

July 2, 1957

H. IRMLER
METHOD OF PRODUCING JUNCTION-TYPE SEMI-CONDUCTOR
DEVICES, AND APPARATUS THEREFOR
Filed July 19, 1956

2,798,013

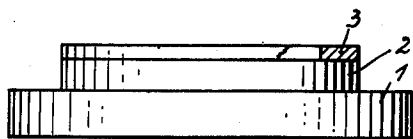


Fig. 1

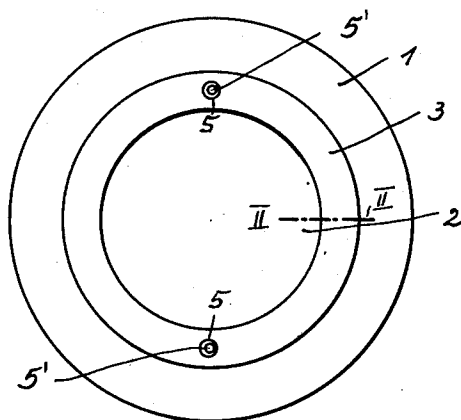


Fig. 2

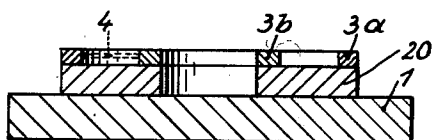


Fig. 3

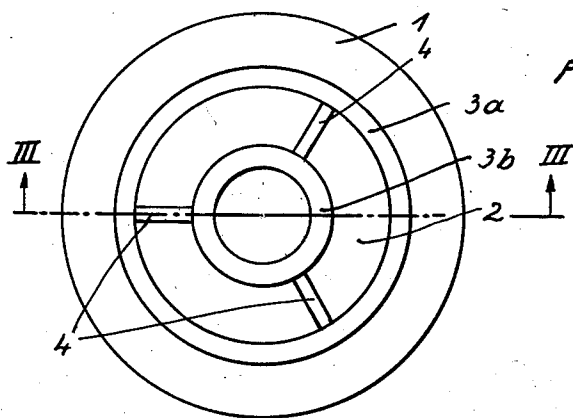


Fig. 4

Inventor:

Horst Irmeler

1

2,798,013

METHOD OF PRODUCING JUNCTION-TYPE SEMI-CONDUCTOR DEVICES, AND APPARATUS THEREFOR

Horst Irmeler, Berlin-Rudow, Germany, assignor to Siemens-Schuckertwerke Aktiengesellschaft, Berlin-Siemensstadt and Erlangen, Germany, a corporation of Germany

Application July 19, 1956, Serial No. 598,954

Claims priority, application Germany August 5, 1955

14 Claims. (Cl. 148—1.5)

This invention relates to a method of or procedure for producing semi-conductor devices of the junction or area type, such as rectifiers and transistors comprised of germanium, silicon, indium arsenide, indium antimonide and other crystalline semiconductor substances and to apparatus employed therefor.

In the manufacture of junction-type rectifiers and transistors it is now known to freely deposit the electrode material upon the semiconductor body prior to applying a thermal treatment which produces an alloy between the deposited electrode body and the semiconductor material. When subsequently performing the thermal treatment, the freely exposed electrode material is melted so that its surface tension becomes effective with the result of contracting this material, which originally corresponded to a relatively large electrode area, more or less to the shape of a drop. For certain purposes, therefore, the application of such a method of freely alloying the electrode material has not been feasible because it does not permit the manufacture of large-size electrodes. Large-area electrodes on semiconductors are often desired in order to obtain a correspondingly great power-carrying capacity. In the latter case, however, it would be desirable to have the possibility of a free alloy formation because this would obviate certain disadvantages which otherwise may occur in the alloyed semiconductor body as a result of the crystallization that takes place after the formation of the alloy, these disadvantages manifesting themselves in the presence of unoccupied lattice points in the crystalline structure with the result of promoting to an undesired extent the recombination of the charge carriers of different polarities.

An object of this invention is to improve the method or procedure employed in the deposition of the electrode material freely upon the surface of the semiconductor to enable or to expedite the production of electrodes of large area and of definitely predetermined shape, upon the semiconductor body.

To this end, and in accordance with one feature of my invention, I deposit or place upon the surface of the semiconductor body a shaped body of electrode material of a desired previously prepared form, together with an auxiliary body which occupies a marginal zone of slight or relatively narrow width. During the subsequent alloying of the liquefied or molten electrode material with the substance of the semiconductor body, the auxiliary body enters into good adhesion, as a solid body, with the said melted electrode material and thereby counteracts the surface tension of the electrode material. In this manner, the marginal auxiliary body preserves the predetermined shape of the freely deposited body of electrode material.

The invention is applicable to electrodes in the form of a full disk, plate, or wafer, which have only an outer peripheral edge, as well as to electrode shapes which have more than one closed perimeter such as an electrode having the shape of an annulus of circular cross section.

2

In the latter case, depending upon the size of the electrode area in the particular construction, either a single auxiliary body may be provided along only one of the edges, or it may be preferable to use a plurality of auxiliary bodies, one being placed upon the semiconductor material in an outer marginal zone of the electrode-material body, and the other being located on the inner marginal zone. When thus using a plurality of auxiliary marginal bodies, each may have to be separately arranged on the surface of the semiconductor body if the marginal bodies are separate from each other. However, the manufacture in such a case can be simplified by combining a plurality of auxiliary bodies so as to form a mechanical entity. For instance, when using in this sense an exterior and an interior marginal auxiliary body or ring, these two bodies or rings, can be joined directly by means of a number of bridges so that only a single structure of auxiliary bodies is to be placed upon the semiconductor body.

According to more specific features, the invention has as its object the provision of several modes of proceeding in the manner generally described in the foregoing. According to one procedure, the body of electrode material and the auxiliary body or bodies arranged in the marginal zone or zones of the electrode body are first prefabricated or previously assembled as a separate, independent structure which forms a mechanical unit which is then placed upon the semiconductor surface at the desired location before the assembly is subjected to thermal treatment for the formation of an alloy between electrode material and semiconductor material. Another way of proceeding according to the invention is to first prepare the electrode-material body in the proper shape and then place it into proper position upon the surface of the semiconductor body, whereafter the auxiliary body is placed along the proper marginal zone of the electrode body. Then, when the electrode material becomes melted at the beginning of the alloy-forming thermal treatment, the adhesion between the liquified electrode-material body and the auxiliary body or bodies remaining in the solid state will also become effective so that the desired shape of the liquified electrode-material body is retained and the body cannot contract by its surface tension, for instance to the shape of a drop or the like, due to the counter-action of the adhesion effect between the auxiliary body and the liquid electrode material.

It is therefore possible in this manner to mount an electrode body of large area onto a semiconductor body with definite retention of a predetermined electrode shape, and to bring about the formation of an alloy between the semiconductor body and a freely deposited electrode-material body throughout a large mutual area of contact engagement with the semiconductor body. If the production of electrodes of very large surface area is involved, it may then be advantageous, according to another feature of the invention, to provide a plurality of mutually surrounding electrode bodies, or to provide between each two auxiliary bodies situated along the inner and the outer marginal zone still further intermediate bodies to serve as auxiliary bodies, in the sense of the invention.

Where the pre-formed auxiliary body is loosely placed upon the electrode-material body, a rapid and simple adjustment of the proper positional relation between both can be obtained by having the auxiliary body and the electrode-material body, so formed and designed that they interengage each other and thereby need only be placed together for securing the proper positioning. Thus, in one form of the novel apparatus and method, one of the bodies is provided with projections or dowels and the other may have matching grooves or recesses.

Suitable materials for the auxiliary body are, for ex-

ample, molybdenum, tantalum, tungsten and iron. The material for the auxiliary body can in general be more broadly described as a metal or metal alloy or compound of a melting point higher than the alloying temperature required for causing the electrode material to form an alloy with the semiconductor material. Where heat conductive or electro-conductive properties of the auxiliary body are not significant, in respect to the particular alloying-melting operation employed, it is sometimes feasible to employ common refractories, including non-metal compounds.

According to a further feature of the invention which particularly relates to the said loose depositing or placing of the auxiliary body upon the electrode-material body, the auxiliary body is given a wetting inducing coating at its contacting surface with the body of electrode material. This coating consists of a material which, during the thermal treatment of the semiconductor assembly, enters into the molten and liquid state before the electrode material proper is liquified. A coating having a lower melting point is chosen. As a result, a reliable mutual wetting between the deposited auxiliary body and the electrode-material body proper takes place prior to the liquification of the electrode material. This very effectively prevents the electrode material from flowing away beneath the auxiliary body as soon as the electrode material becomes liquid. Tin is a suitable material for such a coating on the auxiliary body or bodies. However, it is usually preferable to provide not merely a single-layer coating but to compose this coating of several layers, in cases where the coating material enters into good wetting action with one of the two materials of the electrode and the auxiliary body but not simultaneously with both adjacent materials. It is, therefore, preferable, for instance when the auxiliary body consists of molybdenum and the electrode material of indium, to provide on the auxiliary body a triple coating composed of gold, tin, and a tin-indium alloy, these substances forming a system of layers with the gold on the surface of the auxiliary body, the tin-indium alloy on the outside, and tin in between.

The invention is applicable to a circular ring or annular shape of the electrode as well as to any other surface shapes of the electrode body, such as quadrangular or elliptic shapes. The only essential condition to be satisfied according to the invention is that at or on the marginal zones of the electrode body an auxiliary body is placed or deposited which, by virtue of its adhesion to the semiconductor material, retains the area shape of the electrode material in the liquified condition of the latter and encloses a freely exposed area portion of the electrode-material body not covered by the auxiliary body. This property and structural shape of the auxiliary body also affords the further advantage that the liquification and the condition of the electrode material can readily be observed and supervised and that the electrode-material body proper is subjected by the auxiliary body only to a very slight weight load, which is desirable for a number of manufacturing processes of such semiconductor assemblies.

Several embodiments illustrating the application of the method according to the invention are shown by way of example on the drawing, in which:

Figure 1 is an elevational view partly in section on line II—II of Figure 2;

Figure 2 is a plan view of the apparatus shown in Figure 1, one auxiliary body being employed;

Figure 3 illustrates a modified form in which an annular electrode and two auxiliary bodies are used, the view being in vertical section on line III—III of Figure 4, with the exception that no bridges are shown;

Figure 4 is for most part a plan view of the apparatus of Figure 3, but includes connecting links or bridges between the two auxiliary bodies.

In Figs. 1 and 2 the semiconductor is denoted by 1, the electrode-material body by 2, and the auxiliary body

by 3. The auxiliary body 3 is placed upon the electrode-material body. As mentioned, the auxiliary body 3 may be united with the electrode-material body prior to placing both upon the semiconductor body, or the electrode-material body may first be placed loosely upon the semiconductor body and then the auxiliary body 3 may also be placed loosely upon the electrode body. For proper positioning the auxiliary body 3 is shown provided with holes 5 which are placed upon corresponding bosses 5' of the electrode-material body. During the subsequent thermal processing of the assembly, the auxiliary body 3, due to its adhesion to the electrode-material body, prevents the melting electrode material from noticeably contracting toward the interior of the assembly under the effect of the surface tension. As a result, the contact surface between the electrode-material body and the semiconductor body is substantially preserved in the predetermined, original shape.

In the second embodiment illustrated in Figs. 3 and 4, an electrode-material body 20 of annular shape is placed upon the semiconductor body 1. The auxiliary body or bodies employed to prevent, by its adhesion effect, the electrode-material body from losing its original shape, is in this case composed of two rings 3a and 3b located along the outer periphery and inner periphery of the annular body 2 respectively. During liquification of the electrode-material body 2, the two rings 3a and 3b preserve the shape of the electrode in the above-described manner by virtue of the fact that the adhesion effect acts in opposition to the surface tension which becomes effective in the liquid material. The plan view according to Fig. 4 also shows a number of bridges 4 which, if desired, can be used to interconnect the two rings 3a and 3b, thus combining the two rings into a mechanical entity which can be placed upon the electrode-material body as a unit or, as described, can be combined with the electrode-material body before the electrode-ring assembly is placed upon the semiconductor body 1.

Any of the commonly employed melting furnaces may be used, including resistance, high frequency, or induction.

The application is particularly applicable to semiconductors that possess a crystal lattice of the diamond type, especially the semiconductors consisting of germanium, silicon, and semiconducting binary compounds and alloys of an element from the third group (second subgroup) of the periodic system with an element of the fifth group (second subgroup), that is, compounds of boron, aluminum, gallium or indium with nitrogen, phosphorous, arsenic or antimony. In other words, the invention applies to all semiconductors of the diamond-lattice type that are to be used for the manufacture of p-n, n-p-n or p-n-p junction rectifiers or transistors.

Aside from indium, various other metals and alloys are suitable as material for the electrode, for example aluminum, lead, tin, gold and silver. Lead, tin, gold or silver are preferably used not in the pure elementary state but together with additional components from the third or fifth group of the periodic system such as aluminum, gallium, indium, arsenic or antimony. The auxiliary body, made, for instance, of molybdenum, tantalum, tungsten or iron, may be provided with the above-mentioned coating by means of a pressure plating process or by electroplating. According to the pressure plating process the coating metal is pressed or rolled onto the main body of metal under such a high pressure that both metals are virtually welded together in the cold state at their mutually contacting surfaces. A coating material suitable for this process is the alloy available in the trade under the trade name Kovar or Vakon and consisting of 28% nickel, 18% cobalt and 54% iron. Suitable as a coating to be applied electrogalvanically is preferably gold or nickel.

I claim:

1. In a method for the manufacture of junction-type

rectifiers, transistors, and like semiconductor devices, wherein a body of electrode material having a pre-formed shape is placed upon a semiconductor body for the purpose of furnishing the semiconductor with a large-area electrode, the improvement comprising contacting a marginal zone of the electrode material body with an auxiliary body, melting the electrode-material body to alloy it with the semiconductor body, the auxiliary body being in solid phase at the melting-alloying temperature and providing a surface in contact with the molten electrode-material which surface exerts an adhering force upon the molten electrode-material which is counter to the contractile surface tension of the molten electrode-material and thereby serves to assist in retaining the shape of the body of electrode material.

2. The method defined in claim 1 in which the body of electrode material has an inner closed perimeter and an outer closed perimeter, and there are at least two of the auxiliary bodies, inclusive of the one already recited, a recited auxiliary body being in contact with a marginal zone in the region of each perimeter and each providing a surface exerting said adhering force.

3. The method defined in claim 1 in which the auxiliary body comprises a material containing a substance of the group consisting of molybdenum, tantalum, tungsten and iron.

4. The method defined in claim 1 in which the said surface is in the form of a mutual wetting-inducing coating which has a lower melting point than the electrode material.

5. The method defined in claim 1 in which the said surface is in the form of a layer of tin.

6. The method defined in claim 1 in which the said surface is in the form of a mutual wetting-inducing multi-layer coating, one layer being chosen for optimum wetting of the solid auxiliary body, and another layer being chosen for optimum wetting of the molten body of electrode material.

7. The method defined in claim 1 in which the auxiliary body comprises a material of the group consisting of molybdenum, tantalum, tungsten and iron and the semiconductor is taken from the group consisting of germanium, silicon, and semiconducting compounds of an element of the group consisting of boron, aluminum, gallium and indium with an element of the group consisting of nitrogen, phosphorus, arsenic, and antimony.

8. The method defined in claim 7 in which the electrode material is indium.

9. The method defined in claim 8 in which the auxiliary body is of molybdenum, and the surface thereof in contact with the molten indium is coated with a triple layered coating comprising gold in contact with the molybdenum, tin-indium alloy in contact with the indium, and tin in between in contact with the gold and the tin-indium alloy.

10. A procedure for the manufacture of junction-type rectifiers, transistors, and like semiconductor devices, wherein a body of electrode material having a pre-formed shape providing at least two closed perimeters is placed upon a semi-conductor body for the purpose of furnishing the semi-conductor with a large-area electrode, the improvement comprising contacting, in one operational step, marginal zones of at least two of the closed perimeters with an auxiliary body, melting the electrode-material body to alloy it with the semi-conductor body, the auxiliary body being solid at the melting-alloying temperature and providing two surfaces in contact with respective ones of the said marginal zones of the molten electrode material, which surfaces exert adhering forces upon the molten electrode-material which are counter to the contractile surface tension of the molten electrode-material and thereby serve to resist the alteration of the shape of the body electrode material by the surface tension.

11. The method defined in claim 1 in which the operational step of contacting a marginal zone of the pre-formed body of electrode material with the auxiliary body is facilitated by inter-engaging portions of the respective bodies which serve to position the auxiliary body.

12. A manufacturing operation set, to be used in conjunction with melting means, for the manufacture of junction-type rectifiers, transistors, and like semiconductor devices, comprising a solid body of semiconductor material, a solid body of electrode material thereupon, the latter having at least one closed perimeter, an auxiliary solid body having a surface overlying a marginal zone in the region of a perimeter of the electrode material, the auxiliary body material being a material of the group consisting of molybdenum, tantalum, tungsten and iron, and the semi-conductor material being taken from the group consisting of germanium, silicon and semiconducting substances composed of an element of the group consisting of boron, aluminum, gallium and indium taken with an element of the group consisting of nitrogen, phosphorus, arsenic and antimony.

13. The manufacturing operation set defined in claim 12 in which the auxiliary body and the electrode material body have interdigitating means serving to orient the auxiliary body on the said marginal zone.

14. The manufacturing operation set defined in claim 12 in which the electrode body has an outer closed perimeter and an inner closed perimeter, and the auxiliary body is provided with elements overlying marginal zones in the region of the respective perimeters, and means forming part of the auxiliary body serving to connect the said elements.

References Cited in the file of this patent

UNITED STATES PATENTS

2,651,009	Meyer	Sept. 1, 1953
2,743,693	Schaper	May 1, 1956