

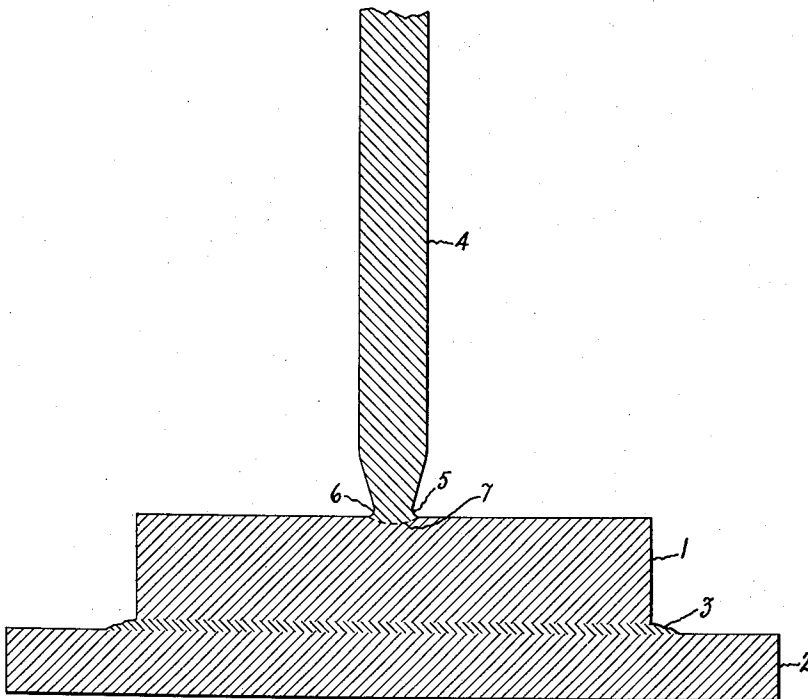
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CALORIZED POINT CONTACT ELECTRODE FOR SEMICONDUCTOR DEVICES

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CALORIZED POINT CONTACT ELECTRODE FOR SEMICONDUCTOR DEVICES

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My invention relates to semiconductor devices. More particularly it relates to improved point contact electrodes for point contact semiconductor devices.

Semiconductors such as prepared germanium and silicon are normally classified as either positive (P-type) or negative (N-type) depending primarily on the type and sign of their main electrical conduction carriers. In P-type semiconductors the excess conduction carriers are electron vacancies or holes produced by the movement of electrons in the valence band, whereas in N-type semiconductors the excess conduction carriers are electrons moving in the conduction band. The direction of rectification as well as the polarity of various voltage effects is different in semiconductors of the two types.

Whether a particular semiconductor is of the P-type or the N-type depends primarily on the type of impurity present in the material. Some impurities called donors, such as antimony, phosphorus, and arsenic furnish free additional electrons to the semiconductors, such as germanium and silicon, and produce an N-type material. Other impurities called acceptors, such as aluminum, gallium, indium, and zinc tend to absorb electrons leaving electron vacancies or holes in the material to produce a so-called P-type semiconductor. Only very small amounts of these impurities are required to produce marked electrical effects of one type or the other.

Point contact semiconductor units are those in which a semiconductor body, such as an N-type germanium, has joined to the surface thereof, a whisker or point contact electrode of a metal such as tungsten, platinum, and the like. When the N-type body is positive and the whisker electrode negative there is high resistance to the flow of current from the body to the electrode. On the other hand, when the N-type body is negative and the electrode positive, a lower resistance is presented to the flow of current across the rectifying point contact. Such devices have found wide-spread use.

An object of my invention is to provide a point contact electrode for semiconductor devices which is characterized by reduced forward voltage.

Another object of my invention is to provide a point contact electrode for semiconductor devices which has advantages of the P-N junction type device while retaining the advantages of the point contact type.

Another object of my invention is to provide semiconductor devices having improved characteristics.

Briefly my invention comprises a semiconductor device of the whisker or point contact type in which the whisker or point contact electrode is calorized by heating in a mixture of aluminum and alumina powders and preferably thereafter subjected to a separate non-oxidizing heat treatment.

The features of my invention which I believe to be novel are set forth with particularity in the appended

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claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which the single figure shows schematically a point contact rectifier as typical of semiconductor devices which may utilize my invention.

In the drawing, body 1 of my semiconductor device is typically of N-type germanium, is preferably mono-crystalline in nature, and is purified to have a resistivity over 2 ohm-centimeters. Body 1 may be conveniently extracted from a monocrystalline germanium ingot grown by seed crystal withdrawal from a melt of germanium having a trace, less than 0.05%, of a donor impurity which makes the body of N-type conductivity. A first metal electrode 2 having a coefficient of thermal expansion comparable to that of the prepared germanium body 1, such as fernico, is attached to the body 1 by means of a solder 3. The particular solder used in the present instance is tin, though others suitable for the purpose will occur to those skilled in the art, including those doped with impurities which supplement or increase the type of conductivity of body 1. A second whisker or point contact electrode 4 is welded to the surface of body 1 as shown by passing therethrough a short pulse of current sufficient to fuse the tip of electrode 4 to body 1.

The crux of my invention lies in the metallurgical structure of electrode 4 and the treatment to which it is subjected.

Electrode 4 is typically 0.004 inch in diameter although it may range from about 0.003 inch to 0.006 inch in diameter. It may be basically platinum, tungsten, or any other physically adaptable metal. The electrodes used in the examples below are of platinum.

In carrying out my invention, the platinum wire is subjected to a calorizing treatment consisting of two steps, a direct calorizing treatment followed by a diffusion treatment. The wire is placed first in a mixture of aluminum powder and alumina (Al_2O_3) powder consisting of from 10 to 20 percent aluminum with the rest alumina and then heated to from 400° C. to 600° C. for from four to six hours in a reducing or non-oxidizing atmosphere. This heat treatment is of a time-temperature nature, the time of treatment being longer at the lowest temperatures and shorter at the higher temperatures. During this process the aluminum impregnates the surface of the wire to form there a platinum-aluminum alloy.

In order to insure that the aluminum impregnates the entire wire, the latter is preferably subjected to a diffusion treatment in which the wire is heated in a reducing or non-oxidizing atmosphere for from four to six hours at a temperature of from 800° C. to 1000° C. during which process the aluminum passes through and alloys with the entire electrode material. Like the first treatment, the diffusion step is also of a time-temperature nature.

The platinum wire is next cut into suitable lengths for electrode use. For purposes of the comparative tests below, all electrodes were ground to an angle of about 20°. Exactly similar angles were obtained by fixing the electrodes to a glass plate with wax and then grinding the plate and wire to the indicated angle. In actual present practice the exact angle of the contact is not critical. Alternatively, the point contact electrodes of my invention may be cut to size and pointed or otherwise formed prior to the calorizing treatment.

When the electrode 4 is arranged in operating position on the germanium body 1, a voltage pulse is passed

through the electrode to weld it to the body as at 5. A pulse of 40 volts for about one-quarter second with a load resistance of 50 ohms is satisfactory with the electrodes of the above size range.

The germanium diodes made by my process were tested with the following results as compared to an exactly similar diode in which the contact electrode was not calorized.

Treatment	Voltage (Forward) (Volts)	Voltage (Reverse) (Volts)	Current (Forward) (M.A.)	Current (Reverse) (M.A.)	Load (Ohms)
No calorization or heat treatment	0.70	18	20	0.54	750
Calorized: 10% Al, 90% Al ₂ O ₃ , 400° C., 6 hrs.	.65	17	20	.78	750
Diffusion: 800° C., 6 hrs.					
Calorized: 10% Al, 90% Al ₂ O ₃ , 600° C., 5 hrs.	.54	26	20	.74	950
Diffusion: 1,000° C., 5 hrs.					
Calorized: 20% Al, 80% Al ₂ O ₃ , 600° C., 4 hrs.	.47	14	20	.69	750
Diffusion: 1,200° C., 4 hrs.					
(Note: wire pitted after treatment.)					
Calorized: 10% Al, 90% Al ₂ O ₃ , 600° C., 5 hrs.	.385	17	20	.72	750
Diffusion: 1,000° C., 5 hrs.					
Calorized after sharpening and forming					

From the above it will be seen that by the present invention the forward voltage is substantially reduced and particularly so for those rectifiers in which the point contact electrode was calorized after forming and sharpening.

While I do not wish to be bound by any particular reason or theory for the improved operation of semiconductor using my calorized whisker or contact electrode, it is felt that the aluminum impregnant or aluminum alloy formed with the basic electrode material such as platinum diffuses into body 1 as at 6 and forms a P-N junction 7 at the lower effect of limit of such diffusion. It is this P-N junction which presents a high resistance to flow of current in one direction and a lower resistance to flow in the opposite direction which provides the improved semiconductor device described.

While I have set forth my invention in connection with the use of certain specific materials for ease and simplicity of description, it will be realized that other materials may be used in this practice. Silicon or other N-type conductivity material may be used in lieu of germanium while other metals such as tungsten may be used as the basic contact electrode material.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A point contact type semiconductor electrical device comprising an "N" type germanium body, a first electrode attached to one surface of said body and a point contact electrode welded to another surface of said body, said second electrode consisting of an alloy of aluminum with a material chosen from the group consisting of platinum and tungsten.

2. A point contact type semiconductor electrical device comprising an "N" type germanium body, a first electrode attached to one surface of said body and a point contact electrode welded to another surface of said body, said second electrode consisting of an alloy of aluminum with platinum.

3. A point contact type semiconductor electrical device comprising an "N" type germanium body, a first electrode attached to one surface of said body and a point contact electrode welded to another surface of said body, said second electrode consisting of an alloy of aluminum with tungsten.

4. A semiconductor electrical device comprising a semiconductor body, a first electrode attached to one surface of said body and a second point contact electrode attached to another surface of said body, said second electrode consisting of an alloy of aluminum with a metal

chosen from the group consisting of platinum and tungsten.

5. The method of making a point contact electrode for a semiconductor device which comprises calorizing wire of material chosen from the group consisting of platinum and tungsten in a mixture of from 10 percent to 20 percent by weight aluminum powder and 80 percent to 90 percent alumina powder at a temperature from 400° C.

to 600° C. for a period of four to six hours in a non-oxidizing atmosphere, removing the wire from said mixture of aluminum powder and alumina and heating said wire at a temperature from 800° C. to 1000° C. for a period of four to six hours in a non-oxidizing atmosphere.

6. The method of making a point contact electrode for a semiconductor device which comprises calorizing platinum wire in a mixture of from 10 percent to 20 percent by weight aluminum powder and 80 percent to 90 percent alumina powder at a temperature from 400° C. to 600° C. for a period of four to six hours in a non-oxidizing atmosphere, removing the wire from said mixture of aluminum powder and alumina and heating said wire at a temperature from 800° C. to 1000° C. for a period of four to six hours in a non-oxidizing atmosphere.

7. The method of making a point contact electrode for a semiconductor device which comprises calorizing tungsten wire in a mixture of from 10 percent to 20 percent by weight aluminum powder and 80 percent to 90 percent alumina powder at a temperature from 400° C. to 600° C. for a period of four to six hours in a non-oxidizing atmosphere removing the wire from said mixture of aluminum powder and alumina and heating said wire at a temperature from 800° C. to 1000° C. for a period of four to six hours in a non-oxidizing atmosphere.

8. A semiconductor electrical device comprising a semiconductor body, a first electrode attached to one surface of said body and a second point contact electrode welded to another surface of said body, said second electrode consisting of an alloy of aluminum with a material chosen from the group consisting of platinum and tungsten.

9. A semiconductor electrical device comprising a semiconductor body, a first electrode attached to one surface of said body and a second point contact electrode welded to another surface of said body, said second electrode consisting of a calorized wire, said wire being formed of a material chosen from the group consisting of platinum and tungsten and calorized in a mixture of from 10% to 20% by weight of aluminum powder and 80% to 90% of alumina powder at a temperature from 400° to 600° C. for a period of four to six hours in a non-oxidizing atmosphere.

10. A semiconductor electrical device comprising a semiconductor body, a first electrode attached to one surface of said body and a second point contact electrode welded to another surface of said body, said second electrode consisting of a calorized wire, said wire being formed of a material chosen from the group consisting of platinum and tungsten and calorized in a mixture of from 10% to

20% by weight of aluminum powder and 80% to 90% alumina powder at a temperature from 400° to 600° C. for a period of four to six hours in a non-oxidizing atmosphere and then heated at a temperature from 800° to 1000° C. removed from said alumina and aluminum powder for a period of four to six hours in a non-oxidizing atmosphere.

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