Nov. 18, 1958 G. C. RICH 2,861,228

SEMI-CONDUCTOR UNIT

Filed May 29, 1953

Fig. 1

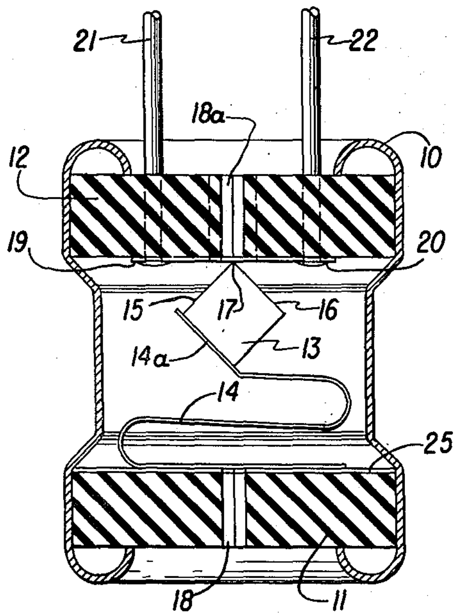


Fig. 2

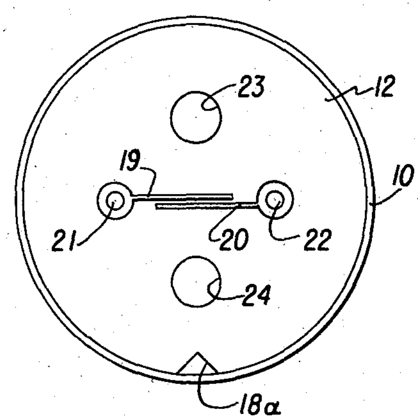


Fig. 3

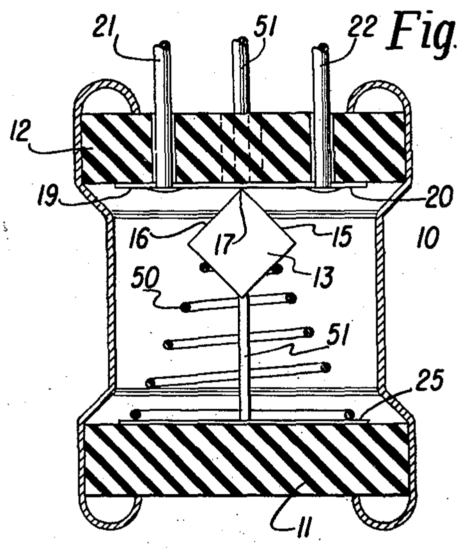
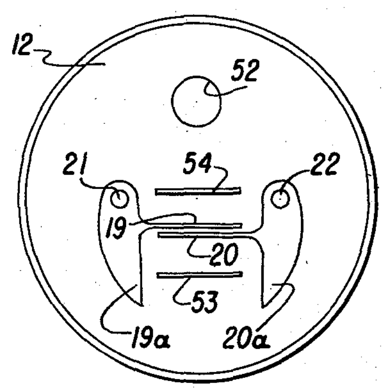


Fig. 4



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SEMI-CONDUCTOR UNIT

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The present invention relates to semi-conductor circuit elements, and more particularly to an improved transistor unit of the point contact type and to a method for manufacturing such a unit.

The point contact type of transistor usually comprises a crystal of semi-conductive material such as germanium or silicon that has been treated with impurities of the donor or acceptor types to form an N or P type semi-conductor. The transistor includes a pair of electrodes known respectively as the emitter and collector which are in point contact with one surface of the crystal. A metal block or tab is also provided and affixed to another surface of the crystal to constitute what is termed a base electrode for the assembly.

The emitter and collector electrodes in the prior art point contact transistor usually take the form of a pair of fine wires or thin metallic ribbons. These wires are supported by the transistor casing to extend perpendicularly to a surface of the crystal with pointed ends in point contact with that surface. These wires have a diameter of the order of .002" and their points are spaced about .002" on the face of a crystal having cubical dimensions of the order of .032" on a side. Such electrodes require a high degree of manual dexterity in their assembly to mount and achieve proper placement thereof due to their microscopic size and spacing. Since these prior art assemblies require visual adjustment and a high degree of manual proficiency, their construction is complicated and expensive and it is difficult to maintain uniformity in the product when the units are fabricated on a mass production basis.

It is an object of the present invention to provide an improved point contact type transistor assembly in which the collector and emitter electrodes are fabricated in a simplified manner by mechanical rather than manual techniques for accurate dimensioning and positioning of the electrodes.

A further object of the invention is to provide such an improved transistor unit that may be produced on a mass production basis and which is constructed so that units so produced have uniform characteristics and are not subject to variations from one unit to the next.

Another object of the invention is to provide such an improved transistor unit that may be produced at a low cost and yet in which the various components are precisely positioned and have a high degree of mechanical stability.

A still further object of the invention is to provide an improved process for obtaining precisely spaced point contact electrodes in a transistor of relatively small size.

A feature of the invention is the provision of a circuit element in the form of a transistor unit in which the emitter and collector electrodes are thin, precisely spaced, metallic coatings on an insulating disc, and in which the disc is placed over the line of juncture between two inclined faces of a semi-conductive crystal with the aforementioned metallic coatings traversing the line of juncture at spaced points along the line and in point contact therewith.

Another feature of the invention is the provision of such a circuit element in which pads are also provided on the disc adjacent the metallic coatings to assure proper contact of the line of juncture of the crystal with the metallic deposits.

Yet another feature of the invention is the provision of an improved process whereby the emitter and collector electrodes of a transistor are obtained by photo engraving with precise minute dimensions and accurate minute spacing.

A further feature of the invention is the provision of such a transistor unit in which the aforesaid insulating disc and transistor are supported and aligned in a simple unitary casing in such a manner that the unit may be easily assembled, and is rugged and exhibits a high degree of mechanical stability.

The above and other features of the invention which are believed to be new are set forth with particularity in the appended claims. The invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description when taken in conjunction with the accompanying drawing in which:

Figure 1 shows a complete transistor assembly constructed in accordance with the invention;

Figure 2 shows a component of the improved transistor unit of the invention;

Figure 3 shows a complete transistor unit constructed in accordance with a modification of the invention; and

Figure 4 shows a component of the modification of Figure 3.

The present invention is directed to a transistor element which comprises a block of semi-conductive material having a pair of inclined faces forming a line of juncture therebetween. A supporting member is provided having a surface facing the aforesaid line of juncture, and a pair of metallic coatings is disposed on the aforementioned surface of the supporting member. The metallic coatings are mutually displaced and insulated one from the other, and these coatings traverse and contact the aforesaid line of juncture at spaced points along such line.

Referring now to Figures 1 and 2, one transistor unit of the invention comprises a casing in the form of a metallic cylinder **10** which has a suitable shape to support a disc-like insulating base **11** at one end and a disc-like insulating member or button **12** at the other. A semi-conductive crystal **13**, such as a germanium crystal, is supported within the casing between members **11** and **12** by means of a resilient spring **14**. The crystal has a pair of inclined faces **15**, **16** with a line of juncture **17** therebetween, and resilient spring **14** urges the line of juncture **17** upwardly against the surface of member **12** facing such line of juncture. The interior of the metallic cylinder **10** which contains crystal **15** is preferably filled with a potting compound.

Base **11** has a notch **18** formed in its periphery which mates with a corresponding deformed section of cylinder **10** for aligning purposes. Disc **12** has a similar notch **18***a* formed in its periphery which mates with a protrusion in cylinder **10** for the same reason.

The resilient spring **14** not only resiliently biases the crystal against the lower surface of disc **12**, but also forms a contact to the base electrode of crystal **13**. The base electrode is formed by the upper end **14***a* of the spring which is affixed to the crystal.

As shown in Figure 2, the surface of disc **12** facing the aforesaid line of juncture **17** of crystal **13** has a pair of bar-shaped metallic elements **19**, **20** formed thereon in mutually spaced parallel relation and insulated one from the other. The metallic elements **19** and **20** are so positioned that when member **12** is assembled in the transistor unit, these elements traverse the aforesaid line of juncture 17 of crystal 13 and contact the crystal at spaced points along the line of juncture. In this manner, metallic elements 19 and 20 respectively form the collector and emitter electrodes for the transistor, and electrical connection is made to these respective elements by wire leads 21, 22 extending through disc 12. Disc 12 also has a pair of apertures 23, 24 therein through which the aforementioned potting compound may be introduced into the interior of the transistor unit.

In accordance with one aspect of the invention, elements 19 and 20 are formed on insulating disc 12 by a photo-engraving technique. The disc has a diameter of the order of .250" and it is desirable that the elements 19 and 20 be about .0005" wide and separated by .001" or less. The use of photo-engraving allows the elements to be drawn about fifteen times normal size and a negative made of the drawing. The negative then may be reduced to the actual size of the disc and elements with all dimensions precisely and rigidly retained.

One process by which elements 19 and 20 may be formed on disc 12 is as follows. A board is provided having a copper coating of, for example, 1.0 mil on at least one surface. Copper clad insulating boards are obtainable commercially and the discs can be formed in quantities from such boards. The copper-clad board is first cleaned with pumice and washed. The board is further cleaned with muratic acid and salt. A nonorganic photo-sensitive resist is then applied over the copper surface of the board. This resist may, for example, be composed of polyvinylalcohol. The resist is dried by spinning the board at approximately 55 R. P. M. over a sink with the coated surface facing downwardly, and then spinning the board over a hot plate for about two minutes. A contact print is made by exposing the portions of the resist corresponding to elements 19 and 20 through an appropriate negative for about two minutes about 7½" from a 275 watt sun lamp. The negative is made by photographing an enlarged drawing of the elements and reducing the photograph to the minute dimensions desired. The resist is then developed by water under a faucet for thirty sections, and the exposed portions of the resist are hardened by immersing the board in a solution of four ounces of chromic acid and one ounce of "Duponul" in one gallon of water. The board is then rinsed and heated to 400° on a hot plate. The unexposed resist is then removed by a solution of one ounce of muratic acid and a pinch of salt in a pint of water. The copper surface of the board uncovered by the removal of the unexposed resist is etched away by a ferric chloride anhydrous ($FeCl_3$) solution. The exposed resist is then removed in any known manner leaving the elements 19 and 20 bonded to the board. The desired shaped disc 12 is then punched from the board.

In this manner, the two elements 19 and 20 are formed on the extremely small disc, these elements having accurate minute dimensions and spacing. These assemblies can be conveniently mass produced, each being held to close tolerances for uniform characteristics in the resulting transistor units.

Base 11 may similarly be coated with a copper or other metallic layer 25 bonded to its upper surface to facilitate electrical connection to resilient spring 14 and, thence, to base electrode 14*a*. Spring 14 (and its end 14*a* forming the base electrode) may be composed, for example, of Phosphor bronze or beryllium copper which exhibits the desired electrical and resilient characteristics. The bottom of spring 14 is soldered to a coating 25, and the coating makes electrical contact with metallic cylinder 10 so that the cylindrical casing itself is connected to the base electrode 14*a* of crystal 13 and suitable electrical connection can be made to the casing to complete the transistor circuit.

The following dimensions are given for the transistor unit of the invention merely by way of example and are not intended to limit the invention in any way.

	Inches
Diameter of cylinder 10	.250
Height of cylinder 10	.300
Thickness of cylinder walls	.005
Thickness of discs 11 and 12	.065
Width of metallic elements 19, 20	.0005
Separation of metallic elements 19, 20	.001
Length of metallic elements 19, 20	.100

The embodiment of the invention shown in Figures 3 and 4 is similar in many respects to that of Figures 1 and 2 and like elements have been indicated by like numerals. In the latter embodiment, a conical shaped resilient coil spring 50 is used to urge crystal 13 against the bottom surface of disc 12, and spring 50 constitutes a base electrode for the crystal and a connection thereto from the coating 25 on disc 11. A lead 51 is soldered or otherwise affixed to coating 25 and extends through an aperture 52 in disc 12 to constitute a connection to the base electrode.

Metallic elements 19 and 20 have enlarged area portions 19*a* and 20*a* adjacent their respective connections to leads 21 and 22 to increase this current carrying and heat dissipating capacity. Moreover, a pair of pads 53 and 54 is provided on each side of elements 19 and 20 and spaced, for example, .020" from the respective elements and parallel thereto. These pads may be in the form of copper bars deposited on disc 12 during the deposition of elements 19 and 20. The purpose of the pads is to maintain the edge 17 of the crystal across the elements and prevent that edge from tilting and contacting only one of the elements. That is, these pads provide an electrically isolated, but mechanically integrated, cushion which implements uniform contact of the edge of the crystal with elements 19 and 20. The pads 53 and 54 also reduce any tendency of the edge of the crystal to slide along elements 19 and 20 due to the increased friction supplied thereby.

The invention provides, therefore, a transistor unit which is capable of being produced in large quantities, and which is so constructed that the transistor units so produced exhibit uniform characteristics from one unit to another. This is achieved since the collector and emitter electrodes 19 and 20 may be formed mechanically to have precise dimensions without need for manual skill in the placement of these electrodes as is the case when fine wires are used. Moreover the transistor unit of the invention may be assembled easily and cheaply since each and every component thereof may be manufactured mechanically and assembled with a high degree of facility.

The transistor unit of the invention utilizes relatively inexpensive component parts and, as mentioned above, may be assembled simply and economically, and this results in a finished unit of relatively low cost. In addition, the transistor unit of the invention has a high degree of mechanical stability and is small in size.

While particular embodiments of the invention have been shown and described, modifications may be made and it is intended in the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

I claim:

1. A transistor unit including in combination, a semi-conductive crystal having a pair of inclined faces forming a line of juncture therebetween, an insulating panel disposed parallel to the aforesaid line of juncture and having a flat surface facing such line, and a pair of etched thin elongated metallic means on the aforesaid surface of said insulating panel in spaced parallel relation and insulated one from the other, and means for resiliently maintaining said semi-conductive crystal in contact with each of said pair of etched thin elongated metallic means.

2. A transistor unit including in combination, a semi-conductive crystal unit having a pair of inclined faces forming a line of juncture therebetween, a cylindrical-

shaped casing, a disc-like insulating member supported in said casing parallel to the aforesaid line of juncture and having a flat surface facing such line, a pair of thin elongated metallic coatings bonded to the aforesaid surface of said insulating member in mutually spaced, parallel relation and insulated one from the other, said metallic coatings traversing the aforesaid line of juncture, a disc-like base member supported in said casing parallel to said first mentioned disc-like member with said crystal unit disposed between said disc-like members, and a resilient spring means connected to said crystal unit and to said disc-like base member for urging said crystal unit against the aforesaid surface of said disc-like insulating member so that said metallic coatings contact the aforesaid line of juncture at spaced points along said line.

3. A transistor unit including in combination, a semi-conductive crystal having a pair of inclined faces forming a line of juncture therebetween, a tubular-shaped casing, a disc-shaped insulating panel supported in said casing parallel to the aforesaid line of juncture and having a surface facing such line, a pair of thin elongated metallic coatings bonded to the aforesaid surface of said insulating panel in mutually spaced, parallel relation and insulated one from the other, said metallic coatings traversing the aforesaid line of juncture, a disc-like insulating base panel supported in said casing parallel to said first mentioned disc-like panel with said crystal disposed between said panels, a metallic coating bonded to the surface of said base panel facing said crystal, and a resilient spring connected to said crystal and to said base panel to constitute an electrode for said crystal and to bias said crystal against the aforesaid surface of said first mentioned disc-like insulating panel so that said metallic coatings contact the aforesaid line of juncture at spaced points along said line.

4. A transistor unit including in combination, a semi-conductive crystal having a pair of inclined faces forming a line of juncture therebetween, a tubular-shaped casing having internal aligning protuberances, a disc-shaped insulating panel supported in said casing parallel to the aforesaid line of juncture and having a surface facing such line, said panel also having a peripheral aligning notch therein engaging one of the aforesaid protuberances of said casing, a pair of thin elongated metallic coatings bonded to the aforesaid surface of said insulating panel in mutually spaced, parallel relation and insulated one from the other, said metallic coatings traversing the aforesaid line of juncture, a disc-like insulating base panel supported in said casing parallel to said first mentioned disc-like panel with said crystal disposed between said panels, said base panel having a peripheral aligning notch therein engaging one of the aforesaid protuberances of said casing, a metallic coating bonded to the surface of said base panel facing said crystal, a resilient spring connected to said crystal and to said base panel to constitute an electrode for said crystal and to bias said crystal against the aforesaid surface of said first mentioned insulating panel so that said metallic coatings contact the aforesaid line of juncture at spaced points along said line, and potting compound completely filling said casing.

5. A circuit element including in combination, a block of semi-conductive material having a pair of inclined faces forming a line of juncture therebetween, a supporting member having a surface facing the aforesaid line of juncture, at least one electrically conductive element disposed on the aforesaid surface of said supporting member, said metallic element traversing the aforesaid line of juncture and in contact therewith, and at least one pad disposed on the aforesaid surface adjacent said electrically conductive element for assuring contact of the aforesaid line of juncture with said element.

6. A circuit element including in combination, a block of semi-conductive material having a pair of inclined faces forming a line of juncture therebetween, an insulating supporting member having a flat surface facing the aforesaid line of juncture, a pair of elongated metallic elements disposed on the aforesaid surface of said insulating supporting member in spaced parallel relation, said metallic elements traversing and contacting the aforesaid line of juncture at spaced points along said line, and a pair of pads disposed on the aforesaid surface of said supporting member adjacent said metallic elements on each side thereof for assuring contact of the aforesaid line of juncture with each of said metallic elements.

7. A circuit element including in combination, a block of semi-conductive material having a pair of inclined faces forming a line of juncture therebetween, an insulating supporting member having a flat surface facing the aforesaid line of juncture, a pair of elongated metallic elements formed on the aforesaid surface of said insulating supporting member in spaced parallel relation, said metallic elements traversing and contacting the aforesaid line of juncture at spaced points along said line, and a pair of elongated metallic pads formed on the aforesaid surface of said supporting member adjacent said metallic elements and parallel thereto on each side of said metallic elements, said pads assuring contact of the aforesaid line of juncture with each of said metallic elements.

8. A method for producing a semi-conductive unit which comprises, providing a flat insulating supporting member, obtaining an enlarged representation of a pair of electrically conductive elements to be disposed on a surface of said supporting member, said representation having dimensions substantially larger than the dimensions of said supporting member, obtaining a photographic negative of said representation having dimensions reduced to correspond to those of said supporting member, utilizing said negative to dispose a pair of spaced electrically conductive elements on said supporting member, providing a block of semi-conductive material having a pair of inclined faces forming a line of juncture therebetween, and supporting said block with its line of juncture facing said surface of said supporting member traversing said pair of electrically conductive elements and in contact therewith.

9. A method for producing a transistor which comprises, providing a flat insulating supporting disc having a diameter of the order of .250″, obtaining an enlarged representation of a pair of electrically conductive elements to be disposed on a surface of said disc, said representation having dimensions substantially larger than the diameter of said disc, obtaining a photographic negative of said representation having dimensions reduced to correspond to those of said disc, and utilizing said negative to dispose a pair of electrically conductive elements on said disc each having a length of the order of .100″, a width of the order of .0005″, and spaced one from the other to the order of .001″ and providing a single semi-conductor element in engagement with said pair of electrically conductive elements.

10. A method for producing a semi-conductor device which comprises, providing a flat metal member, obtaining an enlarged representation of a pair of electrically conductive elements to be disposed on the surface of said metal member, obtaining a photographic negative of said representation, utilizing said negative to provide a pair of spaced electrically conductive elements from said metal member, providing a semi-conductor element in contact with said pair of spaced electrically conductive elements, and providing supporting and encasing means for said semi-conductor device.

11. A method for producing a semi-conductive device which comprises, providing a supporting member, providing a flat metallic layer thereon, obtaining an enlarged representation of a pair of electrically conductive elements, obtaining a photographic negative of said representation having dimensions reduced to a desired value,

and using said negative to form a pair of spaced electrically conductive elements in said metallic layer on said supporting member, providing a unit of semi-conductive material with a contact edge thereon, and supporting said unit on said device with said contact edge traversing said pair of electrically conductive elements and in engagement therewith.

12. In a semi-conductor device which is small in size and must be assembled in precision fashion, the combination with a semi-conductor element supported within an enclosing housing, contact leads extending out of said housing, and means supported within said housing for electrical connection with said contact leads and with said semi-conductor element, said means comprising a pair of etched metal electrodes originally laid out in large size and brought down to a very much smaller size by photographic process for use in the device, with each of said pair of etched metal electrodes being in electrical connection with a corresponding one of said contact leads.

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