

A SEMICONDUCTOR DEVICE, AND A PROCESS FOR
PRODUCING SUCH A DEVICE

The present invention relates to a semiconductor device, and to a process for producing such a semiconductor device, and is particularly directed to a semiconductor device having a heat-radiating member, such as a power transistor or a power IC (integrated circuit).

In power transistors currently used in practical applications, a heat-radiating member such as heat sink or flange is formed in a portion of the transistor case (package) in order to increase the heat radiation characteristics of a semiconductor pellet. The semiconductor pellet is adhered directly to the heat-radiating member such as heat sink or flange, so when the power transistor is operated the heat generated by the semiconductor pellet is radiated into the open air through the heat-radiating member.

In such a power transistor, furthermore, the heat-radiating characteristics may be improved by adhering the semiconductor pellet in electrical contact with the heat-radiating member. The heat-radiating member then also serves as an electrode or an external lead of the transistor.

In mounting the transistor of this type, it is accepted practice to interpose an insulating plate such as a mica plate between a flange 2 of the power transistor 1 and a metallic heat-radiating plate (mounting substrate) 11 as shown in Fig. 1. An insulating washer

16 is fitted to the mounting hole 2a of the flange 2, and the flange 2 and the heat-radiating plate 11 are fastened together by a bolt 17 so the transistor 1 is electrically insulated from the heat-radiating plate 11 it is mounted on.

With the above-mentioned method, however, the large number of parts such as insulating plates 15, insulating washers 16 and the like, make the mounting operation very complicated. Furthermore, when mica is used for the insulating plate 15, the dielectric breakdown voltage is about 1200 volts at the greatest. Use of an insulating plate 15 having increased thickness to increase the dielectric breakdown voltage, on the other hand, decreases the heat-radiating performance due to the thick insulating plate 15. Moreover, the insulating plate made of mica has such poor mechanical strength that it is often broken when the transistor 1 is mounted, and loses its insulating properties. Furthermore, with the above-mentioned mounting method, the insulating plate or the insulating washer may be broken while the device is being used, or deteriorate with time, to lose its insulating property.

In order to preclude the above-mentioned problems, British Patent Specification No. 1,365,658 teaches a resin-sealed semiconductor device in which an insulating plate is interposed between the semiconductor pellet and the heat-radiating member.

According to the resin-sealed semiconductor

device disclosed in this patent specification, however, the insulating plate has a size which is sufficiently greater than the semiconductor pellet to support all of the external electrode leads. Therefore, the heat
5 generated by the semiconductor pellet is not sufficiently radiated.

According to one aspect of the invention, there is provided a semiconductor device comprising:

a semiconductor pellet having a first main surface
10 and a second main surface opposite to said first main surface;

a first external lead having a paddle like segment on which the first main surface of the pellet is attached by a soldering material;

15 a second external lead which is electrically connected to an electrode formed on the second main surface of the pellet by a conductive wire;

a heat-radiating member made of metal;

an insulating member interposed between the
20 paddle-like segment and the heat-radiating member to isolate them electrically from each other; and

a sealing member formed on the heat-radiating member for surrounding and sealing the semiconductor pellet, the paddle-like segment, the insulating member
25 and the conductive wire;

and wherein:

the second external lead is spaced from the insulating member and fixed by the sealing member.

According to a second aspect of the invention, there is provided a process for producing a semiconductor device comprising:

a step for preparing an external lead having
5 a paddle-like segment, a plurality of external leads without paddle-like segment, and a lead frame having connecting portions connecting the leads;

a step for adhering a semiconductor pellet onto said paddle-like segment;

10 a step for electrically connecting said plurality of external leads to a plurality of electrodes formed on the main surface of said semiconductor pellet;

and after

a step for adhering the paddle-like segment
15 to which is attached said semiconductor pellet onto one main surface of a heat-radiating member via an insulator;

a step for sealing said semiconductor pellet with a resin in such a manner that said external leads are supported maintaining electric insulation and the
20 other main surface of said heat-radiating member is exposed;

and

a step for separating said external leads from the coupling portions.

Embodiments of the invention will now be described,
25 by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a section view showing a portion of a conventional electronic circuit device in which

a power transistor is mounted on a metallic substrate and has already been discussed;

Figure 2 is a perspective view of the power transistor according to an embodiment of the present invention;

Figure 3 is a section view showing the power transistor of Figure 2 on an enlarged scale;

Figures 4 to 9 are section views of power transistors according to further embodiments of the present invention;

Figure 10 is a perspective view of a lead frame which is used for obtaining a power transistor according to yet another embodiment of the present invention;

Figures 11 and 12 are section view illustrating the steps for obtaining a power transistor using the lead frame shown in Figure 10;

Figures 13 and 14 are perspective views showing the appearances of power transistors to which the present invention is applied;

Figure 15 is a diagram of an equivalent circuit of the power transistor of the present invention;

Figures 16 and 17 are section views showing composite power transistors in accordance with modified embodiments of the present invention;

Figure 18 is a diagram of an equivalent circuit of the composite power transistor of Figure 16;

Figure 19 is a diagram of an equivalent circuit of the composite power transistor of Figure 17;

Figure 20(A) is a section view showing on an enlarged scale a power transistor according to still another embodiment of the present invention;

Figure 20(B) is a plan view of an insulating plate which is used for the power transistor shown in Figure 20(A);

Figure 21 is a section view showing on an enlarged scale a power transistor according to a further embodiment of the present invention;

10 Figures 22 to 25 are section views showing power transistors according to modified embodiments of the present invention;

Figures 26 to 28 are side views showing the appearances of electronic circuit devices employing the 15 power transistor of the present invention;

Figure 29 is a diagram of an equivalent circuit of the electronic circuit device shown in Figure 28;

Figure 30(A) is a section view schematically illustrating a power transistor of the present invention;

20 Figure 30(B) is a diagram of an equivalent circuit of the power transistor of Figure 30(A);

Figure 31(A) is a section view schematically illustrating another power transistor of the present invention;

25 Figure 31(B) is a diagram of an equivalent circuit of the power transistor shown in Figure 31(A);

and

Figures 32(A), 32(B) and 32(C) are circuit

diagrams of electronic circuit devices employing the power transistors of the present invention.

Semiconductor devices and electronic circuit devices employing the semiconductor devices of the present invention will be described below with reference to various
5 embodiments in conjunction with the drawings.

In the drawings the corresponding parts are denoted by the same reference numerals. Where a part in one Figure has already been described in connection
10 with another Figure, the reference numeral is shown in the Figure, but description of the part is omitted.

Prior to illustrating the embodiments, transistors (hereinafter referred to as insulated transistors) being
embodiments of the present invention are classified as
15 follows depending upon differences in their construction:

(A) Transistors of the internally insulated type:

In a transistor of the internally insulated type, an insulating layer is formed between the semiconductor pellet and the case (stem or flange).

20 Transistors of this type can be further classified as follows:

(A1) Transistor in which an insulating plate (member) is interposed between the semiconductor pellet and the case.

25 (A2) Transistor in which an insulating layer is formed on the case.

Embodiments of the invention will be described below. Before each of the embodiment there is a heading such as "Embodiment A1-1" to clarify the relation to

the above-mentioned classifications. For instance, the heading "Embodiment Al-1" is one which pertains to the group Al.

Embodiment Al-1:

5 Figures 2 and 3 show an insulated transistor IC of the construction in which an insulating plate is interposed between the pellet and a case 18 to insulate them from each other.

10 In these Figures, the pellet 6 is adhered by the soldering material 27 onto a paddle-like segment (tub) 5 that is formed together with a lead 19 as a unitary structure. Although not shown, a layer is plated on the surface of the tub 5 to provide good adhesion to the soldering material. An insulating plate 28 with
15 a size nearly equal to that of the tub 5 is interposed between the tub 5 and a heat sink 3, and is adhered by soldering materials 29,30. The pellet 6 thus has a collector electrode on the bottom surface thereof, and lead 19 formed unitarily with the tub 5 serves as a collector
20 lead. Also the base and emitter electrodes B_o , E_o formed on the upper surface of the pellet 6 are electrically connected to other leads 20,21 through wires 22. Resin 10 is molded around the pellet 6, insulating plate 28, lead posts and wires in such a manner that the lower
25 surfaces of a flange 2 and the heat sink 3 are exposed.

 Here, to be suited for use as the insulating plate 28, the material should satisfy the requirements that (a) it is capable of being adhered onto the metals of tub 5 and heat sink 3; (b) it has a dielectric breakdown

voltage greater than a predetermined necessary value;
and (c) it has a small thermal resistance. Examples
of the materials which satisfy these requirements to
a reasonable extent may include beryllium oxide, polyimide
5 resin, mica, epoxy resin, BN (boron nitride) or a laminated
resin plate consisting of a fluorine-containing resin,
a polyimide resin and a fluorine-containing resin. Among
them, beryllium oxide, alumina ceramic and BN give
relatively good effects.

10 When an alumina ceramic is to be used as the
insulating plate 28, nickel should be plated onto the
upper and lower surfaces of the insulating plate 28 so
that soldering materials 29,30 will easily adhere thereto.

 Furthermore, for the reason mentioned below,
15 boron nitride BN is suited for use as the insulating
plate 28.

 Thus, a film of boron glass (B_2O_3) is formed
when the surfaces of the BN plate are oxidized. The
film of boron glass melts at a relatively low temperature,
20 and serves as an adhesive for the tub 5 and the heat
sink 3. Therefore, insulation can be reliably attained
between the tub 5 and heat sink 3 without a need for
any soldering material.

 According to this embodiment of the present
25 invention, the dielectric breakdown voltage should be
greater than 2 kilovolts, and the thermal resistance
 θ_{JC} should be 1.8 C/W, as in the requirements (a), (b)
and (c) mentioned above.

In assembling the insulated transistor 1C, it is recommended that soldering materials 27, 29 and 30 have the same melting point, so that the adhesion operation can be performed in a single step. Examples of the soldering material include a Pb/Sn solder, a Ag paste, and the like. On the other hand, when consideration is given to the thermal fatigue of the insulated transistor when it is subjected to a power cycling test, it is desirable that the tub 5, insulating plate 28 and heat sink 3 are firmly adhered together. For this purpose, therefore, the soldering materials 29, 30 should have a higher melting point than the soldering material 27 for adhering the pellet 6, and the soldering should be effected before the pellet is attached.

When a conventional transistor is mounted on the heat-radiating plate via an insulating material such as mica, the dielectric breakdown voltage is 1.2 kilovolts. The device according to the embodiment of the present invention, however, exhibits a dielectric breakdown voltage of 2 to 3 kilovolts.

Embodiment A1-2:

Fig. 4 illustrates an insulated transistor 1H₁ in which the resin 10 exhibits a great adhesive force relative to the case 18 (heat sink 3). For example, when the heat sink 3 has a diameter which is small compared

with the size of the insulating plate 28A as shown in Fig. 3, the area of contact between the resin 10 and the upper surface of the heat sink 3 is small, and the adhesive force of the resin is reduced. Therefore, the soldering material 30 between the insulating plate 28A and the heat sink 3 loses its adhesive strength due to thermal fatigue; and life in the power cycling test is shortened. Referring to the transistor $1H_1$ shown in Fig. 4, on the other hand, the heat sink 3A has an upper surface which is large relative to the insulating plate 28A, so that there is a large area of contact (adhesion) between the resin 10 and the upper surface of the heat sink 3A. Therefore, the resin bond is stronger, and thermal fatigue of the soldering material 30 is reduced. The dimensional ratio in the vertical and lateral directions of the heat sink 3A relative to the insulating plate 28A should be greater than 1.2.

Embodiment A1-3:

The insulated transistor $1H_2$ shown in Fig. 5 has rugged grooves 37 in the upper surface of the heat sink 3B in order to further increase the adhesive force of the resin as compared with the insulated transistor $1H_1$ of Embodiment A1-2.

Embodiment A1-4:

The insulated transistor shown in Fig. 6 is designed

so that thermal fatigue of the soldering materials 29, 30 on the upper and lower surfaces of the insulating plate 28A is reduced.

When the soldering materials 29, 30 are not formed uniformly with a suitable thickness (for example, 20 to 80 μm), the soldering materials undergo thermal expansion at different rates, so that thermal fatigue is increased and the life is shortened. In the insulated transistor 11_1 of Fig. 6, on the other hand, tongue and groove portions 38, 39 of a uniform height are formed on the surfaces of the tub 5A and the heat sink 3, and these tongue and groove portions are filled with the soldering materials 29, 30, so the soldering materials thus assume uniform thickness. The tongue and groove portions 38, 39 may be formed in the shape of a lattice, in the shape of sections, or simply in the shape of projections.

Embodiment A1-5:

For the same reasons as Embodiment A1-4, the insulated transistor 11_2 shown in Fig. 7 has tongue and groove portions 40 formed on the upper and lower surfaces of the insulating plate 28B.

The above-mentioned processing can be readily and easily effected when the insulating plate is made of a material such as alumina.

Embodiment A1-6:

Fig. 8 shows an insulated transistor in which the insulating plate exhibits increased insulation reliability. In the case of the transistor 1C shown in Fig. 5, the tub 5 and the heat sink 3 can be short-circuited through the soldering members 29, 30 at the edge of the insulating plate 28A, whereby the insulating plate 28A loses its insulating function and the transistor as a whole loses its reliability. With the insulated transistor 1J₂ shown in Fig. 8, on the other hand, a base portion 19a of a lead 19 formed together with the tub 5 as a unitary structure is folded upwards, so that the soldering material 29 will not melt down beyond the base portion 19a; and the possibility of short-circuiting is thus prevented. An insulating plate 28A of a slightly increased size will also effectively prevent short-circuiting.

Embodiment A1-7:

Referring to a transistor 1J₃ shown in Fig. 9, a plurality of grooves 41 are formed in the upper peripheral portion of the insulating plate 28C. The grooves 41 prevent the soldering material 29 from flowing down to the lower side of the insulating plate through the periphery of the insulating plate 28C. It is therefore possible to prevent the soldering materials applied to the upper and lower surfaces of the insulating plate 28C

from short-circuiting.

It is also possible to form protruded ridges instead of grooves. Formation of grooves or ridges makes it possible to prevent the occurrence of poor insulation as mentioned above, helps increase the insulating distance in the insulating plate 28C, and further helps increase the dielectric breakdown voltage.

Embodiment A1-8:

Figs. 10 to 12 briefly illustrate a process for producing a transistor by using a lead frame which has a tub and external leads formed as a unitary structure.

Namely, in mounting the lead frame with the pellet on the tub, in the case when mounting is followed by soldering or molding with a resin, a problem arises in that it is difficult to position the lead frame relative to the case. On the other hand, according to the embodiment of the present invention as shown in Fig. 10, a lead frame 4A has a tub 5, three leads 19, 20 and 21, and a pair of fixing leads 42, 42, formed as a unitary structure. Prior to soldering the pellet on the tub 5 of the lead frame 4A, the fixing leads 42, 42 are fastened by caulking to projections 2b(2b) formed on the case 18 (flange 2) as shown in Fig. 11, and the lead frame 4A and the case 18 are set together maintaining a predetermined relative position. After the soldering or resin molding has been

finished, the lead coupling portions 43 and fixing leads 42 are cut away as shown in Fig. 12, so good insulation is maintained between the leads and the case. In producing the transistor 1K, no special jig or clumsy positioning operation that must rely upon the positioning holes of the lead frame is required; the manufacturing steps can be greatly reduced, and the positioning precision is increased. For instance, when the lead frame without the fixing lead 42 is used, 15 hours is required to manufacture 1000 transistors. Using the lead frame 4A, however, only 6.4 hours is required to manufacture the same number of transistors.

The foregoing description has dealt with insulated transistors having relatively large output performance of the resin molded type. The internal constructions of the above-mentioned embodiments can also be applied to a transistor 1L with a can-type package shown in Fig. 13; to a transistor 1M with a resin-molded package and small output performance as shown in Fig. 14; and to transistors of any other types. The same is of course true for the insulated transistors of other constructions that will be mentioned below.

As will be obvious from the above description, the electrodes of the insulated transistors are completely insulated from the case. Therefore, referring, for example,

to the bipolar transistor 1N of Fig. 15, it is possible to realize a four-terminal transistor which has a flange (case) terminal F in addition to the lead terminals for the collector C, base B and emitter E. By using the above transistor, therefore, increased freedom is provided for designing a circuit on the mounting substrate (e.g., the flange terminal F can be used for connection to a different electrode), and the heat-radiating plate can be commonly utilized (a variety of transistors can be mounted on a single heat-radiating plate).

Embodiment A1-9:

According to the insulated transistor of the present invention as shown in Fig. 15, the terminals C, B, E and F are insulated from the case. Therefore, as represented by a composite transistor 10₁ of Fig. 16, it is allowed to mount a pair of pellets 6A and 6B (a PNP transistor pellet and an NPN transistor pellet) on the same tub 5, and to connect the wires suitably. Consequently, a complementary composite transistor 10₂ can be constructed as shown in Fig. 18. Namely, referring to the composite transistor 10₁ of Fig. 16, the bases of the pellets 6A, 6B are electrically connected to each other through a wire, and the collectors are connected to each other through the tub 5.

Embodiment A1-10:

Referring to a composite transistor shown in Fig. 17,

a pair of pellets 6A, 6B (PNP transistor pellet, NPN transistor pellet) are mounted on the different tubs 5B and 5C, and their bases and emitters are electrically connected to each other through wires. Consequently, a composite transistor 10₄ can be constructed as shown in Fig. 19..

The above-mentioned embodiments A1-9 and A1-10 help reduce the space required for mounting the transistors, reduce the number of steps for mounting the transistors, and reduce the manufacturing cost.

10 Embodiment A1-11:

Referring to an insulated transistor 1D shown in Figs. 20(A) and 20(B), a metal layer 31 which corresponds to the tub is formed on the upper surface of the insulating plate 28A. The pellet 6 is mounted directly on the metal layer 31 by the soldering material 27. Referring to Fig. 20(B), the insulating plate 28A and the metal layer 31 have a sidewardly protruded portion P; the lead 19 is welded to the metal layer 31a of the protruded portion P. The metal layer 31 is formed by adhering a thin metal plate on the insulating plate. The metal layer 31 may, however, also be formed by vaporizing or coating a metal material.

Embodiment A1-12:

As a modified example of the above embodiment A1-11, there can be contrived an insulated transistor 1E as shown in Fig. 21.

33

The insulated transistor 1E has a metal layer 32 applied to the lower surface of the insulating plate 28A, formed simultaneously with the formation of the metal layer 31. Because of the metal layer 32, the adhesion by the soldering material 30 between the insulating plate 28A and the heat sink 3 can be improved, and the insulating plate 28A and the soldering material 30 can be selected over wider ranges. For instance, solder can be used in place of the silver paste to reduce the manufacturing cost of the transistors.

According to the aforementioned embodiments A1-2 and A1-3, no adhesion is required between the tub and the insulating plate. Therefore, the soldering layer can be eliminated, the number of assembling steps can be reduced to reduce both the manufacturing cost and the thermal resistance.

Embodiment A1-13:

Using the present invention, since the individual terminals are insulated from the case, it is possible to apply any desired bias voltage to any terminal and it is possible to connect any terminal to the case.

For example, a cap-type transistor 1P₁ shown in Fig. 22 can be easily applied to an emitter-grounded circuit.

Namely, referring to Fig. 22 , the collector and base of the pellet 6 are electrically connected through wires to a pair of lead posts 13A and 14A that are supported by, yet insulated from the case (metallic flange 2A) 18. The emitter, on the other hand, is electrically connected to the flange 2A through a wire 22A. Reference numeral 44 denotes a metal cap which is electrically connected to the flange 2A. The thus constructed transistor can be easily applied to an emitter-grounded circuit, which is frequently employed for the transistor circuits. Therefore, the resistance of the emitter wiring can be reduced, and the emitter line is less affected by disturbances. Furthermore, the collector is shielded by the cap 44 and the flange 2A. It is therefore possible to eliminate the difficulties encountered when transistors having high dielectric breakdown voltage and high operation-speed characteristics are required , as well as to eliminate the radiation of undesired electromagnetic waves. The same also holds true when a transistor of the base-grounded type is to be formed.

Embodiment A1-14:

The cap-type transistor $1P_2$ shown in Fig. 23 is a field effect transistor. When the drain electrode D which had been connected to the flange 2A is connected to the lead post 13B, and the source electrode S is connected to the

35

flange 2A, the source inductance can be decreased, and high-frequency and noise characteristics can be improved.

Embodiment A2-1:

Fig. 24 illustrates an insulated transistor 1F in which the insulating layer is formed directly on the surface of the case 18 or, in other words, on the pellet-mounting surface of the case (heat sink 3). Namely, referring to Fig. 24, an insulating material such as a ceramic material is melt-applied to the upper surface of the heat sink 3 to form the insulating layer 33. Further, a metal layer 34 is formed on the upper surface of the insulating layer 33. The tub 5 and pellet 6 are adhered onto the metal layer 34 by the soldering materials 35, 36. Furthermore, the pellet 6 may be adhered directly onto the metal layer 34. In forming the insulating layer 33, the insulating material may be subjected to baking or a sheet-like insulating material may be stuck on.

Embodiment A2-2:

According to a transistor 1G shown in Fig. 25, a portion 10a of the molding resin 10 is interposed between the tub 5 and the heat sink 3 so as to serve as an insulating layer. The insulating layer 10a is inevitably formed if the case 18, pellet 6, lead (tub 5) 19, and the like are molded with a resin using a molding machine. In this case, it is also possible to temporarily mount the pellet

by potting a resin layer on a site which corresponds to the insulating layer 10a, to facilitate positioning.

According to these embodiments A2-1 and A2-2, the insulating layer and the soldering layer can be greatly reduced, to reduce the number of assembling steps and to reduce the manufacturing cost. The transistors thus assembled, however, are slightly inferior to those of the aforementioned embodiments with regard to the dielectric breakdown voltage, thermal resistance and strength.

Externally insulated transistors (in contrast with the aforementioned internally insulated transistors) will be discussed below. The transistors of the externally insulated type have an insulating layer in a portion of the case between the mounting surface of the heat-radiating plate (mounting substrate) and the heat sink. The externally insulated transistors, however, are the same as the internally insulated transistors in that the electrodes of the pellets are insulated from the heat-radiating plate.

Electronic circuit devices being embodiments of the present invention incorporating insulated transistors as necessary constituent of the circuits will now be described:

Assembly 1:

Figure 26 shows an electronic circuit device in which an insulated transistor of the resin-molded type is mounted directly on the mounting substrate. With the electronic

device 100A of the present invention, even when the insulated transistor 1X is directly mounted on the mounting substrate 11, such as the chassis, which also serves as a heat-radiating plate, the lead terminals L are insulated from the heat-radiating plate 11. Therefore, the flange 2 can be directly mounted on the grounded heat-radiating plate using bolts 17a and nuts 17b without a need for any insulating material or insulating washer such as of mica. Since no insulating member is used, the number of steps for mounting the transistor is reduced. Further, the dielectric breakdown voltage is not decreased by defective insulating material or the like. Moreover, the insulating material establishes small capacitance, and the circuit devices develop little loss even under high-frequency conditions. In particular, with an internally insulated transistor using alumina plate as the insulating material, it has been experimentally confirmed that the capacitance can be reduced to 30 pF, which is a striking reduction when compared with the capacitance (about 200 pF) of the conventional mica plate.

Assembly 2:

Fig. 27 shows an electronic circuit device 100B consisting of a plurality of circuit elements, in which a circuit unit 101 has a heat-radiating plate (portion) 51 maintained at a predetermined potential. The circuit unit 102, on the other hand, does not have the heat-radiating plate (portion). These circuit units 101 and 102 are electrically connected together via an insulated transistor 1X. Namely, the transistor 1X is mounted on one unit 101, and the lead terminal L is

connected to the other circuit unit 102. Since the flange and the lead terminal of the transistor 1X have been insulated from each other, the potential of the circuit unit 101 does not affect the lead terminal L, and the 5 circuit units can work independently of each other.

According to this embodiment, the ~~heat~~-radiating space is not restricted to only within the circuit unit but can be more extensive. In accordance with the embodiment of the present invention, therefore, even a compli- 10 cated circuit setup (where, for example, a common ground is not formed) can be simplified, making it possible to reduce the size of the device, increase the density and, eventually, to simplify the design requirements and maintenance.

15 Assembly 3:

Figure 28 shows an electronic circuit device 100C in which a pair of insulated transistors 1X₁ and 1X₂ are opposed to each other, are fastened by the flanges 2X₁, 2X₂ to form a unitary structure. Since the lead 20 terminals L₁, L₂ of the transistors 1X₁, 1X₂ are insulated from the flanges, the electronic circuit device constitutes a complementary circuit as shown in Figures 18 and 19. The device can be utilized for a circuit of Figure 29, which is connected to a load element 52 which drives 25 a motor or has inductance components. This helps to reduce the mounting space. Further, since the two flanges are fastened together, the thermal capacity can be doubled to enhance the heat-radiating performance.

In an electronic device 100D in which the internally insulated transistor 1X is mounted on the grounded heat-radiating plate 11 as shown in Figure 30(A), a capacitance C_x is produced across the insulating plate 5 28A. This circuit setup can be regarded as being equal to one in which a capacitance C_x is connected between the collector and the ground, as shown by an equivalent circuit in Figure 30(B).

Furthermore, as shown in Figure 31(A), if an 10 insulating member 15 is provided between the flange 2 and the heat-radiating plate 11, and electronic circuit device 100E can be constructed, which is equivalent to the circuit of Figure 31(B). Use of the insulated transistor 100E eliminates the need of a capacitor C_x 15 which is usually used as a separate unit in the oscillation-preventing circuits of Figures 32(A) and 32(B). Referring to a protection circuit for electronic circuits used in automobiles shown in Figure 32(C), only a coil L_x and a resistor R need be added, and no extra capacitor 20 is required. Therefore, the construction can be simplified, and the manufacturing cost can be reduced.

According to the present invention as illustrated by way of a variety of embodiments in the foregoing, the transistor can be easily assembled requiring a reduced 25 number of parts. Furthermore, the transistor can be used in a variety of modes to increase the degree of utilization. The transistor further exhibits increased dielectric breakdown voltage and improved heat-radiating

-25-

performance. According to the electronic device of the present invention, insulated transistors can be utilized to a greater extent.

The device according to the present invention
5 exhibits a high degree of reliability and insulation.
Therefore, the device of the present invention is suited
for use in electronic parts for automobiles. The device
of the present invention is of course suited for use under
various other conditions.

10

15

20

25

CLAIMS:

1. A semiconductor device comprising:

a semiconductor pellet having a first main surface and a second main surface opposite to said first main surface;

5 a first external lead having a paddle-like segment on which the first main surface of the pellet is attached by a soldering material;

a second external lead which is electrically connected to an electrode formed on the second main surface
10 of the pellet by a conductive wire;

a heat-radiating member made of metal:

an insulating member interposed between the paddle-like segment and the heat-radiating member to isolate them electrically from each other; and

15 a sealing member formed on the heat-radiating member for surrounding and sealing the semiconductor pellet, the paddle-like segment, the insulating member and the conductive wire;

and wherein;

20 the second external lead is spaced from the insulating member and fixed by the sealing member.

2. A semiconductor device according to Claim 1, wherein the sealing member is made of a resin.

3. A semiconductor device according to Claim 1
25 or Claim 2, wherein the insulating member is substantially planar.

4. A semiconductor device according to Claim 3, wherein the area of the heat-radiating member is greater



than the area of one surface of the insulating member.

5. A semiconductor device according to Claim 2, wherein grooves are formed in a portion of the heat-radiating member that comes into contact with the sealing
5 member.

6. A semiconductor device according to any one of the preceding Claims, wherein the paddle-like segment has a tongue and grooved portion.

7. A semiconductor device according to any one
10 of the preceding Claims, wherein the insulating member is substantially planar but has tongue and grooved portions in the upper and lower surfaces thereof.

8. A semiconductor device according to any one of the preceding Claims, wherein the first external lead
15 has a detouring portion in the vicinity of the paddle-like segment.

9. A semiconductor device according to Claim 3 as dependent on Claim 2, wherein grooves are formed in a portion of the insulating member that comes into contact
20 with the sealing member made of a resin.

10. A semiconductor device according to any one of the preceding Claims, wherein a plurality of semiconductor pellets are mounted on the paddle-like segment.

11. A semiconductor device according to any one
25 of the preceding Claims, wherein provision is made for a third external lead having a paddle-like segment, and semiconductor pellets are mounted on the paddle-like segments of the respective external leads.



12. A semiconductor device according to Claim 3, wherein the insulating member is composed of an alumina ceramic.

13. A semiconductor device according to Claim 3,
5 wherein the insulating member is composed of boron nitride, and the paddle-like segment and the heat-radiating member are adhered to the insulating member with a film of boron glass.

14. A semiconductor device substantially as herein
10 described with reference to and as illustrated in any one of Figs. 2 to 9, or Figs. 10, 11 and 12, or any one of Figs. 16, 17, 20 to 25, 30 and 31 of the accompanying drawings.

15. A process for producing a semiconductor device
15 comprising:

a step for preparing an external lead having a paddle-like segment, a plurality of external leads without paddle-like segment, and a lead frame having connecting portions connecting the leads;

20 a step for adhering a semiconductor pellet onto said paddle-like segment;

a step for electrically connecting said plurality of external leads to a plurality of electrodes formed on the main surface of said semiconductor pellet;

25 and after

a step for adhering the paddle-like segment to which is attached said semiconductor pellet onto one main surface of a heat-radiating member via an insulator;



44

-29-

a step for sealing said semiconductor pellet
with a resin in such a manner that said external leads
are supported maintaining electric insulation and the
other main surface of said heat-radiating member is
5 exposed;

and

a step for separating said external leads from
the coupling portions.

16. A process according to Claim 15 for producing
10 a semiconductor device, substantially as any described
herein.
