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3,044,147

SEMICONDUCTOR TECHNOLOGY METHOD OF CONTACTING A BODY

Filed April 21, 1959

Fig. 1.

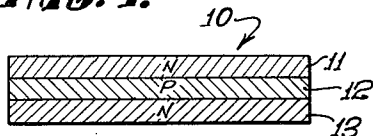


Fig. 2.

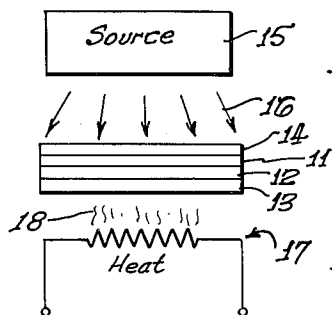


Fig. 4.

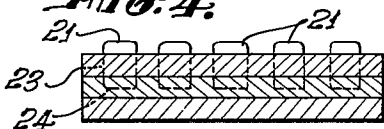


Fig. 3.

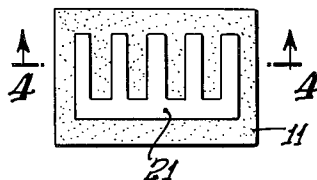


Fig. 5.

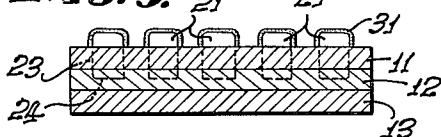


Fig. 9.

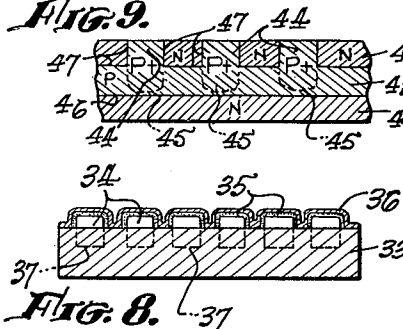


Fig. 6.

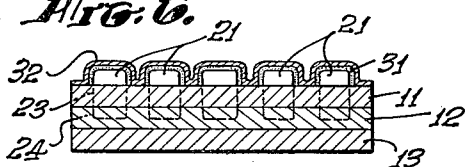
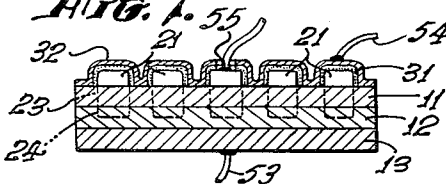


Fig. 8.



Fig. 7.



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SEMICONDUCTOR TECHNOLOGY METHOD OF CONTACTING A BODY

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15 Claims. (Cl. 29—25.3)

This invention relates to electrical devices, and more particularly to a method for providing closely spaced electrodes in an electrical device. This invention also relates to electrical devices having closely spaced electrodes upon at least one surface thereof.

It has long been desirable in the semiconductor art to produce transistors capable of carrying relatively large currents. While this has been accomplished in some instances by increasing the size of the semiconductor body from which the transistor is manufactured, it remains desirable to produce a transistor of relatively small size which has a low base resistance and thereby is capable of carrying large currents. In order to accomplish this it has been recognized that the emitter electrode should have a substantial amount of contact with the base region and at the same time should be as closely spaced to the base electrode as is physically possible.

A structure to meet the above requirements has in the past been attempted by alloying concentric rings of metal into the surface of the semiconductor body from which the transistor has been made. Typical examples of such a structure may be found by referring to volume 45 of Proceedings of the I.R.E., page 544 in an article by N. H. Fletcher, published in 1957. While devices having such a structure as above disclosed work quite well under some circumstances, it has been found that it is exceedingly difficult to control the close spacing between the concentric contact rings. It has also been found that during the alloying step, the material which is being utilized to form adjacent rings has a tendency to dissolve laterally through the semiconductor material and cause the adjacent rings to come into contact with each other, thereby shorting out the various regions of the transistor.

In addition to the above difficulties, when the concentric structure is utilized, and particularly when several of the narrow rings are required in order to obtain the desired amount of contact, it becomes necessary to physically attach leads for electrical connection to each of the concentric rings which are alloyed to the semiconductor device. If a great number of the rings are utilized, this necessitates additional steps in the process of manufacture, thereby greatly increasing the cost of the device. If a large number of the rings are utilized, it becomes exceedingly difficult to make the proper electrical connections thereto and also causes the end product to be quite fragile. Furthermore, in constructing such electrical devices as resistors and the like it often becomes necessary to provide electrical contact to closely spaced regions of the device body. By using prior art techniques it is exceedingly difficult to obtain very close spacing of contacts and in some cases almost impossible.

Accordingly, it is an object of the present invention to provide a method of making closely spaced contacts to a surface of an electrical device.

It is another object of the present invention to provide a method for making semiconductor devices which are capable of carrying a relatively heavy current.

It is another object of the present invention to provide a method for making semiconductor devices having electrodes more closely spaced than heretofore possible, while at the same time providing a large amount of contact to the desired portions of the semiconductor device.

It is yet another object of the present invention to pro-

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vide a method for making more efficient high-current carrying capacity transistors.

It is still another object of the present invention to provide a method for making semiconductor devices having closely spaced electrodes which provide a large amount of contact to desired portions of the semiconductor body and at the same time requires only a single connection to each of the regions of the semiconductor device.

It is a further object of the present invention to provide a method for making transistors which have the emitter and base electrodes thereof located upon one surface of the transistor and spaced close to each other.

It is a further object of the present invention to provide a transistor capable of carrying greater currents than heretofore possible with transistors of comparable size.

It is yet a further object of the present invention to provide an electrical device having closely spaced electrodes located on one surface thereof.

It is yet a further object of the present invention to provide a transistor having the emitter and base electrodes closely spaced and located upon one major surface thereof.

In accordance with the method of the present invention; a layer of electrically conductive material is applied to a portion of one surface of a body. The material is alloyed with the body to cause it to penetrate into the body. An insulative layer of material is formed upon a protrusion remaining at the body surface and thereafter a layer of electrically conductive metal is applied to the surface of the body and over the insulative layer.

Also in accordance with the present invention, a device includes a body having an electrically conductive material alloyed with at least a portion of one surface thereof. A layer of insulative material is provided upon the alloy and a layer of metal is provided upon the surface of the body and over the insulative material.

More specifically, a junction-type semiconductor device in accordance with the present invention includes first and second regions of opposite conductivity type separated by a P-N junction. A heavily doped region having a conductivity type the same as the second region extends through the first region and into the second region and has a protrusion molecularly affixed thereto. The protrusion has a layer of insulative material upon it. A layer of metal is provided upon the surface of the body and over the insulative layer.

Other and more specific objects of the present invention will become apparent from a consideration of the following description taken in conjunction with the accompanying drawing, which is presented by way of example only, and is not intended as a limitation upon the novel features of this invention which are set forth in the appended claims, and in which:

FIG. 1 is a cross-sectional view of a semiconductor device upon which the method of the present invention is to be carried out;

FIG. 2 is a schematic representation of the function of the apparatus which may be used in practicing the method of the present invention;

FIG. 3 is a top view of a semiconductor device after the first step in the method of the present invention has been carried out;

FIG. 4 is a cross-sectional view of the semiconductor device as illustrated in FIG. 3;

FIG. 5 is a cross-sectional view after the next succeeding step of the method of the present invention has been carried out;

FIG. 6 is a cross-sectional view of a semiconductor device after each of the steps of the present invention have been carried out;

FIG. 7 is a cross-sectional view illustrating a finished

semiconductor device in accordance with the present invention;

FIG. 8 is a cross-sectional view illustrating another embodiment of a device in accordance with the present invention; and

FIG. 9 is a schematic representation of a semiconductor device as illustrated in FIG. 6.

Referring now to the drawing, and more particularly to FIG. 1 thereof, there is shown a semiconductor transistor generally designated as 10 which includes an emitter region 11, a base region 12, and a collector region 13. As illustrated, and by way of example, the transistor as shown is an N-P-N type transistor.

Although the semiconductor device as illustrated in FIG. 1 is a transistor of the N-P-N type, it should be expressly understood that the method of the present invention is applicable to many types of bodies to which contact is to be made and to transistors of the P-N-P type and is as well applicable to other semiconductor devices such as diodes, thermistors, resistors, photocells, and the like. For purposes of illustration only, the description of the method of the present invention will be described in connection with an N-P-N transistor of the silicon type. It should also be expressly understood that the method of the present invention is applicable to semiconductor devices constructed from materials other than silicon. Examples of additional materials from which semiconductor devices may be made are germanium, germanium-silicon alloys and the intermetallic compounds such as, by way of example only, gallium-arsenide, indium-phosphide and the like.

The transistor as illustrated in FIG. 1, may be constructed by the well known diffusion process. For example, a P-type silicon body is placed within an open or closed tube type furnace. A gaseous medium is provided in the tube and around the semiconductor body. The gaseous medium will contain an active impurity type material which will diffuse into all surfaces of the semiconductor body and which will convert the exterior regions thereof to the opposite, or N-type, conductivity. The diffusion process has been fully disclosed in the literature and is well known to the art.

The semiconductor body is then formed into the configuration as shown in FIG. 1 by removing the edge portions thereof by dicing, lapping, or the like, thus, leaving first and second regions of N-type conductivity separated by an intermediate region of P-type conductivity as illustrated.

After formation of the transistor, a mask is then placed adjacent the emitter region thereof as illustrated at 14 in FIG. 2, to which reference is hereby made. The masking material may be any which is presently well known to the art, such as, for example, nickel, molybdenum, tantalum, graphite, or the like. In the presently preferred embodiment of this invention, nickel is utilized as the masking material. The masking material is constructed in such a manner that openings are provided therein to expose a predetermined portion of the surface of the semiconductor body upon which the mask 14 is placed.

After the mask 14 is in place adjacent the emitter region 11 of the transistor 10, the transistor is placed within an apparatus which is adapted to apply an electrically conductive material through the openings in the mask and upon the surface of the emitter region 11 of the transistor 10. Such an apparatus is schematically illustrated in FIG. 2, and includes a source 15 of the electrically conductive material. Also included within the apparatus is a source of heat 17 which is used to raise the temperature of the semiconductor body 10. Such an apparatus usually includes means for enclosing the semiconductor body, the source of metal, and the heat source within a vacuum and provides means for controlling the same. Such an apparatus may be constructed as illustrated in Patent No. 2,695,852, entitled "Fabrication of Semicon-

ductors For Signal Translating Devices," issued November 30, 1954 to M. Sparks.

After the semiconductor body is positioned within the apparatus as illustrated in FIG. 2, the electrically conductive material is applied through the openings in the mask and upon the surface of the emitter region 11 as illustrated by the arrows 16 extending from the source 15. In the presently preferred embodiment of the present invention wherein an N-P-N silicon transistor, as illustrated in FIG. 1, is utilized, the electrically conductive material is a metal and preferably is aluminum.

The material which is deposited upon or applied to the surface of the semiconductor device must be capable of dissolving the particular semiconductor material when heated in combination therewith. Although other metals such as bismuth and tin are capable of dissolving semiconductor material, it has been found preferable in practicing the present invention to utilize aluminum which readily dissolves both silicon and germanium.

The aluminum is preferably applied to the semiconductor body by vapor deposition in a vacuum while maintaining the temperature of the semiconductor body 10 above the eutectic temperature of aluminum and silicon and preferably at approximately 800° C. In the alternative, the aluminum may be applied by evaporating through the mask directly upon the semiconductor body without raising the temperature of the semiconductor body. The temperature of the semiconductor body 10 is raised to the desired level by applying a source of potential to the heating device 17 to cause heat to be applied therefrom to the semiconductor body 10 as illustrated by the lines 18 in FIG. 2. As long as an electrical potential is applied to the heating device 17, the temperature of the semiconductor body 10 will be maintained at the desired level.

After the aluminum is applied to the surface thereof, the temperature of the semiconductor body 10 is maintained in excess of the eutectic temperature of silicon and aluminum for a time which is sufficient to allow the penetration of the aluminum into the semiconductor body 10, as will be more fully explained hereinafter.

Referring now more particularly to FIG. 3, there is illustrated the pattern which the evaporated aluminum assumes after passing through the openings in the mask 14 onto the surface of the emitter region 11 of the transistor 10. As is illustrated in FIG. 3, the evaporated aluminum assumes a configuration similar to a bar having a series of elongated protrusions or fingers along one surface thereof and extending across a major portion of the surface of the emitter region 11 of the transistor 10. Although five of these protrusions are illustrated in FIG. 3, one skilled in the art can readily see that fewer or additional fingers may be utilized depending upon the particular application and the amount of current for which the transistor is being designed. It should also be understood that the evaporated aluminum may be deposited in discrete regions upon the region 11 in order to form a series of individual contacts to the body. For the best results with reference to the current carrying capacity of the transistor, the dimensions of each of the fingers should be approximately one to twenty microns in thickness and approximately one to ten mils in width.

The configuration of material as illustrated at 21 in FIG. 3 may also be obtained, in addition to evaporation through a mask, by way of spraying molten aluminum onto the surface, or by pre-forming a solid blank of material and placing this blank upon the surface of the semiconductor body prior to heating the combination. It should also be expressly understood that although the configuration of the aluminum shown at 21 in FIG. 3 is the preferred embodiment in accordance with the method of the present invention, it may vary in accordance with any particular design configuration. For example, a bar of material could be provided across the center of the tran-

sistor with the fingers extending from each side thereof. Other configurations will become readily apparent to those skilled in the art.

Referring now more particularly to FIG. 4, which is a cross-sectional view taken along the line 4—4 of FIG. 3, it is seen that the aluminum has penetrated into the semiconductor body as illustrated by dashed lines 23. As hereinabove described, this penetration is accomplished by maintaining the temperature of the semiconductor body and the aluminum material deposited thereon at a temperature above the eutectic temperature of silicon and aluminum.

The temperature at which the combination of the aluminum and silicon is maintained causes the aluminum to remain or become molten and to dissolve portions of the silicon semiconductor body with which it is in contact. As the aluminum dissolves the semiconductor material, it penetrates into the semiconductor body. The depth of penetration is controlled by the particular temperature and the amount of time during which this temperature is maintained. As illustrated by the terminus 24 of the dashed lines 23 in FIG. 4, the desired depth of penetration is completely through the emitter region 11 of the transistor 10 and into the base region 12 thereof. When applying contacts to a silicon transistor which is approximately one-half inch square and .005 inch in thickness and with the thickness of aluminum, temperature and time as above set forth, the amount of penetration as illustrated in FIG. 4 will occur.

After the desired penetration has been accomplished, the heat is removed from the silicon transistor and it is allowed to cool. Although the rate of cooling is not considered a critical parameter, it has been found that a cooling rate of approximately 0.2° C. per second gives satisfactory results. When this is done, a portion of the dissolved silicon precipitates from the molten aluminum-silicon solution and regrows onto the parent semiconductor body and in so doing follows the crystalline planes present in the parent semiconductor body. As the temperature of the combination of aluminum and silicon goes below the eutectic temperature of silicon and aluminum, the remaining molten portion of the aluminum-silicon solution freezes out as an aluminum-silicon alloy which is predominantly aluminum.

The resulting structure as illustrated in FIG. 4 consists of a silicon transistor as illustrated in FIG. 1 with regions of very low resistivity P-type silicon material extending through the emitter region and into the base region as illustrated by the dashed lines 23 as shown in FIG. 4. The low resistivity is a result of the use of aluminum as the metal which is deposited upon the surface of the semiconductor body 10. This aluminum is, as is well known in the art, an active impurity of the P-type which is capable of doping semiconductor material. If a lower resistivity than that which is possible by utilizing aluminum is desired, or if a metal other than aluminum is deposited from the source 15 as hereinabove described upon the surface of the semiconductor body 10, a material may be added which is a P-type active impurity, for example, gallium, indium, aluminum, or boron from column III, of the periodic table as arranged according to Mendeleev. In the alternative, if the method of the present invention is being carried out upon a P-N-P transistor, N-type active impurities such as phosphorous, arsenic, antimony, or bismuth from column V of the periodic table may be selected and added to the material which is deposited upon the surface of the transistor 10. Particularly, aluminum which is heavily doped with one of the N-type active impurities may be deposited upon the surface of a P-N-P transistor and the remaining steps of the method of the present invention carried out to provide the desired contact.

Since as hereinabove described, a very low resistivity region of P-type semiconductor material extends into a P-type base region, an ohmic contact occurs between the

low resistivity material and the original base region 12 of the transistor 10.

This contact would be constituted by that portion of the dashed line 23 which extends into the base region 12 as illustrated by the dashed portion 24 thereof. Since the emitter region 11 is of N-type conductivity and the low resistivity region is of P-type conductivity, a rectifying contact is established between these two areas.

It is, therefore, seen that to provide the desired contact the low resistivity region that is formed must have the same conductivity type as the base region and opposite conductivity type to that of the emitter region.

Under certain circumstances during the practice of the method of the present invention, it is possible that the molten aluminum may penetrate completely through the base region and contact the collector region. If this should occur, the resulting device would be operative since a rectifying contact would occur between the low resistivity P-type region and the N-type collector region of the transistor. For optimum results, however, this should not be allowed to occur since it will decrease the amount of contact between the low resistivity region and the base region of the transistor, thereby decreasing the amount of voltage which can be supported by the contact structure.

In accordance with the foregoing steps of the method of the present invention, a large amount of contact has now been provided to the base region and is brought to the emitter surface of the transistor.

The structure of a transistor in accordance with the present invention as hereinabove described may be illustrated schematically as shown in FIG. 9 to which reference is hereby made. As therein shown the transistor includes an N-type emitter region 41, a P-type base region 42 and an N-type collector region 43. A junction 46 separates the base region 42 and the collector region 43. A junction also separates the base and emitter regions but it may be viewed in a slightly different manner. It should be recalled that the metal which is applied to the surface of the emitter region is caused to penetrate through the emitter region and into the base region to thereby provide a base contact at the surface of the device. This may also be looked upon as causing the base region 42 to extend in an upward direction through the emitter region 41 and to the surface of the device as shown at 44. The base region 42 therefore includes upwardly extending portions 44 as shown in FIG. 9. Such a structure clearly increases the contact surface between the emitter and base regions. The junction separating the emitter and base region is then as shown at 47. The extended portions 44 of the base region 42 are heavily doped and of low resistivity as above described which is designated by the P+ appearing therein. The P+ portion extends into the base region 42 as shown by dashed lines 45 to accomplish the desired contact therewith. In operation of a device of this type a slightly higher barrier will exist between the N region 41 and the P+ portion 44 of the emitter-base junction than between the N region 41 and the P-type main portion of the base.

Referring now more particularly to FIG. 5, there is illustrated the structure of FIG. 4 and in addition a layer of insulative material 31 is provided upon the aluminum rich alloy material 21 extending above the surface of the emitter region 11 of the transistor 10. As is illustrated in FIG. 5, this region is in the physical configuration of a protrusion above the surface of the transistor.

In accordance with the preferred embodiment of the present invention where aluminum is evaporated upon a silicon transistor, this insulative layer may be aluminum oxide. The aluminum oxide layer may be provided by carrying out a chemical treatment such as the well-known step of anodizing. This comprises the chemical treatment of the aluminum rich protrusion by immersing at least those portions of the semiconductor body bearing

the protrusions into a chemical bath consisting of approximately 15%–18%, by weight, sulphuric acid and the remainder water and having a temperature of between 74–82° F. for a period of time of approximately 20–35 minutes. By so doing, an aluminum oxide layer having a thickness of between approximately .0002 to .0005 inch will be formed upon the aluminum rich protrusion extending above the surface of the transistor 10. This aluminum oxide layer operates as an insulative layer of material over the protrusion.

When materials other than aluminum are utilized in order to form the base electrode to the transistor 10, the insulative layer may be provided in other manners. For example, an insulating material may be applied which completely covers the metallic protrusions extending above the surface of a semiconductor body. Such insulating material may be applied for example, through a mask, by painting, or other well known methods.

After the formation of the insulative layer such as the aluminum oxide layer 31 of FIG. 5, the next step in the method of the present invention is to provide an electrically conductive layer of material upon the exposed emitter portions of the transistor 10. Such a layer of material is as illustrated in FIG. 6. The electrically conductive material which is illustrated at 32 in FIG. 6, may be applied to the emitter region 11 of the transistor 10 by evaporating the material 32 upon substantially the entire surface of the semi-conductive body including the protrusions having the insulative material 31 thereover. Any suitable material may be utilized to provide the layer 32 which is electrically conductive and which will provide good ohmic contact to the surface of the emitter region 11. The semiconductor body is preferably heated during this evaporation. In the alternative, this layer of material 32 may be applied upon the surface by means well known to the art other than evaporating such as electroless plating, chemical reduction, and the like. Types of material which may be utilized and which meet the requirements for the emitter contact material 32 are for example, silver, gold, nickel, copper, and the like, or combinations thereof.

After the formation of the emitter electrode as illustrated in FIG. 6, the only step remaining to provide a completed transistor is the attachment of the electrical leads to the various portions of the transistor. This is as illustrated in FIG. 7. Ohmic contacts are made as illustrated at 53 to the collector region, at 54 to the emitter region, and at 55 to the base region. These ohmic contacts may be made by any well-known method such as thermo-compression bonding, soldering, or the like. As noted, in order to make the base lead 55 contact the base electrode a portion of the material 32 which has been applied in order to form the emitter electrode, together with a corresponding portion of the underlying insulative material 31, must be removed from one of the protrusions 21 in order to allow contact to be made thereto. This may be accomplished by abrading that portion or in the alternative, by applying a small mask to the desired area prior to the deposition of the materials 31 and 32.

It will be noted that the spacing between the emitter and the base electrodes is exceedingly close and is determined only by the thickness of the insulative layer 31 which is applied as illustrated in FIG. 5. Therefore, spacing between emitter and base electrodes of approximately .0002 inch is readily accomplished in accordance with the method of the present invention, thereby providing a transistor which will give optimum results.

Referring now to FIG. 8, there is illustrated a body 33 of P-type semiconductor material which may be used as a resistor or the like. Contacts to portions of the body 33 have been made by alloying a metal thereto as hereinabove described and as illustrated at 34 to provide a region of like conductivity type. The alloying has provided ohmic contact to the body 33 as illustrated by dashed lines 37. An insulative layer of material 35 is

provided over the protrusions 34 and may be aluminum oxide. A layer 36 of conductive metal is then placed over the entire surface of the body 33 including the insulative oxide layer to provide electrical contact directly to body 33. Such a configuration provides contact to very closely spaced portions of the body, the contacts provided by the alloy 34 and the metal layer 36 being separated by the insulative layer 35. Leads may then be applied to the alloy region 34 and to the conductive metal layer 36 as above described to provide the completed device.

There has been thus disclosed a method for making a device having closely spaced electrodes and there is as well disclosed a transistor and a semiconductor body having closely spaced electrodes on at least one surface thereof.

What is claimed is:

1. The method of providing closely spaced contacts upon at least one surface of a body, said method comprising the steps of: applying a contact to one surface of a body; providing a layer of insulative material upon said contact; applying a layer of electrically conductive material upon said one surface and over said insulative layer; removing a predetermined portion of said layer of electrically conductive material and of said insulative layer to expose a surface of said contact; and, ohmically bonding an electrical lead to said exposed surface of said contact.
2. The method of providing closely spaced contacts upon at least one surface of a semiconductor body, said method comprising the steps of: alloying an electrically conductive material with at least a portion of one surface of a semiconductor body, forming a layer of insulative material only upon that portion of said alloyed material extending above said one surface; and applying a layer of electrically conductive material upon said surface and over said insulative layer.
3. The method of providing closely spaced contacts upon at least one surface of a semiconductor body, said method comprising the steps of: alloying aluminum with at least a portion of one surface of a semiconductor body, forming a layer of aluminum oxide upon said alloy, and applying a layer of electrically conductive material upon said surface and over said oxide.
4. The method of providing closely spaced contacts upon one major surface of a semiconductor body, including first and second regions of opposite conductivity type separated by a P-N junction, said method comprising the steps of: applying a solvent metal to a predetermined portion of said surface; heating the combination to cause said solvent metal to penetrate through said first region and into said second region; cooling the combination to provide an area of said solvent metal at said surface and an ohmic contact with said second region and a rectifying contact with said first region; providing an insulative metallic composition upon said area of said solvent metal; and applying a layer of electrically conductive material upon substantially the entire area of said surface.
5. The method of providing closely spaced electrodes for a semiconductor body containing a P-N junction, said method comprising the steps of: providing a semiconductor body having at least a region of one conductivity type separated from a region of the opposite conductivity by a P-N junction; applying a solvent metal containing conductivity type determining atoms of said opposite conductivity type to a predetermined portion of said one conductivity type region of said semiconductor body, heating the combination to a temperature to cause said solvent metal to penetrate through said one conductivity type region and into said opposite conductivity type region; cooling the combination to provide an area consisting predominantly of said solvent metal upon said semiconductor body; providing an insulative oxide layer upon said solvent metal area; and depositing a layer of

electrically conductive metal upon said one conductivity type region of said semi-conductor body.

6. The method of providing closely spaced contacts upon one major surface of a semiconductor body, including first and second regions of opposite conductivity type separated by a P-N junction, said method comprising the steps of: applying aluminum to a predetermined portion of said surface; heating the combination to cause said aluminum to penetrate through said first region and into said second region while retaining an area consisting predominantly of aluminum at said surface; cooling the combination; providing a layer of aluminum oxide on said area of aluminum; and applying a layer of electrically conductive metal upon said surface and over said aluminum oxide.

7. The method of providing close spaced emitter and base electrodes on N-P-N transistors comprising the steps of: providing an N-P-N transistor having emitter, base, and collector regions; depositing a layer of aluminum upon predetermined portions of the emitter region of said transistor; heating the combination to a temperature above the eutectic temperature of said transistor and said aluminum to cause said aluminum to dissolve a portion of said transistor; maintaining said temperature above the eutectic temperature for a time sufficient to permit said aluminum to penetrate into said transistor and at least contact said base region; cooling the combination to provide an area on a portion of said emitter region consisting predominantly of aluminum; anodizing said area of aluminum to provide a layer of aluminum oxide thereupon having a thickness of the order of 0.2 mil; depositing a layer of electrically conductive metal upon said emitter region including said aluminum area; and attaching leads to said aluminum area and said metal layer to provide base and emitter leads, respectively for said transistor.

8. The method of providing closely spaced contacts upon one major surface of a silicon semiconductor body including first and second regions of opposite conductivity type separated by a P-N junction, said method comprising the steps: applying aluminum to a predetermined portion of said surface of said silicon semiconductor body; heating the combination to a temperature exceeding the aluminum-silicon eutectic temperature to cause the aluminum to penetrate through said region and into said second region; cooling the combination to provide an area consisting predominantly of aluminum at said surface; providing a layer of aluminum oxide on said aluminum area; and applying a layer of electrically conductive metal to said surface and over said aluminum oxide.

9. The method of providing closely spaced emitter and base contacts upon one major surface of a silicon transistor housing first and second regions of N-type conductivity separated by an intermediate region of P-type conductivity, said method comprising the steps of: providing a mask adapted to expose a predetermined area adjacent said surface of said silicon transistor; vapor depositing aluminum through said mask and upon said surface of said silicon transistor; heating the combination to a temperature exceeding the silicon-aluminum eutectic temperature to cause the aluminum to penetrate through said first N-type region and into said intermediate P-type region; cooling the combination to provide an area consisting predominantly of aluminum upon said surface of said silicon transistor; treating said transistor to provide a layer of aluminum oxide upon said aluminum area; and depositing an electrically conductive layer of metal upon said surface and over said aluminum area.

10. The method of providing closely spaced emitter and base electrodes upon one major surface of a silicon transistor having N-type emitter and collector regions separated by a P-type base region, said method comprising the steps of: applying a photo emulsion to said surface of said silicon transistor; exposing a predetermined portion of said emulsion; removing the unexposed portion

of said emulsion from said surface; vapor depositing aluminum upon said surface of said silicon transistor; etching said transistor to remove that portion of aluminum which covers said exposed emulsion along with said emulsion; heating said transistor and said aluminum to a temperature exceeding the silicon-aluminum eutectic temperature to cause the aluminum to penetrate through the emitter region and into the base region; cooling the combination to provide an area consisting predominantly of aluminum upon said surface and to provide an ohmic contact with said base region and a rectifying contact with said emitter region; treating at least said surface to provide a layer of aluminum oxide upon said area of aluminum; and depositing a layer of electrically conductive metal upon said surface and over said aluminum area.

11. The method of providing closely spaced contacts upon at least one surface of a semiconductor body, said method comprising the steps of: molecularly bonding an electrically conductive material to a predetermined surface portion of a semiconductor body forming a layer of insulative material upon said electrically conductive material, and applying a layer of electrically conductive material upon the surface of said semiconductor body and over said insulating layer.

12. The method of providing closely spaced contacts upon at least one surface of a semiconductor body, said method comprising the steps of: alloying an electrically conductive material with at least a portion of one surface of a semiconductor body, forming a layer of insulative material only upon that portion of said alloyed material extending above said one surface, applying a layer of electrically conductive material upon said surface and over said insulative layer, removing a predetermined portion of said layer of electrically conductive material and of said insulative layer to expose a surface portion of said alloyed electrically conductive material, and bonding an electrical lead in ohmic contact with said exposed surface portion of said electrically conductive material.

13. The method of providing closely spaced contacts upon at least one surface of a semiconductor body, said method comprising the steps of: alloying aluminum with at least a portion of one surface of a semiconductor body, forming a layer of aluminum oxide upon said alloy, applying a layer of electrically conductive material upon said surface and over said oxide, removing a predetermined portion of said layer of electrically conductive material and of said layer of aluminum oxide to expose a surface portion of said alloyed aluminum, and bonding an electrical lead in ohmic contact with said exposed surface portion of said alloyed aluminum.

14. The method of providing closely spaced contacts upon one major surface of a semiconductor body, including first and second regions of opposite conductivity type separated by a P-N junction, said method comprising the steps of: applying a solvent metal to a predetermined portion of said surface; heating the combination to cause said solvent metal to penetrate through said first region and into said second region; cooling the combination to provide an area of said solvent metal at said surface and an ohmic contact with said second region and a rectifying contact with said first region; providing an insulative metallic composition upon said area of said solvent metal; applying a layer of electrically conductive material upon substantially the entire area of said surface; removing a predetermined portion of said layer of electrically conductive material and of said insulating metallic composition to expose a predetermined surface portion of said solvent metal; and, bonding an electrical lead in ohmic contact with said exposed surface portion of said solvent metal.

15. The method of providing closely spaced contacts upon one major surface of a semiconductor body, including first and second regions of opposite conductivity type separated by a P-N junction, said method comprising

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the steps of: applying aluminum to a predetermined portion of said surface; heating the combination to cause said aluminum to penetrate through said first region and into said second region while retaining an area consisting predominantly of aluminum at said surface; cooling the combination; providing a layer of aluminum oxide on said area of aluminum; applying a layer of electrically conductive metal upon said surface and over said aluminum oxide; removing a predetermined portion of said layer of electrically conductive metal and of said aluminum oxide to expose a surface portion of said aluminum; and,

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bonding an electrical lead in ohmic contact with said exposed surface portion of said aluminum.

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