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SEMICONDUCTOR SIGNAL TRANSLATING DEVICE

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FIG. 1

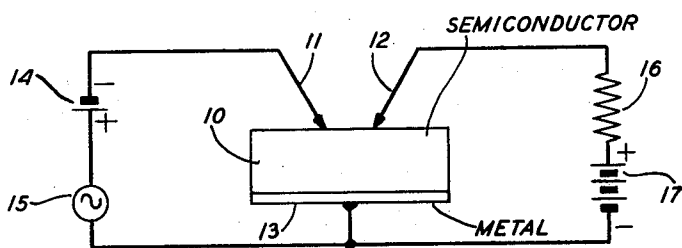
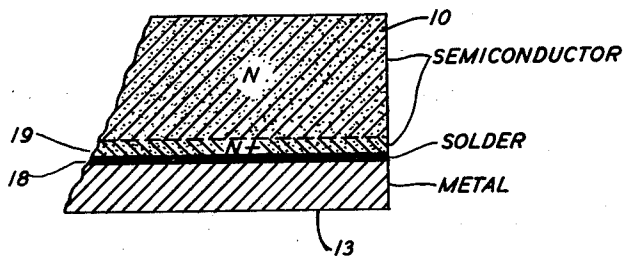


FIG. 2



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SEMICONDUCTOR SIGNAL TRANSLATING
DEVICE

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8 Claims. (Cl. 175-366)

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This invention relates to semiconductor signal translating devices and more particularly to semi-conductor amplifiers of the type disclosed in the application Serial No. 33,466, filed June 17, 1948, of J. Bardeen and W. H. Brattain, now Patent 2,524,035, granted October 3, 1950.

Devices of this type comprise, in general, a body of semiconductive material for example germanium, a pair of connections, for example point contacts, designated the emitter and collector, to the body, and a third substantially ohmic connection, referred to as the base, to the body. Electrical carriers of sign opposite that of those normally in excess in the body are injected at the emitter and flow to the collector whereby amplified replicas of input signals impressed between the emitter and base, appear in a load circuit connected between the collector and base.

The semiconductive body may be of either conductivity type, that is N or P-type. As is known, each type is associated with impurities characteristic thereof, specifically excess donor impurities in the case of N-type material and excess acceptor impurities in the case of P-type material. If the body is of N-type, the carriers normally in excess in the bulk thereof are electrons and the carriers injected at the emitter are holes. On the other hand, if the body is of P-type, the carriers normally in excess in the bulk thereof are holes and the injected carriers are electrons.

It has been found that in such devices the operating characteristics may vary from unit to unit and that, further, individual units are subject to instability as evidenced by oscillatory phenomena.

One general object of this invention is to improve the performance of semi-conductor signal translating devices such as amplifiers. More specific objects of this invention are to enhance the stability of such devices and to increase the uniformity of product in the manufacture of the devices.

It has been determined that instability of devices of the type hereinabove referred to is attributable in many cases to the sporadic generation or injection of carriers in or into the body by mechanisms distinct from the emitter and that one source of such unwanted carriers is at the base connection. Specifically, at the base connection in a device embodying an N-conductivity type semiconductor body, holes may be injected into the body from the base electrode and these deleteriously effect the functioning of

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the device. Similarly, in devices including a P-conductivity type body, electrons may be injected into the body from the base with consequent degradation of the performance characteristics of the device.

In accordance with one feature of this invention, such emission or injection of carriers at the base connection is substantially inhibited. This is effected by establishing between the base electrode and the semiconductive body a barrier to the flow into the semiconductor body from the base electrode of carriers of the sign like that of those introduced intentionally at the emitter, that is of the sign opposite that of those normally in excess of the body. Such a barrier is created by producing at the body-electrode interface a region or zone in which the concentration of impurity characteristic of the conductivity type of the body is greater than that in the bulk of the body.

In one specific embodiment of this invention wherein the body is of N-conductivity type, a donor impurity is introduced into the surface portion of the body to which the base connection is made thereby to make a region of the body contiguous with the base electrode more strongly N-type than the bulk of the body. The donor impurity may be introduced, for example, by utilizing a tin-antimony solder for affixing the base electrode to the body or by plating the surface with antimony and affixing the base electrode to the plated surface under conditions effecting diffusion of the antimony into the body.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 depicts a semiconductor amplifier illustrative of one embodiment of this invention; and

Fig. 2 is a sectional view to an enlarged scale of a portion of the amplifier semiconductor structure.

In the drawing, for the sake of clarity, dimensions of the semiconductive body have been greatly exaggerated. In a typical device, the semiconductive body may be about 100 mils on a side and about 12 mils thick.

Referring now to the drawing, the signal translating device illustrated in Fig. 1 comprises a body 10 of semiconductive material, for example of germanium or silicon, of either conductivity type. The germanium material may

be prepared in the manner described in the application Serial No. 638,351, filed December 29, 1945, of J. H. Scaff and H. C. Theuerer. Suitable silicon material may be prepared in the manner disclosed in the application Serial No. 793,744 filed December 24, 1947, of J. H. Scaff and H. C. Theuerer, now Patent 2,567,970, granted September 18, 1951.

Bearing against one face of the semiconductive body 10 are a pair of closely adjacent point contacts 11 and 12 commonly referred to as the emitter and collector, respectively. The body 10 is affixed in manners which will be described in detail hereinafter to a metallic electrode 13, for example of brass, which constitutes the base connection. An input circuit including the signal source 15 and a direct-current source 14 for biasing the emitter 11 in the forward or low impedance direction is connected between the base 13 and the emitter 11. An output circuit including a load, represented generally by the resistor 16, and a source 17 for biasing the collector 12 in the reverse or high resistance direction is connected between the collector 12 and the base 13. When the semiconductive body 10 is of P-conductivity type the sources 14 and 17 are poled as shown. When the body 10 is of N-conductivity type the polarity of the sources should be reversed from that shown in Fig. 1.

In general, in the operation of the device electrical carriers, specifically holes when the body 10 is of N-type, and electrons when the body is of P-type, are injected at the emitter 11 and flow to the collector 12 thereby effecting a modulation of the current in the load circuit. Amplified replicas of the signals from the source 15 appear across the load 16.

The nature of the junction between the base electrode 13 and the body 10 is of particular moment from the standpoint of the performance of the device. As has been noted hereinbefore, in accordance with a feature of this invention, there is provided at the base electrode-body interface a region of characteristics such as to inhibit flow into the body 10 from the base 13, of carriers of the sign opposite that of those normally present in excess in the body 10.

The barrier is illustrated for an N-type body in Fig. 2. Specifically, the connection to the base 13 is so fabricated as to form in the body 10 and contiguous with the electrode 13, a thin region or zone 19 wherein the impurity concentration characteristic of the conductivity type of the body is greater than that in the bulk of the body. Thus for the case of an N-type body 10, the zone or region 19 should be of more strongly N-type than the body as indicated by the legend N^+ in Fig. 2.

The desired region 19 may be obtained in several ways. For example, a film of a donor impurity, such as antimony, may be deposited upon the lower face of the body 10, and the electrode 13 then secured to this face as by soldering. The antimony deposition may be accomplished in one way by suspending the germanium body in a bath including 300 grams potassium hydroxide and 20 grams antimony per liter, and passing a direct-current of about 255 milliamperes per square inch between the germanium body and an antimony electrode, the electrode being positive and the body negative. A typical solder is one composed of 63 per cent tin and 37 per cent lead. Advantageously, the soldering is effected with pressure applied between the body and the electrode 13. As a result of the soldering oper-

ation, the donor impurity, specifically antimony in the case noted, diffuses into the surface region of the body 10 thereby increasing the donor concentration in this region 19 and rendering this region more strongly N-conductivity type than the bulk of the body 10.

The desired region 19 may be realized also by affixing the electrode 13 to the body 10 with a solder containing a donor impurity, for example a solder composed of 5 to 10 per cent antimony and 95-90 per cent tin has been found suitable, the soldering being effected with a pressure of the order of one pound applied between the body 10 and electrode 13. The solder film is indicated at 18 in Fig. 2. The donor material, specifically antimony, diffuses into the body 10 to convert a region thereof, indicated at 19 in Fig. 2, to greater N-conductivity type.

The effect of the region 19 is to substantially inhibit flow of holes in the case of N material from the base electrode 13 into the body 10 whereby the operating characteristics and particularly the stability of the device are substantially enhanced.

Although the invention has been described thus far specifically with particular reference to translating devices wherein the body is of N-conductivity type, it may be practiced also in devices utilizing a P-conductivity type body. In this case, the region 19 should be of more strongly P-type than the bulk of the body 10. Such region may be obtained by diffusing an acceptor impurity, such as gallium, into the surface portion of the body 10 contiguous with the base 13. When the body is of P-type the effect of the stronger P-type region 19 is to inhibit the flow of electrons from the base electrode into the body thereby improving the operating characteristics of the device.

Although specific embodiments of this invention have been shown and described it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention.

What is claimed is:

1. A signal translating device comprising a body of semiconductive material of one conductivity type and having at one portion thereof a region containing a greater concentration of impurity characteristic of said type than the bulk of said body, point contact emitter and collector connections to said body at parts spaced from said region, and a base connection to said region.

2. A signal translating device comprising a body of semiconductive material of one conductivity type and having on one face thereof a region containing a greater concentration of impurity characteristic of said type than the bulk of said body, a base connection to said one face, and emitter and collector connections to the opposite face of said body.

3. A signal translating device comprising a body of N-conductivity type semiconductive material, point contact emitter and collector connections to said body, a large area base electrode connected to said body, and means comprising a donor material in excess of that in the bulk of said body defining a barrier at the junction of said base electrode and said body.

4. A signal translating device comprising a body of P-conductivity type semiconductive material, point contact emitter and collector connections to said body, a large area base electrode

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connected to said body, and means comprising an acceptor material in excess of that in the bulk of said body defining a barrier at the junction of said base electrode and said body.

5. A signal translating device comprising a body of N-conductivity type germanium, emitter and collector connections to said body, a base electrode, and a solder containing a donor impurity securing said electrode to said body.

6. A signal translating device comprising a body of N-conductivity type germanium having at one surface thereof a region containing donor impurity in excess of that in the bulk of the body, emitter and collector connections to said body at points spaced from said region, and a base connection to said region.

7. A signal translating device comprising a body of P-conductivity type germanium having at one surface thereof a region containing acceptor impurity in excess of that in the bulk of

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the body, emitter and collector connections to said body at points spaced from said region, and a base connection to said region.

8. A signal translating device comprising a body of N-conductivity type germanium having at one face thereof a region containing antimony and of greater donor impurity concentration than the bulk of said body, a base connection to said region, and emitter and collector connections to the opposite face of said body.

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REFERENCES CITED

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Number	Name	Date
2,524,035	Bardeen et al.	Oct. 3, 1950