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2,697,269

METHOD OF MAKING SEMICONDUCTOR TRANSLATING DEVICES

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FIG. 1

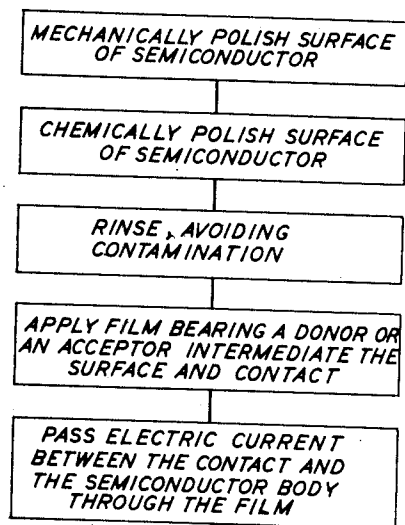


FIG. 2

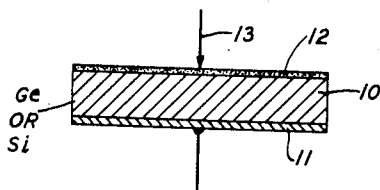


FIG. 3

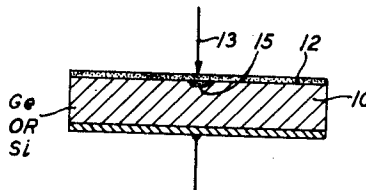


FIG. 5

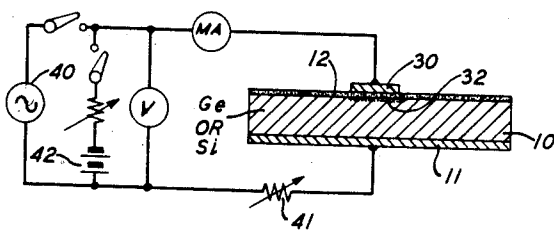
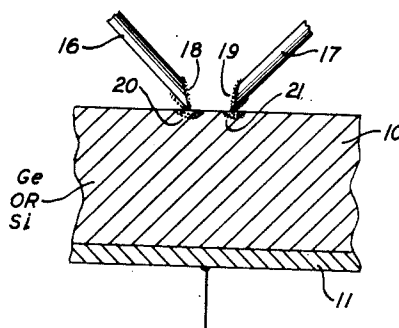


FIG. 4



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METHOD OF MAKING SEMICONDUCTOR TRANSLATING DEVICES

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8 Claims. (Cl. 29—25.3)

This invention relates to circuit elements having semiconductor body portions and more particularly to methods of controlling or altering the electrical characteristics of the body portions.

One object of this invention is to facilitate the control of the electrical characteristics of semiconductor bodies.

Another object of this invention is to provide treatments which determine the reverse conductivity of asymmetric connections to semiconductor bodies.

Semiconductive material such as silicon and germanium as employed in present day translating devices is of such extremely high purity that the presence of only traces of certain elements in the material has major effects upon its electrical characteristics. These elements are generically termed significant impurities and are of two types, acceptors and donors. Their effect may be explained by considering their influence on crystal structure of the semiconductor. A pure silicon or germanium body is made up of a cubic lattice each atom having four valence electrons, and is therefore a poor conductor, all electrons being bound in the lattice. The presence of a significant impurity in the lattice structure disrupts it. A donor impurity has more than four valence electrons and in entering the crystal lattice and supplying four bound electrons of the semiconductor atom it replaces, it thereby provides extra free or unbound electrons available as current carriers. An acceptor impurity has less than four valence electrons with a resulting deficiency of electrons in the lattice when it replaces an atom of semiconductive material. These deficiencies act as positive current carriers by the displacement of electrons into the resulting gaps, and are known as holes.

It has been known that migration or diffusion of impurities in semiconductors cause changes to occur in their electrical characteristics. Thus, R. S. Ohl has disclosed in Patent 2,415,841, issued February 18, 1947, that the positive ions of the metallic impurities in silicon migrate by a process which may be considered a filtering through the crystal lattice, and that this migration can be controlled by adding ions having a size sufficient to lodge within the lattice structure and block further migration. Likewise the production of depletion layers in silicon rectifiers to improve rectification, by heat treatment, surface oxidation and subsequent removal of the oxide, explained as a preferential oxidation of impurities, is known.

One feature of this invention relates to the control of the electrical characteristics of a semiconductor by the application of films of compounds to the surface of the semiconductor body, the films bearing significant impurities, and subjecting the surface to an electrical treatment to make the significant impurities effective.

More specifically, significant impurities are applied to suitably prepared semiconductive surfaces in any one of a number of methods including deposition of colloidal hydrous oxide solutions either with or without externally applied potentials, or adsorption of ions on the semiconductor surface or deposition from the vapor state. These films are placed intermediate the semiconductive surface and a contact member and either alternating, direct, or a combination of both types of electrical current are caused to flow between the contact and the semiconductor to make the films effective in altering the characteristics of the semiconductive body.

Another feature involves the fabrication of P-type germanium rectifiers by applying a film of a donor bearing compound such as arsenic trichloride, or phosphoric

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acid, to the P-type germanium, mounting a contact of either limited area or large area type on the film and electrically forming the resulting rectifier.

A further feature, applicable to semiconductive amplifiers having a germanium body of either conductivity type and including at least one rectifying contact, involves applying a layer containing a significant impurity of the conductivity determining type opposite to that of the body, intermediate the rectifying contact and the body, whereby the electrical forming of the contact so treated results in a device having a lower reverse current through that contact than in the case of a similar contact made to an untreated surface.

Still another feature pertains to increasing the reverse conductivity of asymmetric connections to semiconductor bodies and reducing the output impedance, thereby improving the impedance match of semiconductive amplifiers. This is done by interposing between the non-ohmic output connections and the semiconductive bodies of the devices a layer of a compound bearing significant impurities of the same conductivity determining type as the semiconductive body and electrically forming the output connection through the layer.

It is suggested that the changes in electrical characteristics resulting from treatments according to this invention occur due to a change in the bulk composition of the semiconductor in the neighborhood of the surface of the body. This is supported by evidence of changes in the electrical characteristics of the body by electrical treatment of surface films containing significant impurities of either conductivity determining type. Thus, the application and electrical treatment of a donor bearing film on an N-type semiconductor diode materially reduces the reverse resistance of the device, indicating that a greater number of unbound electrons are available in the semiconductor due to this treatment. For some applications such as some triode amplifiers this seemingly undesirable result may be advantageous since it enables an improved output impedance match to be achieved. Acceptor bearing films treated in a similar manner raise the reverse resistance indicating that fewer unbound electrons are available due to their combination with the holes supplied by the added acceptor impurity. This improves rectifying characteristics.

Other objects and features of this invention will appear more fully from the following description of illustrative embodiments thereof taken in connection with the appended drawing in which:

Fig. 1 is a flow chart representing the steps in the method of treatment according to this invention;

Fig. 2 represents one form of semiconductive body in section, the body having a coated surface on which is set down a contact;

Fig. 3 represents the semiconductive body of Fig. 2 in section after forming, showing the modification of the body composition in the region of the contact;

Fig. 4 is a sectional view, to an enlarged scale, of a semiconductive translating device having a pair of formed contacts set down on its surface; and

Fig. 5 is a diagram illustrating a forming circuit, a semiconductive body having a large area contact being shown in the formed condition associated with the circuit.

It is to be understood that the representations of the drawings, particularly as to the relative thicknesses of the contact layers, the semiconductive bodies, and the impurity bearing films are not to scale. The regions of the bodies modified by this treatment, represented by the dotted portions, are greatly exaggerated for purposes of clarity. The impurity bearing films applied in accordance with this invention are usually limited to a thickness of about 200 Å. Materially thicker films tend to present too high a resistance for satisfactory electrical forming.

The terms coated, coating, layer and film as employed throughout this specification in referring to the deposits of significant impurity bearing compounds are not to be considered necessarily as continuous and may be either of that form or discrete molecules or groups of molecules distributed over the supporting surface.

While it is not intended that this invention be limited to treatments of any particular composition of semiconductor of the germanium or silicon type, it is appli-

cable particularly to those types of materials having a purity sufficient to exhibit an asymmetric conductivity when contacted with limited area connections. These materials are usually of better than ninety-nine per cent purity and contain only very slight amounts of impurities, some of which markedly control the electrical characteristics. Since a variation of a few parts in ten million of some impurities is sufficient to change a semi-conductive body of this nature from one conductivity type to the opposite type, special methods have been developed for preparing the material. In the case of germanium, the material may be prepared, for example, in the manner set forth in the application of J. H. Scaff and H. C. Theuerer filed December 29, 1945, Serial No. 638,351. Silicon material may be made in either conductivity type or in bodies containing both types, by the process disclosed in the application of J. H. Scaff and H. C. Theuerer filed December 24, 1947, Serial No. 793,744 and in United States Patent 2,402,661 to R. S. Ohl.

Considering this process as applied to germanium semi-conductive bodies, the germanium may be prepared by reduction of germanium oxide as follows: About 75 grams of the oxide are placed in a porcelain dish, which is put in a furnace. The furnace is sealed and flushed with pure dry hydrogen and the oxide then is heated to 650° C. and held at this temperature for three hours while a flow of hydrogen of about 10 liters per minute is maintained through the furnace. The temperature is then raised to 1000° C. to complete the reduction with the germanium in the liquid state, and the charge is cooled to room temperature. The reduced germanium may then be reheated with or without the addition of impurities, depending upon the type of material desired, in a closed furnace having a helium atmosphere. A progressive cooling technique is employed in this latter heating step to induce the desired segregation of impurities. With a helium flow of one liter per minute, the charge is first liquefied and then solidified from the bottom upwardly at the rate of about one-eighth inch per minute. This may be done conveniently if the furnace employed is of the induction type having a heating coil which may be moved along the axis of the ingot. When the ingot has reached 650° C. the power is shut off and the ingot is allowed to cool to room temperature. While this process has been described as being performed in separate heating operations it may be done as a single operation without any intermediate cooling. Other processes of preparation are also available.

Depending upon the significant impurities present in the original material, significant impurities being defined as those materials which exist in the final product and by their presence affect the electrical characteristics of the semiconductor, and the treatment of the material after all impurities have been added, it can be either P-type or N-type.

Thus N-type germanium containing only traces of aluminum, copper, manganese and sodium, and germanium of the above type having .005 per cent antimony added to the ingot in the initial forming thereof, are representative of the N-type germanium employed. P-type germanium was prepared for this treatment by heating the first-mentioned N-type germanium in helium for twenty-four hours at from 700 to 900° C. and quenching it in an inert atmosphere.

The semiconductor, as indicated by Fig. 1 is treated according to this invention by first mechanically polishing the surface portion to be operated on, and then chemically polishing and rinsing it. Films bearing donors or acceptors are then applied intermediate the prepared surface and a contact thereto, either by application to the surface, to the contact to be made thereto, or to both, and the contact is set down on the surface. The final step is to apply an electrical forming to the semiconductor and connection by passing electric current between those elements and through the intermediate film.

In preparing the semiconductor for use in circuit elements, slabs are first cut from the ingot and are ground on both sides using 600 mesh Aloxite in water. The slabs may then be cut into wafers and mounted as by soldering to a brass plug preparatory to further treatment or they may be cut into wafers at a later point in the operation. In either event handling is facilitated if the slab or wafer is mounted, this may be done by applying a rhodium surface to the back of the piece and

soldering it to a backing member. Etching of the ground surface may be done with a number of solutions, for example, one consisting of 10 cubic centimeters of concentrated nitric acid, 10 cubic centimeters of water containing 0.2 gram of copper nitrate and 5 cubic centimeters of forty-eight per cent hydrofluoric acid. This etchant is disclosed and discussed more fully in the application of H. C. Theuerer, Serial No. 135,817, filed December 29, 1949, now Patent No. 2,542,727, granted February 20, 1951.

An alternative etching solution consists of five parts by volume of Superoxol, five parts of hydrofluoric acid (48%) and twenty parts of water.

A preferred etchant is that disclosed in the application of R. D. Heidenreich, Serial No. 164,303, filed May 25, 1950, now Patent No. 2,619,414 granted November 25, 1952, consisting of twenty-five parts by volume of concentrated nitric acid, fifteen parts glacial acetic acid, fifteen parts hydrofluoric acid (48%) and .25 part liquid bromine.

These etches are effected at room temperature and are carried on for a period of from fifteen seconds to a minute, in the case of the Superoxol etch up to two minutes is advisable. Throughout the etching and rinsing process it is desirable to keep the surface being treated as free from significant impurities as is possible, spectroscopic purity of the materials and handling equipment being desirable. To maintain this freedom from contamination the materials making up the etchants are all of chemical purity, as are the rinses employed.

The etched slab or wafer is removed from the etchant after a suitable period and rinsed in pure water, double distilled water which has been exposed to no metals, or pure methyl or ethyl alcohol. The rinsing operation is advantageously performed in quartz vessels to further insure against contamination by uncontrolled amounts of acceptor or donor impurities. After the surface is rinsed and dried, for example, by blotting with clean filter paper, it is ready for the application of the significant impurity bearing compounds.

Donor or acceptor bearing compounds may be applied to the prepared surface in various ways. They may, for example, be applied to the germanium surface by contacting the surface with a true solution of the compound, or they may be applied to the semiconductive surface as colloidal solutions or suspensions of the active compounds. They may be applied also as melts or vapors of the compounds. Fig. 2 represents a germanium or silicon wafer 10 having a film 12 bearing a donor or acceptor on which a limited area contact 13, for example a point, is mounted, while an ohmic back contact 11 of some material such as plated layer of rhodium provides means for completing a circuit through the unit. Methods analogous to those suggested above may be employed to deposit the compounds on the contacts which are to be put down on the etched semiconductive surface.

While significant impurity bearing layers may readily be applied by several processes involving the immersion of the semiconductor or contact surface in solutions or sols, the latter being defined as a combination of a solution and a colloidal suspension of the compound involved, it has been found that certain treatments lend themselves more readily to control and stability than others. Thus, while true solutions will provide suitable donor or acceptor bearing layers they are often unstable after drying because of moisture which may be adsorbed from the atmosphere. Similarly, true solutions can be rinsed off the treated surface, and while some acceptor or donor may remain the quantity present will be difficult to control. On the other hand sols adsorbed on the semiconductive surfaces are more stable in the presence of water either from rinses or the atmosphere. One general class of sol which has been used advantageously in the treatments of this invention is that of the hydrous oxides of donors and acceptors, for example, antimony, arsenic, gallium and aluminum hydrous oxides.

Significant impurity bearing layers have been adsorbed on semiconductive surfaces from aqueous solutions by immersing the surface in a solution of a compound bearing the desired impurity. Thus an acceptor can be applied to N-type germanium which has had its surface prepared by grinding and etching in the preferred etchant referred to above at room temperature for one minute by immersing the rinsed and dried surface in a two per cent solution of gallium chloride for two minutes. Thus surface 12 is then

blotted dry with clean filter paper and a contact 13 put down on the surface as shown in Fig. 2. The significant impurity is made effective by subjecting the surface bearing the deposited film to an electrical forming in a circuit as shown in Fig. 5 by passing a 60-cycle alternating-current pulse of 50 volts and 0.8 second duration through a series combination of a 50-ohm resistor and a 5-mil tungsten point contact which is set down on the surface under 3 grams force. This point was anodically cleaned in fifteen per cent sodium hydroxide and rinsed in redistilled water to insure freedom from surface layers bearing significant impurities.

Fig. 3 shows the effects of forming on the bulk composition of the body 10, the shaded area 15 under the contact 13 representing that portion of the body upon which an acceptor such as gallium would be effective.

Another point contact N-type germanium rectifier which had improved reverse current characteristics was produced by preparing a piece of N-type germanium having a resistivity of 10-ohm centimeters as set forth above. The surface to which the rectifying junction was to be made was then immersed for one minute in a colloidal solution of aluminum hydrous oxide prepared by boiling a piece of pure aluminum metal in contact with a drop of pure mercury in an excess of distilled water until a bluish opalescence developed. The concentration of such a colloidal solution is approximately 2 milligrams of aluminum per milliliter of solution. The surface was then rinsed and air dried. After mounting a 5-mil phosphor-bronze pointed wire contact on the resulting film, the unit was connected in the circuit of Fig. 5 and formed electrically by passing a 60-cycle alternating-current pulse of 30 volts through a 50-ohm series resistor for 0.8 second. The resulting rectifiers showed average forward currents at one volt of from 5 to 9 milliamperes and had reverse currents of the order of .001 milliamperes at one volt and 0.05 milliamperes at 50 volts, while rectifiers of identical material which were not coated with the aluminum hydrous oxide film had reverse currents of the order of .004 milliamperes at one volt and 0.60 milliamperes at 50 volts. Marked improvement of treated rectifiers over those that were not were also observed where tungsten contacts were used.

Donor or acceptor ions may be applied by absorption on prepared surfaces of a semiconductor already covered with layers of hydrous oxides of non-donor or non-acceptor type atoms. A suitable inert sol is iron hydrous oxide which may be employed to form a film of iron hydrous oxide deposited by cataphoresis to a thickness of 50 to 200 angstrom units. After rinsing the inert film with pure water and drying the surface, a donor or acceptor bearing layer may be formed by immersing the coated surface in a suitable aqueous solution to absorb donor or acceptor ions therefrom. An acceptor impurity could thus be supplied from gallium chloride or aluminum chloride solution while donor impurities could be adsorbed from a five per cent solution of sodium arsenate.

Direct application by cataphoresis of films containing donor or acceptor impurities lends itself to a more quantitative control of the amount of colloid deposited than the preceding methods.

Thus, a donor impurity may be applied from a dilute sol of arsenic hydrous oxide. The etched face of the semiconductor is immersed in the solution and made $1\frac{1}{2}$ volts positive relative to a platinum electrode in the solution. After two minutes the semiconductor is removed, rinsed in distilled water or alcohol and dried.

When applied to a P-type sample of germanium prepared by heating N-type germanium in an inert atmosphere such as helium or in a vacuum at temperature between 700 and 900° C. and rapidly quenching, as disclosed in the application of J. H. Scaff and H. C. Theuerer filed December 29, 1948, Serial No. 67,894, this treatment with arsenic hydrous oxide results in surfaces which have satisfactory P-type rectification characteristics after electrical forming when contacted with tungsten points. Heretofore, it has been extremely difficult to obtain rectification on P-type germanium with tungsten contacts; however, rectification was observed with all formed samples. Particularly satisfactory units according to this technique were formed by gradually increasing the point pressure on a 5-mil pointed wire while an increasing current was passed in the forward direction up to about 50 milliamperes. An improvement in the forward current from 0.5 milliamperes to 5 milliamperes and of the reverse current from 0.4 milliamperes to 0.1 milliamperes after passing a 5-milli-

ampere forward current through the unit was observed. Attempts to form untreated P-type germanium rectifiers having tungsten points by the same forming process did not result in satisfactory units.

The above electrical forming treatment has also been found to produce good P-type germanium rectifiers where the rectifying junction is formed on a surface which was prepared by abrading and etching and then dipped in a solution of a donor bearing compound comprising a two per cent solution of sodium arsenate for about two minutes.

Where it is desirable to cataphoretically deposit an acceptor bearing film as in the production of N-type germanium rectifiers having low reverse currents, the deposition can be made, for example, from an aluminum hydrous oxide sol. This may be done by preparing the sol in the manner set forth above to produce an aluminum concentration of 2 milligrams per milliliter of solution and depositing an aluminum hydrous oxide film by immersing the face of the germanium and making it 1.5 volts negative relative to a platinum electrode in the solution.

Vapor deposition is also suitable in applying the film of donor or acceptor bearing compound. Thus a semiconductor body can be placed adjacent a dish containing the desired solution with the prepared surface of the body exposed and the vessel containing the dish and sample evacuated to a pressure of .5 millimeter of mercury. After ten minutes at room temperature, the vacuum is removed and the surface of the semi-conductor which is exposed to the vapors is ready for electrical forming.

Donor bearing compounds such as phosphoric acid, or arsenic trichloride, and acceptor bearing compounds such as boron fluoride are suitable for deposition from the vapor state.

In order to make any of the above films effective for the purposes of this invention, i. e., to alter the electrical characteristics supposedly by altering the bulk composition of a portion of the body, it has been found advantageous to apply some electrical treatment through the film. This treatment is generically termed forming and includes a number of techniques. One forming treatment which has been found to make the presence of the deposited films effective, particularly where the characteristic sought is a low reverse current, can be accomplished in the circuit of Fig. 5. This treatment comprises applying a 60-cycle alternating pulse of from 1 to 40 volts from source 40 for about .4 to 1.6 seconds through a series resistor 41 of about 50 ohms. The special forming of P-type germanium rectifiers having tungsten contacts set forth above is an exception to this treatment, although it is advantageous for improved ease of forming these rectifiers to form a barrier by the application of 1 to 10 volts alternating current through a 50-ohm series resistor prior to applying the direct-current forming discussed above from the source 42.

Up to this point the use of the treatment to decrease the reverse current of semiconductor rectifiers by the application of layers bearing significant impurities of the conductivity determining type opposite to that of the semiconductive body has been discussed. It is to be understood, however, that the invention is not related solely to this treatment and that for certain purposes it may be desirable to reduce the resistance of contacts to the body. In such a case, this may be effected by employing a layer of a significant impurity of the same conductivity determining type as the body of the semiconductor and forming a contact through that layer, i. e., donor bearing films on N-type material and acceptor bearing films on P-type.

Thus in some semiconductive translating devices, for example, those of the types disclosed in Fig. 4 and in the applications Serial No. 33,466, filed June 17, 1948, of J. Bardeen and W. H. Brattain, now Patent No. 2,524,035, granted Oct. 3, 1950, Serial No. 35,423, filed June 26, 1948, of W. Shockley, now Patent No. 2,569,347, granted Sept. 25, 1951, and Serial No. 50,897, filed September 24, 1948, of G. L. Pearson and W. Shockley, now Patent No. 2,502,479, granted April 4, 1950, comprising, in general, a body of semiconductive material 10, a pair of connections to spaced regions of the body 16 and 17, and a third connection 11 to another region of the body, it may be desirable to have one of said pair of connections make a low resistance contact to the body. An input circuit is connected between one of the pair of connections which is rectifying in character, termed the emitter 16,

and the third connection, termed the base 11; an output circuit is connected between the other of the pair of connections, designated the collector 17, and the base 11. The output impedance of the device is dependent upon the collector resistance and therefore it may be advantageous for purposes of impedance matching to make the collector resistance low.

An N-type germanium triode translating device of the above type, which as disclosed in the applications noted may be employed as an amplifier, modulator or oscillator, can be conveniently produced with a rectifying emitter connection and a collector connection having a reduced resistance by utilization of the techniques of this invention. Since only limited regions surrounding the connections need be modified in their characteristics, since opposite effects from the standpoint of added impurities are desired in the two connections, and since in the usual structure of this type device the connections are of the order of 2 to 5 mils apart, it would be a difficult task to coat the portion of the germanium surface on which the emitter is to be mounted with an acceptor bearing film and the portion on which the collector is to be mounted with a donor bearing film. Therefore, such a device is most conveniently constructed by adding the donors and acceptors from layers placed on the contacts. This is accomplished where 5-mil pointed tungsten or Phosphor bronze wires are employed as emitter and collector connections 16 and 17 on N-type germanium, for example, by dipping the emitter point in a gallium hydrous oxide sol for about two minutes, then rinsing and drying it to form a film 18 thereon. The collector is similarly treated by exposing its point to the vapors of antimony chloride to apply a layer on the surface as at 19. It is to be understood that other electrode materials, electrode forms, compounds, and methods of application might as readily be employed, the important factor in this process being to apply an acceptor bearing film intermediate the emitter to body connection and a donor bearing film intermediate the collector to body connection. The limited area contacts or points are then positioned on the clean polished and etched germanium surface and each subjected to an electrical forming to alter the bulk characteristics immediately under them as represented by the shaded areas 20 and 21, respectively.

This electrical forming may be accomplished by first connecting the forming circuit of Fig. 5 and forming through the emitter and base as in the case of the rectifiers. The collector connection can then be formed by applying alternating current or direct current or a combination of the former superimposed on the latter and increasing the voltage until a marked increase in current is observed through the connection. Where direct current is used alone, the forming of the collector may be accomplished in the case of an N-type body by applying a negative potential thereto and increasing the potential until the collector to base voltage-current characteristic is in the negative resistance region. A more complete disclosure of electrical forming techniques for semiconductive triodes is found in the applications Serial No. 67,781, of W. H. Brattain, filed December 29, 1948, and Serial No. 67,797, of W. G. Pfann, filed December 29, 1948, now Patent No. 2,577,803, granted Dec. 11, 1951.

Another application of this invention is to large area rectifiers as opposed to the limited area or point contact rectifiers discussed above. Such a device is disclosed in Fig. 5 wherein the germanium body 10 has a back contact 11 of some material such as a plated layer of rhodium, a surface film 12 bearing a significant impurity of the conductivity determining type opposite that of the body and a large area front electrode 30 which makes rectifying contact with the coated face of body 10. The front electrode 30 which may be a plated layer of rhodium or copper or a piece of Phosphor bronze polished so as to make contact over a substantial portion of the germanium surface is formed in the manner discussed above, that is by applying a current pulse of the order of 10^5 amperes per square centimeter of contact area. This requirement of high current density in the forming process limits the size of the "large area" which can be employed practically. The forming treatment, as in the devices previously discussed, causes a migration of donors in a P-type body or acceptors in an N-type body from the film 12 into the body to modify its bulk composition in the region adjacent the contact. This modified region, represented by the

shaded area 32, creates or improves the rectifying barrier between the main portion of the body 10 and the front contact 30. Rectifiers of this construction have high current capacities.

Recapitulating, this invention pertains to a method of altering the electrical characteristics of a semiconductive body, such as one of silicon or germanium, by altering the bulk composition of the body. This is effected by an electrical treatment of a thin film containing donor or acceptor impurities which are thereby caused to enter the semiconductor body through a clean surface whose uniformity as to the reception of the impurities has been assured by special polishing treatments. The film may be applied to either the clean surface or a contact which is to be set down on that surface by a variety of methods including adsorption from solutions or sols, electrolytic or cataphoretic deposition, and vapor deposition. An application of pulses of alternating current between the contact and the body through the film constitutes the electrical forming usually employed and further improvement of characteristics by supplemental forming is advantageous in some instances, particularly where a tungsten contact is applied to P-type germanium to produce a rectifying contact.

It is to be understood that the above-described techniques and arrangements are illustrative of the application of the principles of the invention. Numerous modifications of the methods of cleaning and polishing the semiconductive surfaces, applying films of the compounds suggested as well as others bearing donors or acceptors, and of electrically forming contacts through the films may be devised by those skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. The method of altering the electrical characteristics of a semiconductive circuit element having at least two contacts to a semiconductor body which comprises coating one of said contacts with a significant impurity bearing compound, mounting the coated contact on the semiconductor body, and causing electric current to flow between the body and the contact.
2. The method of altering the electrical characteristics of a circuit element having a semiconductive body and at least two contacts thereto which comprises polishing a portion of the surface of the body, coating one of said contacts with a layer of a significant impurity bearing compound, mounting the coated contact on the polished surface of the body, and causing electric current to flow between the body and the coated contact.
3. The method of reducing the reverse current between an N-type germanium body and a rectifying contact thereto which comprises polishing a portion of the body, depositing an acceptor bearing hydrous oxide film intermediate the contact and the polished body portion, and causing electric current to flow between the body and the contact.
4. The method of producing a semiconductive translating device having a semiconductive body of one conductivity type and input and output connections which comprises applying a layer bearing a significant impurity of the conductivity determining type opposite that of the body intermediate the body and one input connection thereto, electrically forming said connection, applying a layer bearing a significant impurity of the conductivity determining type of the body intermediate the body and one output connection thereto, and electrically forming the output connection.
5. The method of producing a semiconductive translating device having an N-type germanium body and input and output connections which comprises applying a donor bearing layer intermediate the body and one of the output connections thereto, electrically forming the output connection, applying a layer bearing an acceptor significant impurity intermediate the body and one input connection thereto, and electrically forming the input connection.
6. The method of producing a semiconductive translating device having an N-type germanium body and input and output connections which comprises applying a gallium bearing layer to one of the output connections, mounting the coated connection on a polished surface of the body, electrically forming the connection, applying a phosphorous bearing layer to one of the input connections, mounting the coated connection on a

polished surface of the body, and electrically forming the input connection.

7. The method of producing a large area rectifier having a semiconductor body of one conductivity type and at least two contacts which comprises polishing a surface of the semiconductor body, applying a layer of a compound bearing a significant impurity of the conductivity determining type opposite that of the body, plating a contact on the significant impurity bearing layer, and electrically forming the rectifier across the layer.

8. The method of altering the electrical characteristics of a circuit element having a semiconductive body and at least two contacts to the body which comprises depositing a layer of an inert hydrous oxide intermediate

the semiconductive body and one contact, applying a material containing a significant impurity to said inert layer whereby said material is sustained on said body, and passing a forming current between the body and the contact.

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