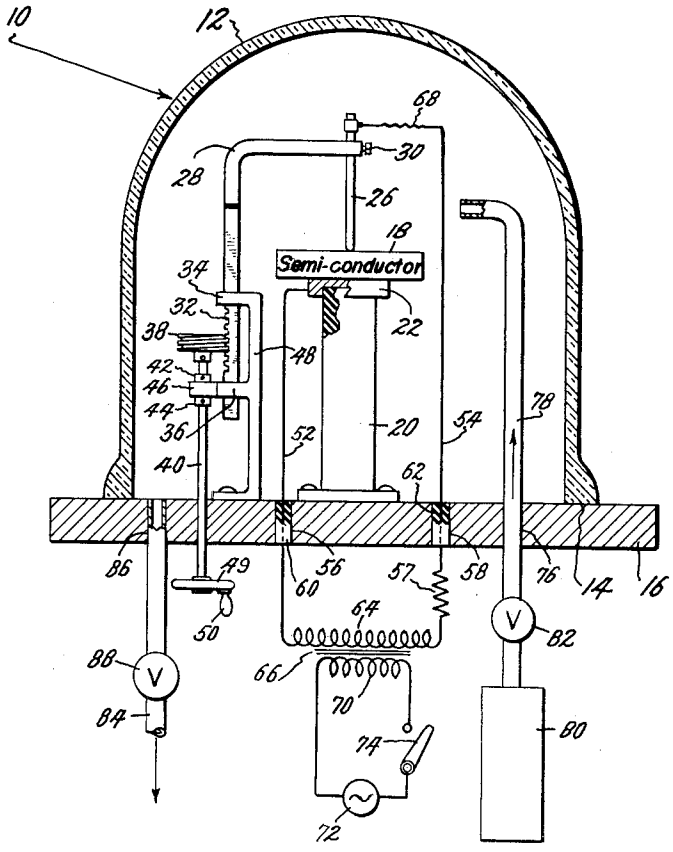
Oct. 25, 1960 C. J. GALLAGHER 2,957,974

METHOD OF APPLYING CONTACTS TO SILICON

Filed Nov. 28, 1958



Inventor:
Charles J. Gallagher,
by John F. Ahern
His Attorney.

United States Patent Office 2,957,974
Patented Oct. 25, 1960

2,957,974

METHOD OF APPLYING CONTACTS TO SILICON

Charles J. Gallagher, Schenectady, N.Y., assignor to General Electric Company, a corporation of New York

Filed Nov. 28, 1958, Ser. No. 776,943

9 Claims. (Cl. 219—74)

This invention relates to electrical contacts and more particularly relates to an improved method of applying non-rectifying electrical contacts to certain types of semi-conducting materials.

In the preparation of certain types of semi-conductor devices for use in electronic or electrical circuitry it is necessary to establish contacts thereon for the purpose of facilitating electrical interconnections with other circuit components. In applying such contacts, it is frequently important to establish a non-rectifying connection between the material of the contact and the material of the semi-conductor wherein the contact material is electrically insignificant or of the same electrical characteristics as the semi-conductor activator. That is, the junction should be bilateral in the sense that it presents substantially equal resistance to current flow in either direction across the connection. Any variation from such a bilateral relationship has the undesirable effect of rectifying alternating potentials that may be applied across the connection.

In applying contacts to bodies of semi-conductor material, particularly non-rectifying contacts, it is important that the surface of the body to which it is applied be clean. The body surface must be free of any oxides and other foreign matter and since semi-conductors, such as silicon, have a great affinity for oxygen, particular care is required in achieving and maintaining a clean body surface.

Typical procedures heretofore utilized for applying contacts to semi-conductors involved the controlled heating of both the entire body of semi-conducting material to which contact is to be applied and a bead of contact forming material in an oven to a temperature at which the bead would fuse to a surface portion of the semi-conductor that has "wetted" or melted to a slight extent due to the heat applied. In forming contacts by this procedure, however, two major difficulties frequently encountered are the high incidence of rectifying connections produced, and the destruction or partial destruction of the heat sensitive semi-conductor material wherein its useful life as a semi-conductor is impaired. The rectifying connections produced are a result of oxides or other impurities that are difficult to remove from the region of the connection and the destructive effect of the semi-conductor occurs by reason of the fact that the entire body of the same rather than a localized portion undergoes a heat treatment and semi-conductor materials are greatly affected by heat excesses.

It is accordingly a primary object of my invention to facilitate the application of electrical contacts to semi-conducting materials without subjecting the entire body of the semi-conducting material to high temperatures destructive of the semi-conductor material.

It is another object of my invention to facilitate the application of electrical contacts to semi-conducting materials according to a method that facilitates cleaning of the surface to assure a clean, oxide-free non-rectifying

connection between the contact and semi-conducting material.

In accordance with my invention the aforementioned and other objects and advantages are achieved by an improved method of applying electrical contact material to a semi-conductor body wherein a rod of contact material and the body of semi-conducting material are enveloped in an atmosphere of a suitable non-reactive gas such as hydrogen gas and a source of suitable potential, preferably alternating potential at commercially available power frequency, is applied across the respective materials. Contact between the rod and body is established and the rod is drawn away to establish an arc between the two materials which extinguishes after a few cycles. The heat of the arc both cleans oxides and other undesirables from, and melts the surface of the body during the time that the body is negative with respect to the rod and also melts a small portion of the rod which is deposited and fused to the body at the melted portion thereof. This procedure may be repeated until a sufficient quantity of rod material is deposited on the semi-conductor body to form a contact thereon and has the advantage of producing a non-rectifying connection to the body and utilizes relatively low and localized power dissipation whereby the entire silicon body is not subjected to a heat treatment cycle as done in procedures heretofore utilized.

Generally, non-rectifying contacts may be applied to bodies of either p- or n-type semi-conductor material wherein the contact material is an activator which produces the same type conductivity characteristics as possible by the semi-conductor initially or wherein the contact material is electrically insignificant.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which I regard as my invention, it is believed the invention will be better understood from the following description taken in connection with the accompanying drawing in which the single figure illustrates one form of apparatus for performing the method of my invention.

Referring now to the drawing, **10** represents generally an apparatus for performing the method of my invention and includes a gas impervious enclosure **12** of glass or other suitable and preferably transparent material, having an open end **14** closable by a base member **16**. For supporting a body of semi-conducting material **18** being from group IV of the periodic table and which may be p-type or n-type silicon or germanium, for example, to which a terminal contact is to be applied, a pedestal **20** of insulating material such as a suitable ceramic, is mounted on base **16** and extends into the interior of enclosure **12**. A member **22** of good electrical conductivity is recessed and fitted on the end of pedestal **20** remote from base **16** to facilitate positioning of and electrical conduction to the body of material **18**.

In general, non-rectifying contacts may be formed on semi-conductor bodies wherein the contact material is electrically insignificant or produces the same electrical characteristics as the semi-conductor activator impurity so as not to change the conductivity characteristics of the semi-conductor. Thus, a rod **26** of suitable contact material is provided for application as a contact to the body **18**. Rod **26** may be of electrically insignificant material such as tin for use as a contact for either p-type or n-type semi-conductor bodies, of an acceptor activator material such as aluminum or indium or alloys thereof for use with p-type semi-conductor bodies or of a donor activator material such as antimony for use with n-type semi-conductor bodies. The rod may also be an alloy of an acceptor activator and an electrically insignificant material for use with p-type semi-conductor bodies or an alloy

of a donor activator and an electrically insignificant material for use with n-type semi-conductor bodies.

For manipulating rod 26, with respect to body 18, an arm 28 having portions disposed at right angles with respect to each other, accommodates rod 26 in a transverse bore near its end and a screw 30 threadedly engaging a bore intersecting the transverse bore from the end of the arm is provided for rigidly securing the rod. The arm 28 terminates in a rack 32 at its end remote from screw 30 and the rack is longitudinally movable along a pair of spaced guides 34 and 36 under the influence of a rotatable screw 38, longitudinally fixed and engaging rack 32. Screw 38 is mounted rigid with a shaft 40 which is longitudinally fixed by a pair of rings 42 and 44 engaging the shaft tightly on opposite sides of bracket arm 46 which along with guides 34 and 36 is integral with a bracket 48. Shaft 40 extends through base 16 and is provided with a wheel 49 and handle 50 for rotating the shaft and screw 38.

As shown in the figure of drawing, an alternating potential may be applied between the rod 26 and body 18 through lines 52 and 54 passing through bores 56 and 58 in base 16, and being insulated therefrom by insulating members 60 and 62. A current limiting resistor 57 is between one end of secondary 64 of transformer 66 and the line 54 is connected between the other terminal of resistor 57 and the rod 26 through a flexible line 68. Line 52 is connected between the other terminal of secondary winding 64 and member 22. A primary winding 70 of transformer 66 is excitable by a suitable alternating voltage source as shown at 72, for example, through a control switch 74. The voltage source 72 is preferably a source of 60 cycle, 115 volt commercial line potential. The magnitude of applied potential from source 72 and the characteristics of transformer 66 are coordinated to supply an output in secondary winding 64 of at least 130 volts at 5 amperes. It is to be understood that although alternating potentials are considered preferable for forming an electric arc, direct potentials wherein the body 18 is negative with respect to rod 26, may also be used effectively.

For performing my invention, enclosure 12 is filled with a gas that is non-reactive with the elements of components exposed to the interior of the enclosure. Such gases may be inert gases which do not cause an electrical arc to tend to persist but preferably hydrogen gas is utilized. To fill the enclosure 12 with hydrogen gas, base 16 is apertured at 76 to accommodate a conduit 78 which establishes communication between a container 80 forming a supply of hydrogen gas under pressure, and the interior of the enclosure 12. Conduit 78 may be disposed at any convenient location and communication therethrough is controllable by a valve 82 interposed in the conduit. For exhausting unsuitable gases displaced by the hydrogen gas admitted into the enclosure 12, another conduit 84, accommodated in an aperture 86 in base 16 and being controllable by a valve 88, establishes communication between the interior of the enclosure and ambient space. Thus, to fill the enclosure 12, with hydrogen gas, both valves 82 and 88 may be opened and when the gases in the enclosure are displaced by hydrogen gas, the valves are closed, or valve 82 may be maintained open to displace gas escaping by leakage.

In applying a terminal contact to the body 18 as, for example, the base contact to a semi-conducting transistor, according to my invention, the body 18 is mounted on member 22 as shown in the drawing and the rod 26 is removed a considerable distance from the body to prevent arcing therebetween and the enclosure 12 is closed by base plate 16. The interior of the enclosure is filled with hydrogen gas at substantially atmospheric pressure. It is to be understood that other gas pressures may be utilized with appropriate changes in applied potential. However, for simplicity and complete effectiveness, atmospheric pressures are preferred. Switch 74 is closed and screw 38 is rotated to bring rod 26 into contact with body 18 immediately after which it is removed from such contact to a distance of the order of one millimeter. An arc is established between rod 26 and body 18 which passes a current of 1 to 5 amperes and across which is a potential drop of 100–130 volts. The arc persists for less than a second, or in other words for a proper fraction thereof and preferably approximately 3 to 10 cycles of the alternating potential and is extinguished by self action. During the period of such arc and in particular during the fractions of such cycles that the body 18 is negative with respect to the rod 26, the arc cleans the surface of the body by removing any oxides or other foreign matter thereon and further "wets" or melts the very surface portion of the body. Simultaneously, the top of the rod 26 is melted and deposited on the surface of the body 18, thus extending the spacing between the two, whereby the arc is self-extinguishing as hereinabove mentioned.

The aforedescribed procedure is effective in applying a minute quantity of rod material on the material of body 18. To increase the amount of alloy applied, the procedure is repeated as many times as necessary to form a contact of desired size and proportions.

In accordance with a specific example of materials and conditions for performing my invention, non-rectifying contacts of indium, aluminum and tin have been applied to p-type silicon semi-conductor material having an aluminum activator and a resistivity of 10 ohm centimeters, in an atmosphere of hydrogen gas at atmospheric pressure by passing an alternating current of 60 cycles at 3 amperes between the contact material and semiconductor body for one tenth of a second. Performing this procedure three times to aggregate contact material produced a contact of the order of 1 mm. in diameter.

In accordance with the method of my invention as set forth herein, good contacts have been established which for temperatures in a range from room temperature to temperature of liquid nitrogen are non-rectifying and of good mechanical bond. As another advantage over prior techniques, the body material 18 is not heat treated during the contact forming process and only a small, very localized portion thereof is intensely heated. The main body of material is only insignificantly raised in temperature and its characteristics remain unaltered while only an insignificant portion of the body material is raised to a high temperature.

While the present invention has been described by reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the invention. I, therefore, aim in the appended claims to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

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

1. The method of applying a contact to a body of semi-conductive material comprising the steps of enveloping said body and a member of contact material in an atmosphere of hydrogen gas, establishing an electrical arc between said body and said member of less than 1 millimeter in length during a portion of which said body is negative with respect to said member, maintaining said arc for a duration sufficient to remove impurities from and to melt a surface portion of said body, said arc melting a portion of said member and depositing the melted portion of said member on the melted portion of said body and repeating the procedure to increase the deposit of material of said member sufficiently to form a contact.

2. The method of applying a contact to a body of semi-conductor material comprising the steps of enveloping said body and a member of contact material in an atmosphere of gas inert to said body and contact material, applying a potential between said body and said member, establishing contact between said body and member and removing said member to form an electrical

arc between said member and said body, maintaining said arc for a proper fraction of a second during a portion of which time said body is negative with respect to said member, a portion of the surface of said body being cleaned and melted during said arc and a portion of said member being melted during said arc and deposited on the melted portion of said body and repeating the stated procedure to increase the quantity of material deposited sufficiently to form a contact.

3. The method of applying conductive contact material to a body of semi-conductor material comprising the steps of enveloping said body and a member of contact material in an atmosphere of hydrogen gas, applying a potential between said body and said member, establishing contact between said body and member and removing said member to form an electrical arc of short duration and having current of approximately three amperes between said member and body, said body being negative with respect to said member for a portion of the duration of said arc, said arc being effective to clean and melt a surface portion of said body and to melt a portion of said member, the melted portion of said member being deposited on the melted portion of said body and repeating the aforementioned steps to increase the quantity of deposited material sufficiently to form an electrical contact.

4. The method of applying a contact to a body of semi-conductive material comprising the steps of enveloping said body and a piece of contact material in an atmosphere of gas inert to the material of said body and contact material, establishing an alternating current arc between said body and said piece of less than one tenth second duration, said arc being effective to heat and melt a surface portion of said body and a portion of said piece, the melted portion of said piece being deposited on the melted portion of said body, and repeating the recited steps to increase the deposit of material on said body in sufficient quantity to provide an electrical contact.

5. The method of applying a contact to a body of semi-conductive material comprising the steps of enveloping said body and a piece of contact material in an atmosphere of gas inert to the materials of said body and contact material, establishing an electrical arc between said piece and said body of 1 to 5 amperes and more than 1 cycle duration, said arc being effective to heat and melt a surface portion of said body and a portion of said piece, the melted portion of said piece being deposited on the melted portion of said body, and repeating the recited steps to increase the deposit of material on said body in sufficient quantity to provide an electrical contact.

6. The method of forming a contact on a body of p-type, semi-conductive silicon material comprising the steps of enveloping said body and a piece of contact material alloyable with said silicon in an atmosphere of gas inert to the materials of said body and contact material, establishing an alternating current arc between said body and said piece of less than one tenth of a second duration, said arc being effective to heat and melt a portion of said body and a portion of said piece and to deposit the melted portion of said piece on the melted portion of said body, and repeating the recited steps to increase the deposit of material on said body in sufficient quantity to provide an electrical contact.

7. The method of forming a non-rectifying contact on a body of semi-conducting material having an activator impurity therein comprising the steps of enveloping said body and a piece of contact material having the same valence as said impurity in an atmosphere of gas inert to said body and contact material, establishing an electrical arc between said body and said piece during a portion of which said body is negative with respect to said piece and being of less than one tenth second duration, said arc being effective to heat and melt the surface portion of said body and to deposit a portion of said piece on said melted surface portion, and repeating the above stated steps to increase the deposit of material on said body in sufficient quantity to provide an electrical contact.

8. The method of applying a non-rectifying contact to a body of semi-conductor material having an activator therein comprising the steps of enveloping said body and a member of contact material producing the same electrical characteristics as said activator in an atmosphere of gas inert to the body and contact material, establishing an arc between said body and said member, maintaining said arc for a duration of time sufficient to melt and clean surface portions of said body and said member, the melted portion of said member being deposited on the melted portion of said body, and repeating the recited steps to increase the deposit of material on said body in sufficient quantity to provide an electrical contact.

9. The method of applying a non-rectifying contact to a body of p-type semi-conductive material comprising the steps of enveloping said body and a piece of indium in an atmosphere of hydrogen gas, establishing an alternating current arc of approximately 3 amperes between said body and said piece for a duration of approximately $\frac{1}{10}$ of a second, said arc being effective to heat and melt the surface portion of said semiconductive material and a portion of said indium, the melted portion of said indium being deposited on the melted portion of said semiconductor, and repeating the recited steps at least 3 times to increase the deposit of material on said body in sufficient quantity to provide an electrical contact.

References Cited in the file of this patent

UNITED STATES PATENTS

2,122,994	Southgate	July 5, 1938
2,430,055	Kennedy	Nov. 4, 1947
2,444,834	Landis et al.	July 6, 1948
2,788,432	Moles	Apr. 9, 1957
2,797,302	Smith	June 25, 1957

FOREIGN PATENTS

528,301	Great Britain	Oct. 25, 1940