

[0017] FIG. **8** is a first diagram depicting one example of an assembly process of a case, multi-layer structures, and beam members according to the first embodiment;

[0018] FIGS. **9**A and **9**B are second diagrams depicting one example of the assembly process of the case, multi-layer structures, and beam members according to the first embodiment;

[0019] FIG. **10** depicts one example of a semiconductor module according to a second embodiment;

[0020] FIGS. **11**A and **11**B are first diagrams depicting examples of a semiconductor module according to a third embodiment;

[0021] FIG. **12** is a second diagram depicting an example of the semiconductor module according to the third embodiment;

[0022] FIGS. **13**A and **13**B depict one example of a semiconductor module according to a fourth embodiment;

[0023] FIGS. **14**A and **14**B are first diagrams depicting example configurations of a multi-layer structure of a semiconductor module according to a fifth embodiment;

[0024] FIGS. **15**A and **15**B are second diagrams depicting example configurations of a multi-layer structure of the semiconductor module according to the fifth embodiment; and

[0025] FIG. **16** depicts one example of a method for manufacturing a semiconductor module according to a sixth embodiment.

DETAILED DESCRIPTION OF THE INVENTION

First Embodiment

[0026] FIG. **1** depicts one example of a semiconductor device according to a first embodiment. FIG. **1** is a perspective view schematically depicting a principal part of one example of a semiconductor device.

[0027] A semiconductor device **1** depicted in FIG. **1** includes a semiconductor module (also referred to as a "semiconductor device") **10**, a capacitor **20**, and connector members **30** that connect the semiconductor module **10** and the capacitor **20**.

[0028] The semiconductor module **10** includes a case **11**. The case **11** of the semiconductor module **10** houses an insulating substrate and semiconductor elements and the like mounted on the insulating substrate.

[0029] As one example, PPS resin is used here for the case **11** of the semiconductor module **10**. As alternatives, polybutylene terephthalate (PBT) resin, polybutylene succinate (PBS) resin, polyamide (PA) resin, acrylonitrile butadiene styrene (ABS) resin, or the like may be used as the case **11** of the semiconductor module **10**. The case **11** of the semiconductor module **10** may be formed by injection molding, for example, using the resin materials listed above.

[0030] One example of the insulating substrate housed in the case **11** of the semiconductor module **10** is a ceramic substrate with conductor layers provided in predetermined patterns on both main surfaces. As examples of the ceramic substrate, a substrate made of alumina, a composite ceramic containing alumina as a main component, aluminum nitride, or silicon nitride is used. Metal such as copper or aluminum is used for the conductor layers. As the insulating substrate, it is possible to use a direct copper bonding (DCB) substrate, an active metal brazed (AMB) substrate, or the like.

[0031] As examples, a semiconductor element such as an insulated gate bipolar transistor (IGBT) or a metal oxide semiconductor field effect transistor (MOSFET) is used as the semiconductor elements mounted on the insulating substrate housed inside the case **11** of the semiconductor module **10**. As other examples of the semiconductor elements, a diode such as a free wheeling diode (FWD) or a Schottky barrier diode (SBD) may be used, or a device where one of these diodes is integrated with an IGBT or MOSFET may be used. As other components, a terminal component or the like to be connected to the semiconductor element(s) may be mounted on the insulating substrate.

[0032] Terminal structure portions **12** are provided on one edge of the case **11** of the semiconductor module **10** in which the insulating substrate and the semiconductor elements and the like mounted on the insulating substrate are housed. The terminal structure portions **12** are connected to the housed insulating substrate, semiconductor elements, and the like and connect the semiconductor module **10** to an external capacitor **20**. Beam members **17** are further provided on one edge of the case **11**. Here, as one example, the semiconductor module **10** that has three terminal structure portions **12** and beam members **17** provided on one side of the case **11** is depicted. Note that the terminal structure portions **12** and the beam members **17** of the semiconductor module **10** will be described later.

[0033] The capacitor **20** includes a case **21**. The case **21** of the capacitor **20** internally houses capacitance elements.

[0034] Here, as one example, PPS resin is used for the case **21** of the capacitor **20**. As alternatives, materials such as PBT resin, PBS resin, PA resin, and ABS resin may be used for the case **21** of the capacitor **20**. The case **21** of the capacitor **20** may be formed by injection molding, for example, using the resin materials listed above.

[0035] Terminal structure portions **22** are provided on one edge of the case **21** of the capacitor **20** in which the capacitance elements are housed. The terminal structure portions **22** are connected to the housed capacitance elements and connect the capacitor **20** to the external semiconductor module **10**. Here, as one example, three terminal structure portions **22** are provided on one edge of the case **21**. Note that the terminal structure portions **22** of the capacitor **20** will be described later.

[0036] The semiconductor module **10** and the capacitor **20** are disposed so that the terminal structure portions **12** and the terminal structure portions **22** face each other, and the respective terminal structure portions **12** and terminal structure portions **22** are connected to each other using connector members **30** such as bus bars. By connecting the semiconductor module **10** and the capacitor **20** in this way, the semiconductor device **1** is realized.

[0037] In the semiconductor device **1**, a circuit with a predetermined function, such as a power converter circuit or an inverter circuit, is formed using the insulating substrate of the semiconductor module **10** and the semiconductor element(s) and the like mounted on the insulating substrate and the capacitance elements of the capacitor **20**.

[0038] Connected parts of the semiconductor module **10** and the capacitor **20** of the semiconductor device **1** will now be described.

[0039] FIG. **2** depicts one example of connected parts of a semiconductor module and a capacitor according to the first embodiment. FIG. **2** is a schematic cross-sectional view taken along a line II-II in FIG. **1**.

[0040] As one example, as depicted in FIG. **2**, the case **11** of the semiconductor module **10** is provided with the terminal structure portions **12**, which each include a multilayer structure **16** where a terminal **13**, an insulating sheet **14**, and a terminal **15** are stacked in that order. As one example, the terminal **13** is a negative (N) terminal of the semiconductor module **10** and the terminal **15** is a positive (P) terminal of the semiconductor module **10**. The terminal **13** and the terminal **15** are respectively connected to negative terminals and positive terminals of the insulating substrate housed inside the case **11**, a semiconductor element, or a component connected to the insulating substrate and/or a semiconductor element. The terminal **13**, the insulating sheet **14**, and the terminal **15** are stacked so that the insulating sheet **14** is interposed between the terminal **13** and the terminal **15**. Metal such as copper or aluminum is used as the terminal **13** and the terminal **15**. An insulating resin

material such as aramid resin, PA resin, fluororesin, or polyimide resin is used for the insulating sheet **14**.

[0041] The terminal **13**, the insulating sheet **14**, and the terminal **15** of the multi-layer structure **16** are provided in a stacked arrangement so that the terminal **13**, the insulating sheet **14**, and the terminal **15** form a stepped arrangement when viewed in cross section as in FIG. **2**. The multi-layer structure **16** including the terminal **13**, insulating sheet **14**, and terminal **15** that are stacked is fixed to the case **11** together with the beam member **17** provided above the multi-layer structure **16**. Note that the case **11** and the multi-layer structure **16** and the beam member **17** fixed to the case **11** will be described later.

[0042] As one example, as depicted in FIG. **2**, the case **21** of the capacitor **20** connected to the semiconductor module **10** is provided with the terminal structure portions **22**, which each include a terminal **23**, an insulating sheet **24**, and a terminal **25**. As one example, the terminal **23** is an N terminal of the capacitor **20** and the terminal **25** is a P terminal of the capacitor **20**. Metal such as copper or aluminum is used as the terminal **23** and the terminal **25**. An insulating resin material such as aramid resin, PA resin, fluororesin, or polyimide resin is used for the insulating sheet **24**.

[0043] As one example, as depicted in FIG. **2**, one end of the terminal **23** is connected to the case **21** and another end is bent toward an outside of the case **21**. The terminal **25** is provided at a position on the case **21** that is closer to the inside of the case **21** than the terminal **23**, has one end connected to the case **21**, and has another end bent toward an inside of the case **21**. The insulating sheet **24** has one end connected to a position on the case **21** that is between the terminal **23** and the terminal **25** and is flexible so as to be capable of bending toward the terminal **23**. The insulating sheet **24** is sized so that when bent toward the terminal **23**, the insulating sheet **24** is capable of covering the terminal **23**.

[0044] The semiconductor module **10** and the capacitor **20** are disposed so that the terminal structure portions **12** of the case **11** and the terminal structure portions **22** of the case **21** face each other. One part (also referred to as a "connecting region") **13***a* of the terminal **13** that is exposed from the insulating sheet **14** in a terminal structure portion **12** of the semiconductor module **10** and the terminal **23** of a terminal structure portion **22** of the capacitor **20** are connected together. As one example, the terminal **13** of the semiconductor module **10** and the terminal **23** of the capacitor **20** are both N terminals.

[0045] The terminals **13** of the semiconductor module **10** and the terminals **23** of the capacitor **20** are connected by laser welding, for example. This laser welding may be performed using a seam laser that continuously emits laser light or may be performed using a spot laser that emits pulsed laser light. Note that the terminals **13** of the semiconductor module **10** and the terminals **23** of the capacitor **20** may be connected by another method, such as soldering or ultrasonic bonding.

[0046] After the terminals **13** of the semiconductor module **10** and the terminals **23** of the capacitor **20** have been connected, the insulating sheets **24** of the capacitor **20** are bent toward the connected parts of the terminals **13** and the terminals **23**. When the insulating sheets **24** of the capacitor **20** are bent in this way, the terminals **23**, the connecting regions **13***a* of the terminals **13** connected to the terminal **23**, and also the insulating sheets **14** become covered with the bent insulating sheets **24**.

[0047] Note that although FIG. **2** depicts a state in which a bent insulating sheet **24** does not contact the terminal **23** of the capacitor **20** or the insulating sheet **14** of the semiconductor module **10** out of convenience, the bent insulating sheet **24** may contact the terminal **23** of the capacitor **20** and the insulating sheet **14** of the semiconductor module **10**.

[0048] After the insulating sheets **24** of the capacitor **20** have been bent, the terminals **15** of the semiconductor module **10** and the terminals **25** of the capacitor **20** are connected using the connector members **30**. Metal such as copper or aluminum is used for the connector members **30**. As one example, bus bars are used as the connector members **30**. The connector members **30** are disposed so as to straddle the insulating sheets **24** of the capacitor **20**, which are themselves provided so as to cover the connected parts of the terminals **13** of the semiconductor module **10** and the terminals **23** of the capacitor **20** along with the insulating sheets **14** of the semiconductor module **10**, and are connected to the terminals **15** of the semiconductor module **10** and the terminals **25** of the capacitor **20**. As one example, the terminals **15** of the semiconductor module **10** and the terminals **25** of the capacitor **20** are both P terminals, and the connector members **30** are P terminal connector members that connect the P terminals of the semiconductor module **10** and the capacitor **20** to each other.

[0049] Note that although FIG. **2** depicts a state in which a connector member **30** does not contact the bent insulating sheet **24** out of convenience, the connector member **30** may contact the bent insulating sheet **24**.

[0050] The terminal **15** of the semiconductor module **10** and the terminal **25** of the capacitor **20** may be connected to the connector member **30** by laser welding, for example. Laser welding may be performed using a seam laser or a spot laser. Note that the terminals **15** of the semiconductor module **10** and the terminals **25** of the capacitor **20** may be connected to the connector members **30** by another method, such as soldering or ultrasonic bonding.

[0051] By connecting the terminal structure portions **12** and the terminal structure portions **22** using the connector members **30** as described above for example, the semiconductor module **10** and the capacitor **20** are connected to each other.

[0052] Although the capacitor **20** is given here as an example of a component connected to the semiconductor module **10**, the component connected to the semiconductor module **10** is not limited to the capacitor **20**. It is possible to connect the semiconductor module **10** to various electronic components, such as a module or component with terminals that connect to the PN terminals of the semiconductor module **10**.

[0053] The semiconductor module **10** will now be described further.

[0054] As described above, the semiconductor module **10** has the multi-layer structures **16**, in which the terminal **13**, the insulating sheet **14**, and the terminal **15** are stacked in that order, on the case **11**.

[0055] Here, as one method of providing the multi-layer structures **16** on the case **11**, there is a conventional method where the multi-layer structures **16** are insertion molded using the same resin material as the case during molding of the case **11** using a resin material such as PPS resin.

However, when the multi-layer structures **16** are insertion molded in this way, the insulating sheets **14** of the multi-layer structures **16** may contact the case resin material, such as PPS resin, which becomes relatively hot during molding. This means that when the insulating sheets **14** are made of an insulating material whose withstand temperature is lower than the molding temperature of the case resin material (which at the maximum is around 330° C. for example), the insulating sheets **14** may deteriorate due to contact with the case resin material that is a relatively high temperature during molding. When the insulating sheets **14** deteriorate, this may result in problems in achieving sufficient insulation between the terminals **13** and the terminals **15** provided on both sides of the insulating sheets **14**. This makes it difficult to ensure the reliability of the semiconductor module **10** in which the multi-layer structures **16** formed of the terminal **13**, the insulating sheet **14**, and the terminal **15** are provided on the case **11**.

[0056] To solve the problem described above, the semiconductor module **10** according to the first embodiment uses the configurations described above and below.

[0057] FIG. **3** depicts one example of a semiconductor module according to the first embodiment. FIG. **3** is a perspective view schematically depicting a principal part of one example of a semiconductor module.

[0058] As depicted in FIG. **3** (and also in FIGS. **1** and **2** described earlier), the semiconductor module **10** includes the case **11**, the multi-layer structures **16**, and the beam members **17**. In this example, a case in the shape of a frame or a part of a case that is frame-shaped is depicted as the case **11**. The case **11** is frame-shaped and has a concave portion **11***a* on one edge of the frame shape. The case **11** has a side wall to form the frame, and the side wall has the concave portion **11***a*. As one example, FIG. **3** depicts a case **11** with three concave portions **11***a* provided in one edge of a frame. Multi-layer structures **16**, which is to say, multi-layer structures **16** in which the terminal **13**, the insulating sheet **14**, and the terminal **15** are stacked in that order, are disposed in the respective concave portions **11***a* of the case **11**. A beam member **17** is then disposed and fixed in each concave portion **11***a* of the case **11** in which a multi-layer structure **16** has been placed, and the multi-layer structure **16** is fixed to the concave portion **11***a* by the beam member **17**.

[0059] The case **11**, the multi-layer structures **16**, and the beam members **17** of the semiconductor module **10** will now be described further with reference to FIGS. **4**A to **6**C.

[0060] First, the case **11** of the semiconductor module **10** will be described with reference to FIGS. **4**A to **4**C.

[0061] FIGS. **4**A to **4**C depict one example of a case of a semiconductor module according to the first embodiment. FIG. **4**A is a perspective view schematically depicting a principal part of an example case of a semiconductor module. FIG. **4**B is a plan view schematically depicting a principal part of an example case of a semiconductor module. FIG. **4**C is a side view schematically depicting a principal part of an example case of a semiconductor module.

[0062] FIGS. **4**A to **4**C schematically depict one example of a case **11** of the semiconductor module **10** in a part labelled P in FIG. **3**. Concave portions **11***a* like that depicted in FIGS. **4**A to **4**C are provided in one edge of the frame-shaped case **11**. The concave portion **11***a* is provided so as to pass through one edge of the case **11** in the inside/outside direction of the case **11**, that is, to pass through the edge in a direction that is perpendicular to the direction in which the edge extends. The width of each concave portion **11***a* in the length direction of the edge is set at a width capable of accommodating the multi-layer structure **16** and the beam member **17** which are to be disposed in the concave portion **11***a* as described later.

[0063] As depicted in FIGS. **4**A to **4**C, each concave portion **11***a* of the case **11** is partially recessed at the bottom to form a recess **11***b*. The recess **11***b* at the bottom of the concave portion **11***a* is set at a width and depth capable of accommodating the terminal **13** of the multi-layer structure **16** to be disposed in the concave portion **11***a* as described later. That is, the terminal **13** of a multi-layer structure **16** is housed in the recess **11***b* provided at the bottom of the concave portion **11***a*. The parts of the bottom of the concave portion **11***a* where the recess **11***b* is not formed face the insulating sheet **14** of the multi-layer structure **16**.

[0064] A resin material such as PPS resin, PBT resin, PBS resin, PA resin, or ABS resin is used for the case **11**. The case **11**, which is provided with the concave portions **11***a* that each have a recess **11***b* as described above, may be formed by injection molding, for example, using a predetermined resin material.

[0065] Next, the multi-layer structures **16** of the semiconductor module **10** will be described with reference to FIGS. **5**A to **5**C.

[0066] FIGS. **5**A to **5**C depict one example of a multi-layer structure of a semiconductor module according to the first embodiment. FIG. **5**A is a perspective view schematically depicting a principal part of an example multi-layer structure of the semiconductor module. FIG. **5**B is a plan view schematically depicting a principal part of an example multi-layer structure of the semiconductor module. FIG. **5**C is a side view schematically depicting a principal part of an example multi-layer structure of the semiconductor module.

[0067] FIGS. **5**A to **5**C schematically depict one example of a multi-layer structure **16** of the semiconductor module **10** in a part labelled P in FIG. **3**. Each multi-layer structure **16** is configured with the terminal **13**, the insulating sheet **14**, and the terminal **15** stacked in that order. As one example, the terminals **13** and **15** that face each other with the insulating sheet **14** in between have the same or a similar width in plan view and in side view as depicted in FIGS. **5**B and **5**C. As one example, the insulating sheet **14** interposed between the terminal **13** and the terminal **15** has a larger width than the terminal **13** and the terminal **15** in plan view and in side view as depicted in FIGS. **5**B and **5**C. The insulating sheet **14** that is wider than the terminal **13** and the terminal **15** is set at a width that is capable of being housed in the concave portion **11***a* of the case **11**, for example, which is to say, equal to or narrower than the width of the concave portion **11***a* in the length direction of the edge of the case **11** in which the concave portion **11***a* is provided.

[0068] As one example, a cutout portion **14***a* is provided on one edge (a front end portion that becomes positioned outside the case **11**) of the insulating sheet **14** as depicted in FIGS. **5**A to **5**C. The connecting region **13***a* of the terminal **13** is exposed from the cutout portion **14***a* of the insulating sheet **14**. The terminal **13** is covered with the insulating sheet **14** in a state where the connecting region **13***a* is positioned at the cutout portion **14***a* of the insulating sheet **14**. In this configuration, the terminal **13** is covered with the insulating sheet **14** except for the connecting region **13***a* positioned at the cutout portion **14***a* of the insulating sheet **14**. The

terminal **15** is provided on the insulating sheet **14**, that is, on the opposite side of the insulating sheet **14** to the terminal **13** side. In plan view, the terminal **15** is provided at a position that faces the terminal **13** with the insulating sheet **14** in between but does not overlap the connecting region **13***a*. The terminal **15**, the insulating sheet **14**, and the connecting region **13***a* of the terminal **13** exposed from the cutout portion **14***a* of the insulating sheet **14** are in a stepped arrangement. As depicted in FIG. **5**C, the terminal **13** is bonded to the insulating sheet **14** using an adhesive **18***a* (first second-adhesive), and the terminal **15** is bonded to the insulating sheet **14** using an adhesive **18***b* (second second-adhesive).

[0069] Out of a multi-layer structure **16**, the connecting region **13***a* of the terminal **13** is connected for example to the terminal **23** of the capacitor **20** as described above, and the terminal **15** is connected for example to the connector member **30** which is connected to the terminal **25** of the capacitor **20** as described above.

[0070] Next, the beam members **17** of the semiconductor module **10** will be described with reference to FIGS. **6**A to **6**C.

[0071] FIGS. **6**A to **6**C depict one example of a beam member of a semiconductor module according to the first embodiment. FIG. **6**A is a perspective view schematically depicting a principal part of one example of a beam member of a semiconductor module. FIG. **6**B is a plan view schematically depicting a principal part of one example of a beam member of a semiconductor module. FIG. **6**C is a side view schematically depicting a principal part of one example of a beam member of a semiconductor module.

[0072] FIGS. **6**A to **6**C schematically depict one example of a beam member **17** of the semiconductor module **10** in a part labelled P in FIG. **3**. The beam member **17** is provided between facing side walls of the concave portion **11***a* of the case **11**. Clearance may be provided between the side walls of a concave portion **11***a* of the case **11** and the side surfaces of a beam member **17** facing the side walls to allow (a part of) adhesive **18***d* described later to enter. The beam member **17** is a member that is disposed in a concave portion **11***a* of the case **11** and fixes the multi-layer structure **16** disposed in a concave portion **11***a* of the case **11** so that the multi-layer structure **16** is interposed and fixed between the beam member **17** and the bottom portion of the concave portion **11***a*.

[0073] As depicted in FIGS. **6**A to **6**C, the beam member **17** is partially recessed to form a recess **17***b* on the side that faces the multi-layer structure **16** to be fixed. The recess **17***b* of the beam member **17** is set at a width and depth capable of accommodating the terminal **15** of the multi-layer structure **16**. That is, when the beam member **17** is provided in a concave portion **11***a* of the case **11**, the terminal **15** of a multi-layer structure **16** becomes housed in the recess **17***b* of the beam member **17**. Parts of the side of the beam member **17** facing a multi-layer structure **16** that are not the recess **17***b* face the insulating sheet **14** of the multi-layer structure **16**.

[0074] A resin material such as PPS resin, PBT resin, PBS resin, PA resin, or ABS resin is used for the beam member **17**. As one example, the same type of resin material as the case **11** is used for the beam member **17**. However, it is also possible to use a different resin material to the case **11** for the beam member **17**. As one example, a beam member **17** with a recess **17***b* like that described above may be formed by injection molding using a predetermined resin material.

[0075] Next, assembly of the case **11**, the multi-layer structures **16**, and the beam members **17** of the semiconductor module **10** will be described.

[0076] The case **11** and the beam members **17** are both prepared before assembly of the case **11**, the multi-layer structures **16**, and the beam members **17** commences. That is, the case **11** that includes the concave portions **11***a* with the recesses **11***b* as depicted in FIGS. **4**A to **4**C is formed and prepared for example by injection molding using a predetermined resin material, such as PPS resin. The beam members **17** with the recesses **17***b* as depicted in FIGS. **6**A to **6**C are formed and prepared for example by injection molding using a predetermined resin material such as PPS resin.

[0077] Before assembly of the case **11**, the multi-layer structures **16**, and the beam members **17**, in addition to the case **11** and the beam members **17**, the multi-layer structures **16**, that is, the multi-layer structures **16** in which the terminals **13**, the insulating sheets **14**, and the terminals **15** are stacked in that order, are prepared.

[0078] Here, FIGS. **7**A and **7**B depict one example of a process that prepares a multi-layer structure according to the first embodiment. FIG. **7**A is a side view (an exploded side view) of a principal part schematically depicting one example of the terminals, the insulating sheet, and the adhesive before stacking, and FIG. **7**B is a side view schematically depicting a principal part of one example of a state after the terminals, the insulating sheets, and the adhesive have been stacked.

[0079] As one example, as depicted in FIG. **7**A, the terminal **13**, the insulating sheet **14** and the terminal **15** that have been formed in advance in predetermined sizes are prepared, and the adhesive **18***a* and the adhesive **18***b* are provided between the terminal **13** and the insulating sheet **14** and between the insulating sheet **14** and the terminal **15**, respectively. After this, as depicted in FIG. **7**B, the terminal **13** and the insulating sheet **14** are bonded using the adhesive **18***a*, and the insulating sheet **14** and the terminal **15** are bonded using the adhesive **18***b*.

[0080] As the adhesive **18***a* and the adhesive **18***b*, it is possible to use an epoxy-based adhesive, a silicone-based adhesive, a ceramic-based adhesive, or the like. As the adhesive **18***a* and the adhesive **18***b*, it is possible to use liquid adhesive, but it is also possible to use an adhesive in sheet form. The same kind of adhesive may be used for both the adhesive **18***a* and the adhesive **18***b*, or different adhesives may be used. To bond the terminal **13** and the insulating sheet **14** using the adhesive **18***a*, it is possible to stick a terminal **13** that has been provided in advance with the adhesive **18***a* onto the insulating sheet **14**, or to stick the terminal **13** onto an insulating sheet **14** that has been provided in advance with the adhesive **18***a*. Likewise, to bond the insulating sheet **14** and the terminal **15** using the adhesive **18***b*, it is possible to stick a terminal **15** that has been provided in advance with the adhesive **18***b* onto the insulating sheet **14**, or to stick the terminal **15** onto an insulating sheet **14** that has been provided in advance with the adhesive **18***b*.

[0081] As one example, the adhesive **18***a* interposed between the terminal **13** and the insulating sheet **14** and the adhesive **18***b* interposed between the insulating sheet **14** and the terminal **15** are cured using a method, such as heating

and irradiation with light, that depends on the material(s) used for the adhesive **18***a* and the adhesive **18***b*. Alternatively, the adhesive **18***a* and the adhesive **18***b* may be in an uncured or semi-cured state during a preparation stage of the multi-layer structure **16** (that is, before the multi-layer structure **16** is disposed in a concave portion **11***a* of the case **11**).

[0082] As one example, multi-layer structures **16** like that depicted in FIGS. **7**B and FIGS. **5**A to **5**C, that is, multi-layer structures **16** in each of which the terminal **13**, the insulating sheet **14**, and the terminal **15** have been stacked in that order, are prepared.

[0083] Note that preparation of the case **11**, preparation of the beam members **17**, and preparation of the multi-layer structures **16** may be performed in any order.

[0084] FIG. **8** and FIGS. **9**A and **9**B depict one example of an assembly process of the case, the multi-layer structures, and the beam members according to the first embodiment. FIG. **8** is a side view (an exploded side view) schematically depicting a principal part of one example of a case, multi-layer structures, beam members, and adhesive before assembly. FIG. **9**A is a plan view schematically depicting a principal part of one example state after assembly of the case, multi-layer structure, beam member and adhesive, and FIG. **9**B is a side view schematically depicting a principal part of one example of a state after assembly of the case, multi-layer structure, beam member, and adhesive.

[0085] As one example, as depicted in FIG. **8**, adhesive **18***c* (first first-adhesive) and adhesive **18***d* (second first-adhesive) are provided between the concave portion **11***a* (including the recess **11***b* of the concave portion **11***a*) of the case **11** that has been prepared in advance and (the terminal **13** side of) the multi-layer structure **16**, and between (the terminal **15** side of) the multi-layer structure **16** and (the recess **17***b* side of) the beam member **17**, respectively. Note that aside from being placed between a multi-layer structure **16** and a beam member **17**, the adhesive **18***d* may also be provided between the side walls of the concave portion **11***a* of the case **11** and the side surfaces of the beam member **17** provided that there is sufficient clearance. After this, as depicted in FIGS. **9**A and **9**B, the multi-layer structure **16** is bonded to the concave portion **11***a* of the case **11** using the adhesive **18***c* and the beam member **17** is bonded to the multi-layer structure **16** (or to the multi-layer structure **16** and the side walls of the concave portion **11***a* of the case **11**) using the adhesive **18***d*.

[0086] As the adhesive **18***c* and the adhesive **18***d*, it is possible to use an epoxy-based adhesive, a silicone-based adhesive, a ceramic-based adhesive, or the like. As the adhesive **18***c* and the adhesive **18***d*, it is possible to use liquid adhesive, but it is also possible to use an adhesive in sheet form. The same kind of adhesive may be used for both the adhesive **18***c* and the adhesive **18***d*, or different adhesives may be used. To bond the multi-layer structures **16** to the concave portions **11***a* of the case **11** using the adhesive **18***c*, it is possible to stick multi-layer structures **16** that have been provided in advance with the adhesive **18***c* onto the case **11**, or to stick the multi-layer structures **16** onto a case **11** that has been provided in advance with the adhesive **18***c*. To bond the beam members **17** to the multi-layer structures **16** (or to the multi-layer structures **16** and the side walls of the concave portions **11***a*) using the adhesive **18***d*, it is possible to stick beam members **17** that have been provided in advance with the adhesive **18***d* onto the multi-layer structures **16** (or onto the multi-layer structures **16** and the side walls of the concave portions **11***a*), or to stick the beam members **17** onto multi-layer structures **16** (or onto multi-layer structures **16** and the side walls of the concave portions **11***a*) that have been provided in advance with the adhesive **18***d*.

[0087] As one example, first, the multi-layer structures **16** are disposed via the adhesive **18***c* in the concave portions **11***a* of the case **11**. The multi-layer structures **16** are disposed in the concave portions **11***a* via the adhesive **18***c* so that the terminals **13** of the multi-layer structures **16** become housed in the recesses **11***b* of the concave portions **11***a* in the case **11**. After this, the beam members **17** are disposed via the adhesive **18***d* in the concave portions **11***a* of the case **11** in which the multi-layer structures **16** have been disposed. The beam members **17** are disposed via the adhesive **18***d* on the multi-layer structures **16** (or the multi-layer structures **16** and the side walls of the concave portions **11***a*) so that the terminals **15** of the multi-layer structures **16** are housed in the recesses **17***b* of the beam members **17**. By doing so, the state depicted in FIGS. **9**A and **9**B is obtained.

[0088] Alternatively, the beam members **17** are first disposed via the adhesive **18***d* on the multi-layer structures **16**. The beam members **17** are disposed via the adhesive **18***d* on the multi-layer structures **16** so that the terminals **15** of the multi-layer structures **16** become housed in the recesses **17***b*. After this, the multi-layer structures **16** on which the beam members **17** have been disposed via the adhesive **18***d* are disposed via the adhesive **18***c* in the concave portions **11***a* of the case **11**. The multi-layer structures **16** are disposed via the adhesive **18***c* in the concave portions **11***a* so that the terminals **13** become housed in the recesses **11***b* of the concave portions **11***a* in the case **11**. The adhesive **18***d* may also be provided between the beam members **17** and the side walls of the concave portions **11***a*. By performing the above steps, the state depicted in FIGS. **9**A and **9**B is obtained.

[0089] After the state depicted in FIGS. **9**A and **9**B has been obtained, the adhesive **18***c* and the adhesive **18***d* are cured using a method, such as heating and irradiation with light, that depends on the material(s) used for the adhesive **18***c* and the adhesive **18***d*. Before curing of the adhesive **18***c* and the adhesive **18***d* or during curing, to suppress the generation of voids and the like, a defoaming process may be performed in a vacuum. When curing the adhesive **18***c* and the adhesive **18***d*, to suppress positional displacements of the multi-layer structures **16** and the beam members **17** and/or the generation of regions that are not filled with the adhesive **18***c* and the adhesive **18***d*, a process that presses the beam members **17** toward the bottoms of the concave portions **11***a* of the case **11** may be performed. As one example, the adhesive **18***c* and the adhesive **18***d* are cured by heating while being defoamed in a vacuum in a state where the beam members **17** are pressed toward the bottoms of the concave portions **11***a* in the case **11**.

[0090] Note that when the adhesive **18***a* and the adhesive **18***b* interposed between the insulating sheet **14** and the terminals **13** and **15** are left in an uncured or semi-cured state during the preparation stage of the multi-layer structures **16** depicted in FIGS. **7**A and **7**B described above, it is possible, when curing the adhesive **18***c* and the adhesive **18***d*, to cure the adhesive **18***a* and the adhesive **18***b* at the same time as the adhesive **18***c* and the adhesive **18***d*.

[0091] As described above, the multi-layer structures **16** are disposed via the adhesive **18***c* in the concave portions

11*a* of the case **11** so that the multi-layer structures **16** are attached using the adhesive **18***c*. The beam members **17** are disposed via the adhesive **18***d* in the concave portions **11***a* of the case **11** in which the multi-layer structures **16** have been disposed so that the beam members **17** are attached using the adhesive **18***d*. By doing so, a state is obtained where the multi-layer structures **16** disposed in the concave portions **11***a* of the case **11** are fixed by the beam members **17**.

[0092] In this way, by using the method described above, the case **11** including the concave portions **11***a* is prepared and the multi-layer structure **16** and the beam member **17** are both prepared separately to the case **11**. After this, the multi-layer structures **16** that have been prepared separately to the case **11** are disposed in the concave portions **11***a* of the case **11** and the beam members **17** that have been prepared separately to the case **11** are attached to the concave portions **11***a*, thereby fixing the multi-layer structures **16** to the concave portions **11***a*. Accordingly, unlike when the multi-layer structures **16** including the insulating sheets **14** are insertion molded using a case resin material, such as the PPS resin used for the case **11** and/or the beam members **17**, which reaches a comparatively high temperature during molding, a situation where the insulating sheets **14** contact the case resin material that reaches a comparatively high temperature during molding is avoided. Since the insulating sheets **14** are prevented from contacting the case resin material that reaches a comparatively high temperature, it is possible to prevent deterioration of the insulating sheets **14**, which would result in problems in achieving sufficient insulation between the terminals **13** and the terminals **15** and make it difficult to ensure the reliability of the semiconductor module **10** including the multi-layer structures **16**.

[0093] When insertion molding is performed, to suppress deterioration of the insulating sheet **14**, an insulating material with a certain level of heat resistance relative to the molding temperature (as one example, around 330° C.) of the case resin material that may be contacted during insertion molding is selected as the insulating material of the insulating sheet **14**. On the other hand, with the method described above that separately prepares and then assembles the case **11**, the multi-layer structures **16**, and the beam members **17**, since contact between the insulating sheet **14** and the case resin material at a comparatively high temperature, such as a molding temperature, is avoided, it is possible to select an insulating material with a lower withstand temperature than the molding temperature of the case resin material as the insulating sheet **14**. As one example, it is possible to select an insulating material capable of withstanding the curing temperatures of the adhesive **18***a*, the adhesive **18***b*, the adhesive **18***c*, and the adhesive **18***d* and/or the mounting temperature (as one example, around 220° C.) of components such as semiconductor elements that are mounted on the semiconductor module **10**. Accordingly, it is possible to greatly increase the range of insulating materials that are able to be selected for use as the insulating sheets **14**.

[0094] Also with the method described above that separately prepares the case **11**, the multi-layer structures **16**, and the beam members **17** and performs assembly using the adhesive **18***c* and the adhesive **18***d*, the spaces between the case **11** and the multi-layer structures **16** are filled with the adhesive **18***c* and the spaces between the multi-layer structures **16** and the beam members **17** are filled with the adhesive **18***d*. This avoids the formation of gaps between the case **11** and the multi-layer structures **16** and the formation of gaps between the multi-layer structures **16** and the beam members **17**. Since a defoaming process is performed in a vacuum during curing, the formation of gaps is further suppressed. By suppressing the formation of gaps, the risk of partial discharge is suppressed. Note that to effectively suppress the risk of partial discharge, it is preferable to provide no clearance between the side walls of the concave portions **11***a* of the case **11** and the side surfaces of the beam members **17** that face the side walls or alternatively to fill any clearance provided between the side walls and the side surfaces with the adhesive **18***d*.

[0095] It is also possible to adjust the thickness of the adhesive **18***c* that fills the spaces between the case **11** and the multi-layer structures **16**, and the thicknesses of the adhesive **18***a* and the adhesive **18***b* between the insulating sheets **14** of the multi-layer structures **16** and the terminals **13** and **15**. By adjusting the thicknesses of the adhesive **18***c* and/or the adhesive **18***a* and the adhesive **18***b* in this way, it is possible to adjust the height positions of the terminals **13** and the terminals **15** relative to the bottom of the concave portions **11***a* of the case **11**. By adjusting the height positions of the terminals **13** and the terminals **15**, it is possible to adjust the connecting heights of the insulating substrate or semiconductor elements housed in the case **11** or of components connected to the insulating substrate and/or semiconductor elements.

Second Embodiment

[0096] FIG. **10** depicts one example of a semiconductor module according to a second embodiment. FIG. **10** is a side view schematically depicting a principal part of one example of a semiconductor module.

[0097] A semiconductor module (hereinafter also referred to as the "semiconductor device") **10**A depicted in FIG. **10** is configured with channels (grooves) **11***c*, which communicate with the recess **11***b* and extend in the depth direction relative to the plane of the drawing in FIG. **10**, formed in the recess **11***b* provided in each concave portion **11***a* of the case **11** and with channels (grooves) **17***c*, which extend in the depth direction of the plane of the drawing in FIG. **10** formed in the recess **17***b* provided in each beam member **17**. The channels **11***c* in each concave portion **11***a* of the case **11** are formed so as to communicate with the recess **11***b* in the concave portion **11***a* and the channels **17***c* of each beam member **17** are formed so as to communicate with the recess **17***b* of the beam member **17**. By having the configuration described above, the semiconductor module **10**A differs to the semiconductor module **10** according to the first embodiment described earlier.

[0098] By having the channels **11***c* formed in the recesses **11***b* of the concave portions **11***a* in the case **11**, it is possible with the semiconductor module **10**A for excess amounts of the adhesive **18***c* that attaches the multi-layer structures **16** to the concave portions **11***a* to accumulate in the channels **11***c*. Since it is possible for excess amounts of the adhesive **18***c* to accumulate in the channels **11***c*, it is possible to avoid a situation where the height positions of the terminals **13** and the terminals **15** of the multi-layer structures **16** relative to the bottoms of the concave portions **11***a* of the case **11** become higher than predetermined positions due to the thicknesses of excess amounts of the adhesive **18***c*. By doing so, it is possible to suppress displacements in the connecting heights between the terminals **13** and terminals **15** of the multi-layer structures **16** and the insulating substrate or

semiconductor elements housed in the case **11** or components connected to the insulating substrate and/or semiconductor elements.

[0099] Also, by having the channels **17***c* formed in the recesses **17***b* of the beam members **17**, it is possible with the semiconductor module **10**A for excess amounts of the adhesive **18***d* that attaches the beam members **17** to the multi-layer structures **16** (or to the multi-layer structures **16** and the case **11**) to accumulate in the channels **17***c*. Since it is possible for excess amounts of the adhesive **18***d* to accumulate in the channels **17***c*, it is possible to avoid a situation where the height positions of the beam members **17** relative to the case **11** become higher than a predetermined position due to the thicknesses of excess amounts of the adhesive **18***d*. By doing so, it is possible to avoid problems such as visual imperfections due to the beam member **17** sticking out of the case **11** and/or a cover rattling when a cover is provided on the case **11**.

[0100] Note that an example configuration where the channels **11***c* and the channels **17***c* are formed in the concave portions **11***a* of the case **11** and the beam members **17** is described here. As alternatives, out of the concave portions **11***a* and the beam members **17**, it is possible to form the channels **11***c* in only the concave portions **11***a* and have excess amounts of the adhesive **18***c* accumulate in the channels **11***c*, or to form the channels **17***c* in only the beam members **17** and have excess amounts of the adhesive **18***d* accumulate in the channels **17***c*.

[0101] The positions, sizes, and number of the channels **11***c* formed in the concave portions **11***a* of the case **11** are not limited to the example described above and so long as it is possible for excess amounts of the adhesive **18***c* to accumulate, various changes may be made to the positions, sizes, and number of the channels **11***c*. Likewise, the positions, sizes, and number of the channels **17***c* formed in the beam members **17** are not limited to the example described above and so long as it is possible for excess amounts of the adhesive **18***d* to accumulate, various changes may be made to the positions, sizes, and number of the channels **17***c*.

[0102] In the same way as the semiconductor module **10** according to the first embodiment described earlier, it is possible to connect the semiconductor module **10**A to other electronic components, such as the capacitor **20**, using the terminals **13** and the terminals **15** of the multi-layer structures **16** that are provided with the insulating sheets **14** in between.

Third Embodiment

[0103] FIGS. **11**A and **11**B and FIG. **12** depict examples of a semiconductor module according to a third embodiment. FIGS. **11**A and **11**B and FIG. **12** are plan views schematically depicting principal parts of examples of a semiconductor module.

[0104] A semiconductor module (hereinafter also referred to as the "semiconductor device") **10**B depicted in FIG. **11**A has locking portions **17***d* that lock onto the case **11** provided on each beam member **17** and has mating portions **11***d* that mate with the locking portions **17***d* of the beam members **17** provided on the case **11**. By having the configuration described above, the semiconductor module **10**B differs to the semiconductor module **10** according to the first embodiment described earlier. Locking portions that correspond to the mating portions **11***d* may also be formed on the insulating sheet **14** disposed below the beam member **17**. By using this configuration, it becomes possible to easily position the insulating sheets **14** on the case **11**.

[0105] In the semiconductor module **10**B, locking portions **17***d* that protrude from the side surfaces that face the side walls of the concave portions **11***a* of the case **11** in plan view are provided as the locking portions **17***d* of the beam member **17**, and mating portions **11***d* that are recessed from the side walls of the concave portions **11***a* of the case **11** in plan view are provided as the mating portions **11***d* of the case **11**. With the semiconductor module **10**B, when the beam members **17** are attached to the concave portions **11***a* of the case **11**, the locking portions **17***d* of the beam members **17** are inserted into and mate with the mating portions **11***d* of the case **11**. By doing so, the beam members **17** are attached to the case **11** that has the multi-layer structures **16** disposed in the concave portions **11***a* in a state where positional displacements are suppressed. In addition, due to the locking portions **17***d* mating with the mating portions **11***d* of the case **11**, the strength of attachment of the beam members **17** is increased and it is possible to avoid detachment of the beam members **17** due to external forces.

[0106] A semiconductor module (hereinafter also referred to as the "semiconductor device") **10**C depicted in FIG. **11**B is configured to include locking portions **17***d* that are recessed from the side surfaces of the beam members **17** that face the side walls of the concave portions **11***a* of the case **11** in plan view as the locking portions **17***d* of the beam member **17** and mating portions **11***d* that protrude from the side walls of the concave portions **11***a* of the case **11** in plan view as the mating portions **11***d* of the case **11**. Concave portions that correspond to the mating portions **11***d* may also be formed in the insulating sheets **14** disposed below the beam members **17**. By using this configuration, it becomes possible to easily position the insulating sheets **14** on the case **11**. By having the configuration described above, the semiconductor module **10**C differs to the semiconductor module **10** according to the first embodiment described earlier.

[0107] With the semiconductor module **10**C, when the beam members **17** are attached to the concave portions **11***a* of the case **11**, the mating portions **11***d* of the case **11** are inserted into and mate with the locking portions **17***d* of the beam members **17**. By doing so, the beam members **17** are attached to the case **11** that has the multi-layer structures **16** disposed in the concave portions **11***a* in a state where positional displacements are suppressed. In addition, due to the locking portions **17***d* mating with the mating portions **11***d* of the case **11**, the strength of attachment of the beam members **17** is increased and it is possible to avoid detachment of the beam members **17** due to external forces.

[0108] A semiconductor module (hereinafter also referred to as the "semiconductor device") **10**D depicted in FIG. **12** includes beam members **17** that are larger than the multi-layer structures **16** disposed in the concave portions **11***a* of the case **11**. The semiconductor module **10**D is configured so that locking portions **17***d* that protrude toward an inside of a frame of the case **11** are provided on end portions of the beam members **17**, and mating portions **11***d* that are recessed toward the inside of the frame and mate with the locking portions **17***d* of the beam member **17** are provided on the case **11**. By having the configuration described above, the semiconductor module **10**D differs to the semiconductor module **10** according to the first embodiment described earlier.

[0109] With the semiconductor module **10**D, in the same way as described above, the locking portions **17***d* of the beam members **17** are inserted into and mate with the mating portions **11***d* of the case **11**. By doing so, the beam members **17** are attached with high strength to the case **11** in a state where positional displacements are suppressed.

[0110] Note that in the semiconductor module **10**B, the semiconductor module **10**C, and the semiconductor module **10**D, sufficient clearance for the adhesive **18***d* to enter may be provided between the locking portions **17***d* and the mating portions **11***d*.

[0111] In the semiconductor module **10**B, the semiconductor module **10**C, and the semiconductor module **10**D, the concave portions **11***a* of the case **11** and the beam members **17** may be provided with the channels **11***c* in which the adhesive **18***c* accumulates and the channels **17***c* in which the adhesive **18***d* accumulates in accordance with the example described in the second embodiment above.

[0112] In the same way as the semiconductor module **10** described in the first embodiment, it is possible to connect the semiconductor module **10**B, the semiconductor module **10**C, and the semiconductor module **10**D to other electronic components, such as the capacitor **20**, using the terminals **13** and the terminals **15** of the multi-layer structures **16** provided with the insulating sheets **14** in between.

Fourth Embodiment

[0113] FIGS. **13**A and **13**B depict one example of a semiconductor module according to a fourth embodiment. FIG. **13**A is a plan view schematically depicting a principal part of one example of a semiconductor module, and FIG. **13**B is a plan view schematically depicting a principal part of one example of a semiconductor module where encapsulating resin is provided inside a case.

[0114] The semiconductor module (also referred to as the "semiconductor device") **10**E depicted in FIG. **13**A is configured to include a part that has been roughened (hereinafter referred to as the "roughened portion") **17***e* provided on the surface of each beam member **17** that becomes the inside of the case **11**. By having the configuration described above, the semiconductor module **10**E differs to the semiconductor module **10** according to the first embodiment described earlier.

[0115] As one example, it is possible to form the roughened portion **17***e* of each beam member **17** using a mold provided with a part corresponding to the roughened portion **17***e* when molding the beam members **17** by injection molding. As alternatives, it is possible to form the roughened portions **17***e* of the beam members **17** by processing the surface that forms the inner surface of the case **11** using an appropriate processing method such as laser processing, sandblasting, or etching after the beam members **17** have been molded by injection molding. By providing the roughened portion **17***e* on the surface of each beam member **17** that forms the inside of the case **11**, the surface area of this surface is increased.

[0116] In the semiconductor module **10**E, an insulating substrate and components such as semiconductor elements mounted on the insulating substrate are housed inside the case **11**. As depicted in FIG. **13**B, as one example, the insulating substrate and/or semiconductor elements housed inside the case **11** are encapsulated with encapsulating resin **19**, such as epoxy resin or silicone resin. When the inside of the case **11** is encapsulated with the encapsulating resin **19** in this way, due to the roughened portion **17***e* provided on the surface of each beam member **17** that forms the inside of the case **11** increasing the surface area of this surface, the strength of attachment between the beam members **17** and the encapsulating resin **19** is increased.

[0117] Note that with the semiconductor module **10** described in the first embodiment, the semiconductor module **10**A described in the second embodiment, and the semiconductor module **10**B, the semiconductor module **10**C, and the semiconductor module **10**D described in the third embodiment also, it is possible to encapsulate the inside of the case **11**, in which the insulating substrate and the semiconductor elements and the like are housed, with the encapsulating resin **19** in the same way as the semiconductor module **10**E described in the fourth embodiment.

[0118] Also, in the semiconductor module **10**E, the concave portions **11***a* of the case **11** and the beam members **17** may be provided with the channels **11***c* in which the adhesive **18***c* accumulates and the channels **17***c* in which the adhesive **18***d* accumulates in accordance with the example described in the second embodiment above.

[0119] It is also possible for the semiconductor module **10**E to be configured so that the mating portions **11***d* and the locking portions **17***d* are provided on the case **11** and the beam members **17** in accordance with the example described in the third embodiment above.

[0120] In the same way as the semiconductor module **10** described in the first embodiment, it is possible to connect the semiconductor module **10**E to other electronic components, such as the capacitor **20**, using the terminals **13** and the terminals **15** of the multi-layer structures **16** provided with the insulating sheets **14** in between.

Fifth Embodiment

[0121] The configuration of the multi-layer structures **16** in which the terminals **13**, the insulating sheets **14**, and the terminals **15** are stacked in that order is not limited to the configurations described above in the first to fourth embodiments. A different example configuration of the multi-layer structures **16** will now be described as a fifth embodiment.

[0122] FIGS. **14**A and **14**B and FIGS. **15**A and **15**B depict example configurations of multi-layer structures of semiconductor modules according to the fifth embodiment. FIGS. **14**A and **14**B and FIGS. **15**A and **15**B are plan views schematically depicting principal parts of the respective examples of semiconductor modules.

[0123] As one example, as depicted in FIG. **14**A, in each multi-layer structure **16**, the insulating sheet **14** may be formed without a cutout portion **14***a*. So long as the terminal **13** and the terminal **15** are provided with the insulating sheet **14** in between, a front end portion of the terminal **13** that forms an outside of the case **11** is exposed from the insulating sheet **14**, and the terminal **13**, the insulating sheet **14**, and the terminal **15** are stacked so that the front end portion of the terminal **13**, the insulating sheet **14**, and the terminal **15** are in a stepped arrangement when viewed in cross section, the insulating sheet **14** may omit the cutout portion **14***a*. The front end portion of the terminal **13** that is exposed from the insulating sheet **14** functions as the connecting region **13***a* that is to be connected to a terminal of an electronic component, such as the capacitor **20**.

[0124] Since the multi-layer structure **16** depicted in FIG. **14**A includes an insulating sheet **14** that is not provided with a cutout portion **14***a*, it is easier to prepare and dispose the insulating sheet **14**.

[0125] It is possible to use a configuration like that depicted in FIG. **14**A as the multi-layer structure **16**.

[0126] Also, as another example, the terminal **13** of each multi-layer structure **16** may be provided so that the front end portion of the terminal **13** protrudes from an outer edge of the concave portion **11***a* of the case **11** as depicted in FIG. **14**B. Here, the insulating sheet **14** is provided in a concave portion **11***a* of the case **11** so that the front end portion of the terminal **13** that protrudes from the outer edge of the concave portion **11***a* of the case **11** is exposed. The front end portion of the terminal **13** that protrudes from the outer edge of the concave portion **11***a* of the case **11** and is exposed from the insulating sheet **14** functions as the connecting region **13***a* to be connected to the terminal of an electronic component, such as the capacitor **20**.

[0127] In the multi-layer structure **16** depicted in FIG. **14**B, since the connecting region **13***a* of the terminal **13** protrudes outside the concave portion **11***a* of the case **11**, it is possible to prevent damage to the concave portion **11***a* of the case **11** situated below the terminal **13** when the terminal of an electronic component, such as the capacitor **20**, is connected by laser welding or the like to the connecting region **13***a*.

[0128] It is possible to use a configuration like that depicted in FIG. **14**B as the multi-layer structure **16**.

[0129] Also, as depicted in FIG. **15**A, the multi-layer structure **16** may be configured so that the front end portion of the terminal **13** protrudes from the outer edge of the concave portion **11***a* of the case **11** and is covered with the insulating sheet **14** that has the cutout portion **14***a*. The part of the terminal **13** that extends from the outer edge of the concave portion **11***a* of the case **11** and is exposed from the cutout portion **14***a* of the insulating sheet **14** functions as the connecting region **13***a* that is connected to the terminal of an electronic component, such as the capacitor **20**.

[0130] In the multi-layer structure **16** depicted in FIG. **15**A, since the connecting region **13***a* of the terminal **13** protrudes outside the concave portion **11***a* of the case **11**, it is possible to avoid damage to the concave portion **11***a* of the case **11** situated below the terminal **13** when the terminal of an electronic component, such as the capacitor **20**, is connected to the connecting region **13***a* by laser welding or the like.

[0131] Also, in the multi-layer structure **16** depicted in FIG. **15**A, aside from the part that forms the connecting region **13***a*, the front end portion of the terminal **13** that protrudes from the outer edge of the concave portion **11***a* of the case **11** is covered with the insulating sheet **14**, which is wider, in plan view, than the terminal **13**. With this configuration, as described above for example, sufficient insulation distance (or "creepage distance") across the insulating sheet **14** is achieved between the terminal **13** (which is an N terminal) and the connector member **30** (or "P terminal connecting terminal", indicated out of convenience with thin solid lines in FIG. **15**A) which is connected to the terminal **15** (the P terminal) when an electronic component such as the capacitor **20** is connected and becomes positioned above the terminal **13**.

[0132] It is possible to use the configuration depicted in FIG. **15**A as the multi-layer structure **16**.

[0133] As depicted in FIG. **15**B, the multi-layer structure **16** may be configured so that the front end portion of the terminal **13** protrudes from the outer edge of the concave portion **11***a* of the case **11** and is covered with the insulating sheet **14** that includes the cutout portion **14***a*, with the terminal **13** being wider in plan view than the configuration depicted in FIG. **15**A described above. The insulating sheet **14** is shaped so that a region that protrudes from the outer edge of the concave portion **11***a* of the case **11** is made even wider in plan view than the terminal **13** that has been widened.

[0134] With a multi-layer structure **16** like that depicted in FIG. **15**B also, it is possible to prevent damage to the concave portion **11***a* of the case **11** situated below the terminal **13** when the terminal of an electrical component, such as the capacitor **20**, is connected to the connecting region **13***a* that protrudes outside the concave portion **11***a* of the case **11** by laser welding or the like.

[0135] In addition, with a multi-layer structure **16** like that depicted in FIG. **15**B, as described above for example, sufficient insulation distance (or "creepage distance") across the insulating sheet **14** is achieved between the terminal **13** (which is an N terminal) and the connector member **30** (or "P terminal connecting terminal", indicated out of convenience with thin solid lines in FIG. **15**B) which is connected to the terminal **15** (the P terminal) when an electronic component such as the capacitor **20** is connected and becomes positioned above the terminal **13**. In addition, according to the multi-layer structure **16** depicted in FIG. **15**B, since the terminal **13** (the N terminal) is wider than the connector member **30** (the P terminal connector member) connected to the terminal **15** (P terminal) and the cross-sectional area of the terminal **13** is larger than the configuration in FIG. **15**A described above, the inductance at the part of the terminal **13** connected to an electronic component, such as the capacitor **20**, is reduced. According to the multi-layer structure **16** depicted in FIG. **15**B, it is possible to reduce inductance while achieving a sufficient insulation distance.

[0136] It is possible to use the configuration depicted in FIG. **15**B as the multi-layer structure **16**.

[0137] Note that in the semiconductor module **10** described in the first embodiment, the semiconductor module **10**A described in the second embodiment, the semiconductor module **10**B, the semiconductor module **10**C, and the semiconductor module **10**D described in the third embodiment, and the semiconductor module **10**E described in the fourth embodiment also, it is possible to use multi-layer structures **16** like those depicted in FIGS. **14**A and **14**B and FIGS. **15**A and **15**B.

Sixth Embodiment

[0138] A method for manufacturing (that is, an assembly method of) the semiconductor module **10** and the like described above will now be described as a sixth embodiment.

[0139] FIG. **16** depicts one example of a method for manufacturing a semiconductor module according to the sixth embodiment.

[0140] First, the case **11** equipped with the concave portions **11***a* including the recesses **11***b* is prepared (step S**1**). As one example, the case **11** is formed as depicted in FIGS. **4**A to **4**C described above by injection molding using a predetermined resin material, such as PPS resin. Alternatively, as

depicted in FIG. **10** described above, a case **11** that has the channels **11***c* provided in the recesses **11***b* of the concave portions **11***a* as depicted in FIG. **10** described above is formed. As another alternative, a case **11** provided with the mating portions **11***d* as depicted in FIGS. **11** and **12** described above is formed.

[0141] The beam members **17** that each include the recess **17***b* that is to be disposed in a concave portion **11***a* of the case **11** are prepared separately to the case **11** (step S**2**). As one example, beam members **17** like that depicted in FIGS. **6**A to **6**C described above is formed by injection molding using a predetermined resin material such as PPS resin, and as one example, the same resin material as the resin material used as the case **11**. Alternatively, beam members **17** that each have the channels **17***c* provided in the recess **17***b* like that depicted in FIG. **10** described above are formed. Alternatively, beam members **17** provided with locking portions **17***d* like those depicted in FIGS. **11**A and **11**B and FIG. **12** described above are formed. As another alternative, beam members **17** provided with a roughened portion **17***e* like that depicted in FIGS. **13**A and **13**B described above are formed.

[0142] The multi-layer structures **16** to be disposed in the concave portions **11***a* of the case **11**, that is, multi-layer structures **16** in which the terminal **13**, the insulating sheet **14**, and the terminal **15** are stacked in that order, are prepared separately to the case **11** and the beam members **17** (step S**3**). As one example, as depicted in FIGS. **5** and **7** described above, the terminal **13** is provided via the adhesive **18***a* on one surface of the insulating sheet **14** and the terminal **15** is provided via the adhesive **18***b* on the other surface of the insulating sheet **14**. Alternatively, multi-layer structures **16** like those depicted in FIGS. **14**A to **15**B described above are prepared.

[0143] Note that preparation of the case **11** (step S**1**), preparation of the beam members **17** (step S**2**), and preparation of the multi-layer structures **16** (step S**3**) may be performed in any order.

[0144] After the case **11**, the beam members **17**, and the multi-layer structures **16** have been prepared, the multi-layer structures **16** are disposed via the adhesive **18***c* in the concave portions **11***a* of the case **11** according to the example in FIG. **8** and FIGS. **9**A and **9**B described above (step S**4**).

[0145] In addition, the beam members **17** are disposed via the adhesive **18***d* in the concave portions **11***a* of the case **11** in which the multi-layer structures **16** have been disposed to attach the beam members **17** to the concave portions **11***a* according to the example in FIGS. **8** and FIGS. **9**A and **9**B described above (step S**5**). By doing so, the multi-layer structures **16** are fixed to the concave portions **11***a* of the case **11**.

[0146] When the mating portions **11***d* are provided on the case **11** and the locking portions **17***d* are provided on the beam member **17**, during disposing of the beam members **17** in the concave portions **11***a* of the case **11**, the locking portions **17***d* mate with and are locked to the mating portions **11***d*. When the beam members **17** are attached to the concave portions **11***a* of the case **11** in which the multi-layer structures **16** have been disposed, as one example, the beam members **17** are attached by applying heat while defoaming in a vacuum.

[0147] Note that the disposing of the multi-layer structures **16** (step S**4**) and the disposing of the beam members **17** (step S**5**) may be achieved by providing the beam members **17** via the adhesive **18***d* on the multi-layer structures **16** and then providing the multi-layer structures **16**, on which the beam members **17** have been provided in this way, via the adhesive **18***c* in the concave portions **11***a* of the case **11**.

[0148] As one example, a method like steps S**1** to S**5** is used to manufacture the semiconductor module **10** and the like described above.

[0149] The manufactured semiconductor module **10** or the like may be connected for example to the capacitor **20** using the terminals **13** and the terminals **15** of the multi-layer structures **16** that have the insulating sheets **14** provided in between in accordance with the example depicted in FIGS. **1** and **2** described above. By doing so, a semiconductor device **1** like that depicted in FIGS. **1** and **2** described above is obtained. Note that so long as the component is connected using the terminals **13** and the terminals **15** of the multi-layer structures **16**, it is possible to connect other electronic components to the semiconductor module **10** and the like, without the connected component being limited to the capacitor **20**.

[0150] An example configuration is described above where the multi-layer structures **16** are attached to the concave portions **11***a* of the case **11** using the adhesive **18***c* and the beam members **17** is attached to the concave portion **11***a* of the case **11** using the adhesive **18***d*. As an alternative, it is also possible to provide an encapsulating material that has an adhesive property or no adhesive property and is capable of filling gaps between the multi-layer structures **16** and the concave portions **11***a* of the case **11** or the beam members **17**, and to fix the beam members **17** to the case **11** by mating or by screw engagement.

[0151] According to the present embodiments, it is possible to realize a semiconductor device with high reliability.

[0152] All examples and conditional language provided herein are intended for the pedagogical purposes of aiding the reader in understanding the invention and the concepts contributed by the inventor to further the art, and are not to be construed as limitations to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although one or more embodiments of the present invention have been described in detail, it should be understood that various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A semiconductor device, comprising:

a case that has a side wall to form a frame, the side wall having a concave portion;

a multi-layer structure in which a first terminal, an insulating sheet, and a second terminal are stacked in that order and which is disposed on the concave portion; and

a beam member that is attached to the concave portion of the case to fix the multi-layer structure disposed on the concave portion.

2. The semiconductor device according to claim **1**, further comprising a first first-adhesive interposed between the concave portion of the case and the multi-layer structure and a second first-adhesive interposed between the multi-layer structure and the beam member.

3. The semiconductor device according to claim **1**, wherein the multi-layer structure further includes a first second-adhesive interposed between the first terminal and

the insulating sheet and a second second-adhesive interposed between the insulating sheet and the second terminal.

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

the multi-layer structure is disposed such that the first terminal is positioned at a bottom side of the concave portion of the case and the second terminal is positioned at a beam member side,

the concave portion of the case includes, at the bottom side, a first recess in which the first terminal of the multi-layer structure is housed, and

the beam member includes a second recess in which the second terminal of the multi-layer structure is housed.

5. The semiconductor device according to claim **4**, wherein

the case includes a first groove that communicates with the first recess, and

the beam member includes a second groove that communicates with the second recess.

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

the beam member includes a locking portion, and

the case includes a mating portion with which the locking portion of the beam member engages.

7. The semiconductor device according to claim **1**, wherein a material of the beam member is a same material as a material of the case.

8. The semiconductor device according to claim **1**, wherein the beam member attached to the concave portion of the case includes a roughened surface that forms a part of an inner surface of the side wall of the case.

9. A method for manufacturing a semiconductor device, comprising:

preparing a case that has a side wall to form a frame, the side wall having a concave portion;

preparing a beam member capable of being disposed in the concave portion of the case;

preparing a multi-layer structure in which a first terminal, an insulating sheet, and a second terminal are stacked in that order;

disposing the multi-layer structure in the concave portion of the case; and

attaching the beam member to the concave portion of the case in which the multi-layer structure is disposed to fix the multi-layer structure.

10. The method for manufacturing a semiconductor device according to claim **9**, further comprising bonding the concave portion of the case and the multi-layer structure together using a first first-adhesive and bonding the multi-layer structure and the fixed member together using a second first-adhesive.

11. The method for manufacturing a semiconductor device according to claim **9**, wherein the preparing of the multi-layer structure includes bonding the first terminal and the insulating sheet together using a first second-adhesive and bonding the insulating sheet and the second terminal together using a second second-adhesive.

12. The method for manufacturing a semiconductor device according to claim **9**, wherein

the disposing of the multi-layer structure includes disposing the multi-layer structure such that the first terminal is housed in a first recess provided in a bottom of the concave portion of the case, and

the attaching of the beam member to the concave portion of the case includes attaching the beam member such that the second terminal of the multi-layer structure disposed in the concave portion is housed in a second recess provided in the beam member.

13. The method for manufacturing a semiconductor device according to claim **9**, wherein

the beam member includes a locking portion,

the case includes a mating portion with which the locking portion of the beam member engages, and

the attaching of the beam member to the concave portion of the case includes engaging the locking portion of the beam member with the mating portion of the case.

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