Dec. 1, 1953 G. H. RODGERS, JR 2,661,448

TRANSFER RESISTOR AND METHOD OF MAKING

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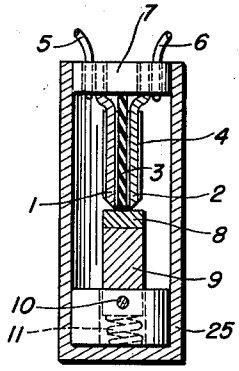



FIG. 1

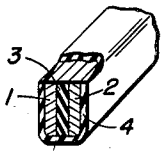



FIG. 2

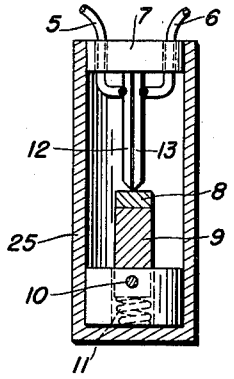



FIG. 3

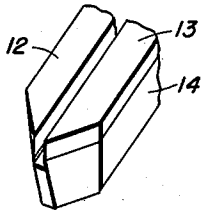



FIG. 4

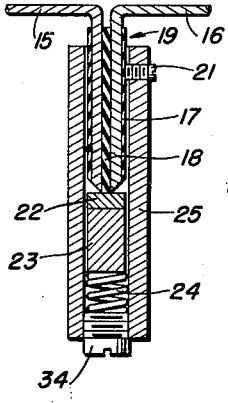



FIG. 5

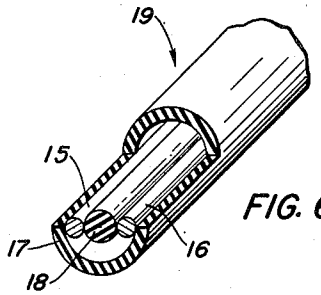



FIG. 6

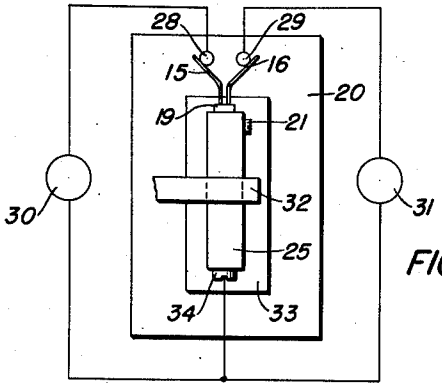



FIG. 7

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## TRANSFER RESISTOR AND METHOD OF MAKING

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6 Claims. (Cl. 317—235)

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This invention pertains to the use of the variable semi-conducting properties of germanium crystals as electrical amplifiers. It particularly pertains to the manufacture of a device which takes advantage of those properties.

Amplifying properties are exhibited by a germanium crystal if it is arranged so that two small electrodes are mounted so as to touch one face of the crystal with a separation of the order of two or three one-thousands of an inch and a third contact is made with the base of the crystal. The amplification is apparent between a potential applied to the crystal between the base of the crystal and one electrode (emitter) and a current flow in a circuit comprising the other electrode (collector) and the base of the crystal. Such an arrangement or device has been denoted a transfer resistor or "transistor."

In the past, the fabrication of satisfactory devices of this type has been complicated because two characteristics—spacing of the collector and emitter electrodes, and the pressure exerted by them on the crystal—are critical. Therefore, it has been necessary to employ a large amount of highly skilled labor in their manufacture, and to perform the critical adjustments under the microscope. Furthermore, these precision adjustments imposed a lower limit upon the practicable size of the transfer resistor which would otherwise not have been imposed. The germanium crystal itself is normally of the order of $\frac{1}{16}$ inch on a side and the collector and emitter electrodes need be no larger than one hundredth of an inch in diameter. Yet because of the method of fabrication heretofore used, it has been impracticable to attain the small size indicated by the above dimensions.

A further difficulty has been that the hand adjustment factor in each individual transfer resistor has prevented the attainment of uniformity of the final products. In other words, each individual transfer resistor fabricated and adjusted by hand had different performance characteristics than the others.

It is therefore an object of this invention to provide a transfer resistor which is relatively easy to fabricate on a large scale.

It is another object of this invention to provide a transfer resistor which can be made uniformly.

It is another object of this invention to provide a transfer resistor which requires a minimum of skilled labor for its fabrication.

It is another object of this invention to provide a method of fabrication of transfer resistors which eliminates tedious precision adjustments.

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It is a further object of this invention to provide a transfer resistor with fixed spacing between emitter and collector electrodes and with easily adjustable pressure by emitter and collector electrodes on the germanium crystal.

It is still a further object of this invention to provide a method and means for making transfer resistors of minimum size with a minimum of microscopic adjustment and skilled labor.

Other objects of invention will become apparent from the following description taken in connection with the accompanying drawings, in which

Fig. 1 is a view of a transfer resistor constructed according to this invention;

Fig. 2 is an enlarged partial view of a component of the device shown in Fig. 1;

Fig. 3 is a view of a modified form of the invention;

Fig. 4 is an enlarged partial view of a component of the device shown in Fig. 3;

Fig. 5 is a view of a second modification of the invention;

Fig. 6 is an enlarged detail view of a part of the device shown in Fig. 5; and

Fig. 7 is a plan view of the equipment used to assemble the device shown in Fig. 5.

Referring to Fig. 1 there is shown a cross-sectional view of a transfer resistor constructed according to this invention. Two small metallic conductors 1 and 2 are separated by an insulating strip 3, and covered by insulator 4 and are connected at one end to leads 5 and 6 in insulating block 7, and at the opposite end touch germanium crystal 8 held in mount 9 by set screw 10 and spring 11. Mount 9 and insulating block 7 are held in rigid relationship by tubular case 25.

Fig. 2 shows how conductors 1 and 2, which are the emitter and collector electrodes in the completed device, are fabricated so as to eliminate haphazard spacing and non-uniformity. Conductors 1 and 2, which may conveniently be of tungsten or Phosphor bronze, are cemented, molded, or laminated to strips of plastic insulation which form insulators 3 and 4 to separate and cover, respectively, the assembled electrode. This operation may be carried on to form indefinitely long continuous lengths of assembled electrode. When it is desired to fabricate a transfer resistor, it is necessary only to cut a short length of assembled electrode normal to its axis, and bevel the ends of conductors 1 and 2 as indicated in Fig. 1 by grinding the edges, the grinding being conducted on each side toward the point to leave a burr on the ends of the piece ex-

tending beyond the insulating material. The opposite end of the piece is uncovered and the two electrodes attached to leads in block 7. The end of insulator 3 fits firmly against block 7 where it can be cemented in place. Conductors 1 and 2 contact the face of germanium crystal 8 and, since they are separated by insulator strip, are held rigidly in a fixed spatial interrelationship. In order to improve contact between crystal 8 and the electrodes, it may be necessary to electroplate the ends of conductors 1 and 2 briefly, thereby extending them a small distance beyond the ends of insulator 3.

The amount of pressure exerted upon the crystal by the electrodes is controlled by spring 11 which is chosen to give the optimum pressure with a given electrode length and spacing between top and bottom of the transfer resistor. Since these factors can be kept constant using this method of fabrication, the problem of adjusting pressure is practically eliminated. Set screw 10 is provided to make the relationship between crystal and electrodes rigid.

Fig. 3 shows a somewhat modified form of the invention in which the electrodes are formed by plating a continuous strip of metal on a plastic or ceramic body. Electrodes 12 and 13 are formed by electroplating on strip 14, and by scratching a groove through the deposited metal to form the two substantially equal strips of metal. The formation of this element of the transfer resistor can be continuous and of indefinitely long lengths. When the transfer resistor is prepared, the appropriate length is cut and beveled, as shown in Fig. 4, in a plane normal to the plane of the plated material, and the plastic material is beveled slightly to bring the metallic points in contact with the germanium crystal. The same result may be achieved by brief electroplating as indicated in reference to Figs. 1 and 2.

Figs. 5 and 6 show a third embodiment of the invention. Two Phosphor bronze wires 15 and 16, .005–.02 of an inch in diameter, but preferably .010 of an inch in diameter, are inserted in a continuous rigid tube 17 separated by a thin separator 18 of uniform thickness. The wires are cemented firmly to the separator and rigid tube to form a continuous assembly, which is not unlike a pencil and will hereafter be denoted pencil 19, having two uniformly separated "leads" of Phosphor bronze which form the electrodes of the transfer resistor. The rigid tube may be of ceramic material, and the separator may be of Lucite.

Alternatively, the tube and electrodes may be brought together continuously by enameling two Phosphor bronze wires continuously, drying them, and bringing them together with only the thickness of the enamel separating them, and covering them by extruding them in a plastic coating material, such as a low-shrinkage modified polystyrene casting resin, to form a rigid integral shell. For the assembled transfer resistor shown in Fig. 5, pencil 19 is held in adjustable position in case 25 of the transfer resistor. A set screw 21 is provided to fix the pencil at optimum pressure against germanium crystal 22 supported on base 23 by spring 24 bearing against screw 34. Crystal 22 is attached to base 23 to make adjustment more convenient with screw 34.

To construct this embodiment of the invention the continuously formed pencil is sharpened by insertion in a rigid holding block and by turning and grinding it at an angle against a grinding wheel. The pencil is then cut in appropriate lengths normal to its longitudinal axis. The ends of the electrodes which are to contact the crystal may be slightly extended by electrolytic deposition upon them of platinum in potassium hydroxide to assure firmer contact with the crystal, but normally this is not necessary because grinding of the pencil point produces microscopic burrs which extend beyond the plastic or enamel insulating material. The pencil is then inserted into case 25 by means of the arrangement shown in Fig. 7. A flat plate 20 of insulating material mounts terminal posts 28 and 29 attached to resistance meters 30 and 31. Resistance meters 30 and 31 are also attached to metal clamp 32 which contacts the base of the germanium crystal either through case 25 or metal backplate 33. The unsharpened end of the pencil is stripped, exposing the bare Phosphor bronze wires. These are separated as shown in Fig. 7 and the point of the pencil is placed in the open end of the case 25 with the two stripped ends of Phosphor bronze wire against terminals 28 and 29. Case 25 is slowly brought up under clamp 32 until meters 30 and 31 read an equal amount, indicating equal pressure of the electrodes on the germanium crystal. Set screw 21 is then tightened to secure the relationship. A small drop of cement may be applied to pencil 19 and case 25 to further secure their rigid relationship. Set screw 34 in the opposite end of case 25 is then tightened until the optimum readings of meters 30 and 31 are secured. An additional drop of cement may be applied to set screw 34 to prevent accidental displacement from adjusted position. The entire assembly may then be dipped in plastic material, such as a low-shrinkage casting resin, to seal and secure the entire assembly.

There are thus provided transfer resistors and methods of making them which assure uniformity of product, ease of construction, simplicity, and versatility in size. Since the steps involved are principally mechanical, the transfer resistor may be made very small, being limited only by the minimum crystal and conductor sizes which, as pointed out hereinbefore, are not serious limitations.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the appended claims.

I claim:

1. A double electrode for germanium alloy crystal transfer resistor devices comprising two parallel conductors having uniform cross-sectional areas of .000005 to .00001 square inch, means for separating said conductors by from .001 to .005 inch and means for holding the aforesaid means in rigid assembly.

2. The method of making electrodes for a germanium alloy crystal transfer resistor comprising securing two similar electrical conductors to a binding and insulating strip of constant thickness and indefinite length to form a continuous double electrode, cutting said double electrode normal to its longitudinal axis into predetermined lengths and extending said electrical conductors by electrolytic deposition.

3. The method of making uniformly spaced collector and emitter electrodes for a transfer

resistor comprising rigidly attaching in parallel orientation and at predetermined distance apart two metallic conductors to a continuous insulating strip of indefinite length, cutting the resulting continuous assembly into predetermined lengths and extending said metallic conductors by the electrolytic deposition of metal on the cut ends of said conductor to thereby obtain collector and emitter electrodes.

4. The steps in making a transfer resistor comprising continuously applying a uniform film of enamel to two Phosphor bronze conductors of indefinite length, drying said enamel, and applying a plastic casting material to said conductors while parallel and adjacent to each other to thereby form a double electrode capable of reproduction with uniform internal spacing between conductors.

5. Electrical amplifying means comprising a crystal exhibiting semi-conductive properties, a tubular holder for said crystal adapted to allow freedom for translational motion of said crystal in one direction only, means for adjusting the position of said crystal in said holder while maintaining resilient pressure on it, a cylindrical member fitted within said holder in opposed position to said crystal containing two conductors adapted to contact said crystal at a predetermined distance apart, and means for holding said crystal and said cylindrical member rigidly in opposed position within said holder when said adjustment is completed.



6. A device as recited in claim 1 in which said conductors comprise metallic strips plated as a single metallic strip on an insulating strip and in which said means for separating said conductors is a scratch inscribed on said single metallic strip to thereby divide it into separate conductors.

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