PATENT SPECIFICATION 883,700

DRAWINGS ATTACHED.

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COMPLETE SPECIFICATION.

Improvements in and relating to Transistors.

We, TEXAS INSTRUMENTS INCORPORATED, of 6000 Lemmon Avenue, Dallas, Texas, United States of America, a Corporation organized and existing under the laws of the State of Delaware, 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:—

The present invention provides a new and improved transistor and method of making it by diffusion techniques.

In the manufacture of transistors, it is common to produce single crystals of a semiconductive material such as germanium or silicon, in a crystal pulling machine and to introduce impurities into the material during crystal growth. By carefully controlling the introduction of the impurity material, it is possible to determine the conductivity type of the growing crystal and by selectively adding another impurity material characteristic of opposite conductivity type to change the conductivity type of the recrystalling material from N to P type and *vice versa*. The general technique may be employed to produce a double-doped single crystal containing at least 2 PN junctions usually located in proximity to each other and preferably being separated by less than one mil. The frequency response of transistors made by the above-described technique is limited, and in order to achieve greater frequency response and adapt transistor devices to function in circuits at substantially higher frequencies, it has been necessary to develop new techniques.

Briefly stated the present invention provides a transistor comprising a body of semiconductive material having a collector region of a first conductivity type, and a base region of opposite conductivity type produced by vapor diffusion into said semiconductive body, and an emitter wire containing impurities characteristic of said first conductivity type alloyed with the diffused base region.

The invention also provides a method of fabricating such a transistor which comprises diffusing impurities characteristic of said opposite conductivity type into a predetermined region of a semiconductive body containing impurities characteristic of said first conductivity type, and alloying a wire containing impurities characteristic of said first conductivity type with the diffused region.

The invention will become more readily apparent from the following detailed description of a preferred embodiment taken in conjunction with the accompanying drawings:

Figure 1 illustrates the first step in the preparation of the device of the present invention and illustrates schematically the apparatus and manner of diffusing impurities into a semi-conductor crystal;

Figure 2 illustrates schematically the device partially fabricated being provided with a collector attachment; and

Figure 3 illustrates the transistor configuration illustrating its structure schematically.

Referring now to the invention in detail, a preferred embodiment is described in clear, concise, and exact terms as to enable a worker skilled in this art to practice this invention. For purpose of explanation it is assumed that the transistor to be produced is of the PNP type, but, as will be appreciated, the invention applies equally well to the manufacture of transistors of the NPN type. Again for purpose of explanation the

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invention is described with reference to germanium as the semiconductor material, but it is equally adapted to silicon as the semiconductor material, and would be feasible with any other known semiconductor material.

The germanium semiconductor material selected was chosen from a single crystal of germanium having a resistivity of 2 ohm centimeters. The particular wafer selected was cut on the 1, 1, 1, plane. The wafer is of P type conductivity, this property having been imparted by the addition of a carefully calculated quantity of impurity to the molten charge of germanium in the crystal puller. In this regard it may be mentioned that the single crystal of germanium is obtained by a crystal, pulling technique and that the crystal drawn or pulled is of uniform resistivity material. The technique differs from double-doping previously described in that the impurity content of the semiconductor charge in the crystal puller is not altered during crystal growth.

The wafer of germanium is enclosed in a suitable quartz tube 10 at one end thereof and a suitable quantity of germanium-arsenic alloy comprising approximately .5% by weight arsenic and approximately 99.5% by weight germanium is also placed within the quartz tube behind a baffle indicated in Figure 1 by the numeral 15. The quartz tube is then evacuated and heated to approximately 675° C. for approximately thirty hours. During this time the germanium-arsenic alloy is vaporized and diffuses into the surface of the germanium wafer while in the gaseous state. The extent of the diffusion and the depth of penetration is determined by the concentration of the gaseous phase, the temperature, and the time. The mechanics of diffusion have been explored extensively and this technique has become a recognized procedure in the art.

At the conclusion of the diffusion operation, the wafer is removed from the quartz tube and the collector side of the wafer is lapped off or otherwise removed in order to eliminate the undesired diffused portion of the wafer on the collector side of the proposed device. A tab of material 20 compatible with the semiconductor material being worked is then soldered to the wafer on the collector side. It has been found that nickel is a compatible material with germanium and can be used as the material of the tab. The tab can then be spot welded to a header of any suitable design. The physical construction of the header preferably follows conventional header constructions although the header may consist of a central raised portion circumferentially contiguous with an outer deformed ring having a U-shaped cross-section adapted to receive, in mating relationship, the edge of a can functioning to enclose or complete the encapsulation of the finished device when mounted upon the header. As is usual, three leads or wires approximately 10 to 20 mils in diameter project through the raised central portion of the header and are insulated from the header by means of glass beads. The material of the header may be an alloy consisting of iron, cobalt and nickel or other recognized material for this use.

After attachment of the collector contact it is necessary to form the emitter junction and to attach the emitter and base leads. The collector-base junction comprises the interface between the region having the original doping material only and the region containing the diffused impurity; namely, arsenic in the specific example. The emitter-base junction is formed by alloying into the diffused surface (base region) of the wafer a doped gold wire consisting of approximately 98% gold and approximately 2% gallium by weight. The wire chosen is approximately one mil in diameter and is alloyed with the diffused surface of the wafer. Since the gold wire contains a P-type impurity, gallium, a PN junction is created which functions as the emitter-base junction. The gallium in the gold wire thus causes a rectifying junction to be formed in the N type diffused surface of the wafer and results in the final formation of a PNP structure.

The N-type diffused region of the wafer constitutes the base region and connection is made to this region using a doped gold wire chosen to have a diameter of approximately one mil and consisting of approximately 99.3% gold and 0.7% antimony by weight. The base connection is bonded very close to the emitter connection about two or three mils away. Since the base lead consists of a heavily doped gold wire in which the wire is doped with antimony, an N type impurity, an ohmic contact is made to the N-type diffused region of hte wafer and results in an ohmic contact to the base layer of the device. The heat bonding process for both wires is identical and thedifference in the result is determined wholly by the type of impurity employed.

A similar transistor of NPN type can be fabricated by commencing with single crystal germanium of N-type conductivity and by vapour diffusing into the surface thereof a P-type impurity. Thereafter, the connections to the transistor device are effected by the same type gold wires but in this case the gold wire heavily doped with antimony constitutes the emitter connection and forms the emitter-base junction when attached to the diffused surface of the wafer by being bonded to it. The gold wire doped with gallium becomes the base connection

since it forms an ohmic contact with the P diffused region of the wafer.

Although the present invention has been shown and described in terms of a particular embodiment, it will be appreciated that various changes and modifications are conceivable which do not depart from its scope.

Transistors as herein described have been found to operate more efficiently and effectively at higher frequencies than devices heretobefore available, and they are cheaper to produce than transistors of the grown junction type.

WHAT WE CLAIM IS:—

1. A transistor comprising a body of semiconductive material having a collector region of a first conductivity type, a base region of opposite conductivity type produced by vapor diffusion into said semiconductive body, and an emitter wire containing impurities characteristic of said first conductivity type alloyed with the diffused base region.

2. A transistor according to Claim 1, wherein a base contact wire containing impurities characteristic of said opposite conductivity type is bonded to the diffused base region to form an ohmic contact thereto.

3. A transistor according to Claim 1 or 2, wherein said emitter wire contains by weight a large percentage of gold and a small percentage of impurities characteristic of said first conductivity type.

4. A transistor according to Claim 2 or 3, wherein the base contact wire contains by weight a large percentage of gold and a small percentage of impurities characteristic of said opposite conductivity type.

5. A transistor according to any of Claims 2 to 4 wherein each wire has a diameter of approximately one thousandth of an inch.

6. A transistor according to any of Claims 2 to 5 wherein one of the wires contains approximately 98% gold and 2% gallium by weight and the other wire contains approximately 99.3% gold and 0.7% antimony by weight.

7. The method of fabricating a transistor according to any of the preceding claims, comprising diffusing impurities characteristic of said opposite conductivity type into a predetermined region of a semiconductive body containing impurities characteristic of said first conductivity type, and alloying a wire containing impurities characteristic of said first conductivity type with the diffused region.

8. A transistor substantially as herein described with reference to the accompanying drawing.

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3. A transistor according to Claim 1 or 2, wherein said emitter wire contains by weight a large percentage of gold and a small percentage of impurities characteristic of said first conductivity type.

4. A transistor according to Claim 2 or 3, wherein the base contact wire contains by weight a large percentage of gold and a small percentage of impurities characteristic of said opposite conductivity type.

5. A transistor according to any of Claims 2 to 4 wherein each wire has a diameter of approximately one thousandth of an inch.

6. A transistor according to any of Claims 2 to 5 wherein one of the wires contains approximately 98% gold and 2% gallium by weight and the other wire contains approximately 99.3% gold and 0.7% antimony by weight.

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