PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Power Transistor

We, RCA CORPORATION (formerly RADIO CORPORATION OF AMERICA), a corporation organised under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

A number of problems have been encountered in designing bipolar power transistors. One of these problems is that emitter-base current tends to concentrate at certain points along the emitter-base junction, causing local over-heating and eventual breakdown of the crystal structure and failure of the device.

Another problem found in power transistors is that of heat dissipation. The amount of heat which must be dissipated per unit of area is considerable, and if it is not properly dissipated it can lead to device failure.

Power transistors have previously been made with a number of different emitter region and base region configurations. Since it was found that nearly all the emission from an emitter region takes place around its periphery, emitters were designed to achieve maximum periphery with lowest possible surface area. One type of design for achieving this large perimeter dimension was the comb-shaped emitter having fingers interdigitated with a complementary comb structure for the base region. Another structural form was the pin wheel or star-shaped emitter having tapered fingers or spokes interdigitated with complementary shaped fingers of the base region. Still another more recently used structure has been the emitter consisting of a multiplicity of separate sites all connected together in parallel to function as a single emitter. The comb-shaped structure had the disadvantage of having the active areas of the emitter concentrated in a relatively small area of the device surface, which increased the heat dissipation problem since a relatively large amount of heat was being generated in a relatively small area. The star-shaped emitter had the disadvantage that it could use only a single contact at the center and, because of the heavy current concentration, heavy metallizing of the central portion was necessary. The multiple emitter site type solved the problems with respect to device operation, especially at higher voltages where it greatly decreased the danger of junction breakdown, but it required relatively expensive evaporated metal deposition to connect the emitter sites.

In the accompanying drawings:—

Figure 1 is a plan view of the emitter and base regions of a device in accordance with the present invention, before it is completely assembled;

Figure 2 is a view similar to that of Figure 1 of a more completely assembled device, and

Figure 3 is a section view taken along the line 3-3 of Figure 2.

The invention comprises a power transistor in which the emitter is composed of a plurality of segments symmetrically arranged about a central device area which comprises part of the base region of the device. Each emitter segment, which radiates outwardly from the central area, is composed of a tree-like diffused portion having a central trunk from opposite sides of which project pairs of branches. The base region has branches of complementary shape, interdigitated with the emitter branches. A particular

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feature of the invention is the emitter contact electrode which comprises a metal plate with a central aperture, suspended above the wafer surface and connected to each emitter segment adjacent its outer periphery. A base contact electrode extends through its aperture of the emitter contact electrode and connects to the base region in the central area of the device.

As illustrated in Figure 1, a preferred embodiment of a device in accordance with the present invention includes a semiconductor wafer 2 having an emitter region which is composed of four separate segments 4*a*, 4*b*, 4*c* and 4*d* radiating outwardly from the central area of the device. Each of these emitter segments is in a different quarter of the semiconductor pellet. Each emitter segment has a tree-like configuration and is composed of a central trunk portion 8 (*a*, *b*, *c* & *d*) with pairs of lateral branches 10 (*a*, *b*, *c*, & *d*) extending from opposite sides thereof. The branches are of regularly increasing length in a direction looking outwardly from the center of the device. Preferably, the emitter region is of mesa type and projects above the surface of the surrounding base region.

The remainder of the top portion of the semiconductor pellet 2 is occupied by a base region 6. The base region 6 includes a central portion 6′ and four segments 6 (*a*, *b*, *c* and *d*) connected to the central portion 6′ and radiating therefrom. Each of the base region segments comprises a trunk portion 12 (*a*, *b*, *c* & *d*) and pairs of laterally-extending branches 14 (*a*, *b*, *c* & *d*) which are interdigitated with the emitter region branches 10 (*a*, *b*, *c*, & *d*). The base region trunk portions 12 (*a*, *b*, *c* & *d*) are all connected with a rectangular frame portion 16 of the base region extending around the periphery of the pellet 2.

The emitter and base regions, as described above, have been designated to distribute emitter-base current evenly over the entire surface area of the pellet.

The emitter and base regions are separated by four p-n junctions 18. The device also includes a collector region 19 (Figure 3) of conductivity type opposite that of the base region.

In order to make good low resistance contact to all parts of the top surface of the emitter and base regions they are provided with metal layers. The metal layer on the emitter region segments comprises an adherence-promoting sug-layer of nickel 20 (Figure 3) and a top layer portion of solder 22. Similarly, the base region has a sublayer of nickel and a top layer of solder 26.

The nickel layer is deposited as follows. First a thin layer of nickel is electrolessly deposited from a solution over the entire upper surface of the pellet. This is then sintered at 800°C. in a hydrogen atmosphere for 15 minutes. A second layer of nickel is then deposited electrolessly over the first layer. This is done by first defining the areas where the nickel is to be deposited, using conventional photoresist and masking methods and removal of photoresist where the metal is to be deposited. The second layer of nickel is not deposited over the exposed line of p-n junction 18. Nickel is deposited on the surfaces not covered by photoresist. The deposit area includes a layer 28 on most of the bottom surface of the pellet 2.

With the photoresist remaining in place, the entire unit is dipped in molten solder. The solder adheres to the nickel layers 20 and 24 on the emitter and base regions respectively forming solder layers 22 and 26. A solder layer 30 also deposits on the bottom nickel layer 28.

The pellet is then etched to remove the photoresist and to etch the exposed p-n junction 18.

The pellet 2 is then mounted on a molybdenum plate 32 by melting the solder layer 30. The molbdenum plate was previously brazed to a copper header 34. The collector of the transistor is thus grounded to the header.

A particular feature of the present invention is the emitter contact electrode. This electrode comprises a rectangular-shaped metal plate 36 having a central aperture 38. The plate also has an arm 40 extending from one edge and the arm is soldered to a pin 42 which passes through the header but is insulated therefrom by means of a ceramic eyelet (not shown). The plate 36 is spaced above the pellet surface except at its corners. The corners of the plate 36 have dimpled projections 44 which are soldered to peripheral portions of the emitter segments 4 (*a*, *b*, *c* & *d*). The emitter contact electrode is capable of carrying heavy currents, is a good heat radiator, and, because of its cooperation with the emitter region described, distributes current evenly to all parts of the emitter. Using this contact electrode, transistors have been constructed which easily handle 70 amps of current.

The transistor also includes a base contact electrode 46 which comprises a tapered piece of phosphor bronze having one end soldered to a pin 48 that passes through header 34 but is insulated therefrom by means of a ceramic eyelet (not shown). The other end of contact electrode 46 is bent down through the aperture 38 in the emitter contact electrode 36 and makes contact with the base region in central area 6′.

WHAT WE CLAIM IS:—

1. A transistor including (a) a wafer of semiconducting material including emitter, base and collector regions, (b) said emitter

feature of the invention is the emitter contact electrode which comprises a metal plate with a central aperture, suspended above the wafer surface and connected to each emitter segment adjacent its outer periphery. A base contact electrode extends through its aperture of the emitter contact electrode and connects to the base region in the central area of the device.

As illustrated in Figure 1, a preferred embodiment of a device in accordance with the present invention includes a semiconductor wafer 2 having an emitter region which is composed of four separate segments 4*a*, 4*b*, 4*c* and 4*d* radiating outwardly from the central area of the device. Each of these emitter segments is in a different quarter of the semiconductor pellet. Each emitter segment has a tree-like configuration and is composed of a central trunk portion 8 (*a, b, c & d*) with pairs of lateral branches 10 (*a, b, c, & d*) extending from opposite sides thereof. The branches are of regularly increasing length in a direction looking outwardly from the center of the device. Preferably, the emitter region is of mesa type and projects above the surface of the surrounding base region.

The remainder of the top portion of the semiconductor pellet 2 is occupied by a base region 6. The base region 6 includes a central portion 6′ and four segments 6 (*a, b, c* and *d*) connected to the central portion 6′ and radiating therefrom. Each of the base region segments comprises a trunk portion 12 (*a, b, c & d*) and pairs of laterally-extending branches 14 (*a, b, c & d*) which are interdigitated with the emitter region branches 10 (*a, b, c, & d*). The base region trunk portions 12 (*a, b, c & d*) are all connected with a rectangular frame portion 16 of the base region extending around the periphery of the pellet 2.

The emitter and base regions, as described above, have been designated to distribute emitter-base current evenly over the entire surface area of the pellet.

The emitter and base regions are separated by four p-n junctions 18. The device also includes a collector region 19 (Figure 3) of conductivity type opposite that of the base region.

In order to make good low resistance contact to all parts of the top surface of the emitter and base regions they are provided with metal layers. The metal layer on the emitter region segments comprises an adherence-promoting sug-layer of nickel 20 (Figure 3) and a top layer portion of solder 22. Similarly, the base region has a sublayer of nickel and a top layer of solder 26.

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With the photoresist remaining in place, the entire unit is dipped in molten solder. The solder adheres to the nickel layers 20 and 24 on the emitter and base regions respectively forming solder layers 22 and 26. A solder layer 30 also deposits on the bottom nickel layer 28.

The pellet is then etched to remove the photoresist and to etch the exposed p-n junction 18.

The pellet 2 is then mounted on a molybdenum plate 32 by melting the solder layer 30. The molbdenum plate was previously brazed to a copper header 34. The collector of the transistor is thus grounded to the header.

A particular feature of the present invention is the emitter contact electrode. This electrode comprises a rectangular-shaped metal plate 36 having a central aperture 38. The plate also has an arm 40 extending from one edge and the arm is soldered to a pin 42 which passes through the header but is insulated therefrom by means of a ceramic eyelet (not shown). The plate 36 is spaced above the pellet surface except at its corners. The corners of the plate 36 have dimpled projections 44 which are soldered to peripheral portions of the emitter segments 4 (*a, b, c & d*). The emitter contact electrode is capable of carrying heavy currents, is a good heat radiator, and, because of its cooperation with the emitter region described, distributes current evenly to all parts of the emitter. Using this contact electrode, transistors have been constructed which easily handle 70 amps of current.

The transistor also includes a base contact electrode 46 which comprises a tapered piece of phosphor bronze having one end soldered to a pin 48 that passes through header 34 but is insulated therefrom by means of a ceramic eyelet (not shown). The other end of contact electrode 46 is bent down through the aperture 38 in the emitter contact electrode 36 and makes contact with the base region in central area 6′.

WHAT WE CLAIM IS:—

1. A transistor including (a) a wafer of semiconducting material including emitter, base and collector regions, (b) said emitter

region being of one conductivity type and being disposed adjacent a surface of said wafer, said emitter region being composed of a plurality of separate portions each of which comprises a trunk with pairs of lateral branches extending from opposite sides thereof, all of said trunks extending radially from a central area of said surface and said branches being of progressively increasing length toward the periphery of said surface, (c) a base region of opposite conductivity type also adjacent said wafer surface, said base portion including said central surface area and having branches interdigitated with said emitter region branches, characterized by: (d) an emitter contact electrode comprising a metal plate suspended above said wafer surface, said plate being connected to each of said emitter region portions adjacent the periphery therof, said plate having a central aperture, and (e) a base contact electrode extending through said aperture connected to said central area base region portion.

2. A transistor according to claim 1 in which said emitter is composed of four separate segments each of which is located in a different quarter of said wafer surface.

3. A transistor according to claim 1 in which said emitter region is a mesa type.

4. A transistor according to claim 1 in which said emitter and base regions are metallized with solder.

5. A transistor as claimed in claim 1 and substantially as described with reference to the accompanying drawings.

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