

March 31, 1942.

H. L. B. GOULD ET AL

2,278,072

ELECTRICAL RESISTANCE DEVICE AND METHOD OF MANUFACTURE THEREOF

Filed June 3, 1939

FIG. 2

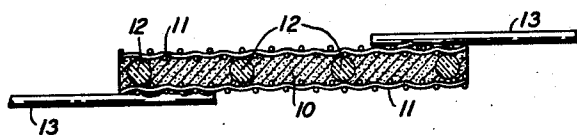


FIG. 1

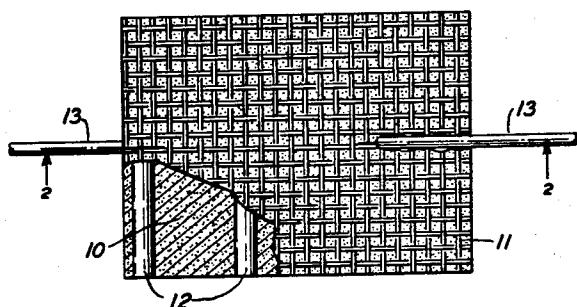


FIG. 3

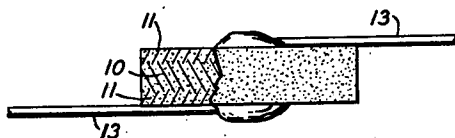


FIG. 4

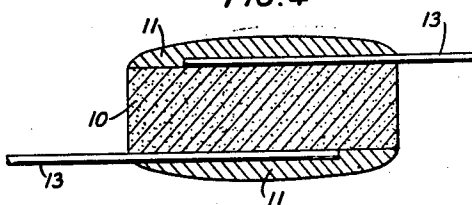


FIG. 5

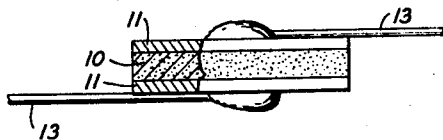
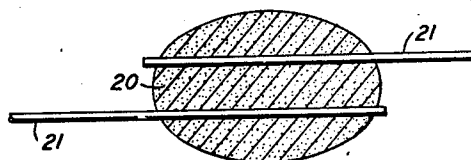


FIG. 6

INVENTORS: H. L. B. GOULD
B. A. KINGSBURY

BY

Walter C. Kiesel

ATTORNEY

XR

UNITED STATES PATENT OFFICE

2,278,072

ELECTRICAL RESISTANCE DEVICE AND METHOD OF MANUFACTURE THEREOF

Harold L. B. Gould, Towaco, and Burton A. Kingsbury, East Orange, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 3, 1939, Serial No. 277,126

7 Claims. (Cl. 201-76) 63

This invention relates to electrical circuit elements the resistance of which varies markedly with temperature. More particularly, this invention relates to resistance devices having a high positive temperature coefficient of resistance, and to methods of manufacturing such devices.

Resistance devices in which the resistance is highly sensitive to temperature are used as regulating and control elements in electric circuits. The so-called semiconductors, because of their high resistance-temperature coefficient and intermediate specific resistance values, have been employed considerably in this field. The resistance-temperature coefficient of semiconductive materials and resistors made therefrom have heretofore been found to be negative at ordinary temperatures.

The positive resistance-temperature coefficient characteristic of materials ordinarily classed as conductors is so small that such materials are inadequate for resistor units where a wide range of resistance variation is desired. For example, iron does not double in resistance for less than 70° C. rise in temperature at any point below 500° C.

One object of this invention is to produce resistance devices having a high positive temperature coefficient at relatively low temperatures, for example, temperatures between 0° and 100° C.

Another object of this invention is to obtain firm, uniform low resistance contact between the body of a resistor unit and electrodes therefor.

A further object of this invention is to assure uniform spacing of the electrodes in formed resistance devices.

Still another object of this invention is to increase the density and ruggedness of formed electrical resistance devices.

In one illustrative embodiment of this invention, an electrical resistance device comprises a body of a material having a positive temperature coefficient of resistance at relatively low temperatures, and electrodes attached to spaced portions of the body.

In accordance with one feature of this invention, the body of the resistance device is formed of an oxide of chromium, more particularly chromic oxide.

In accordance with another feature of this invention, the electrodes are made of metallic sheets or gauze intimately adhered to the body of the resistance device.

In accordance with a further feature of this invention, insulating spacers, such as glass rods,

are incorporated in the body of the resistance device to assure uniform spacing of the electrodes.

In accordance with still another feature of this invention, the formed resistance device is subjected to heat treatment to produce a dense rugged unit.

Other and further objects and features of the invention will be understood more fully and clearly from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a plan view of an illustrative form of resistor unit embodying the invention, with parts broken away to show internal structure;

Fig. 2 is a section taken on line 2-2 of Fig. 1; and

Figs. 3, 4, 5 and 6 are sectional views of other forms of resistor units illustrative of the invention.

Referring now to Figs. 1 and 2 of the drawing, 10 denotes a body of high positive resistance-temperature coefficient material having electrodes 11 attached thereto. Members of insulating material, such as glass rods 12, may be disposed at intervals throughout the body 10 to insure uniform spacing of the electrodes. Circuit connections may be made by conductors 13 which are secured to the electrodes 11 by welding or other suitable means. The body 10 comprises finely divided, pressed, chromic oxide or chromic oxide plus a binder material, such as sodium silicate. The electrodes 11 may comprise a wire gauze as illustrated, a preferred material being nickel or platinum. Sheet metal with or without perforations may also be employed for the electrodes. A reticulated or foraminated electrode is preferred as it adheres better to the body of oxide material 10.

A preferred method of fabricating these units is as follows: An electrode member 11 of suitable size is placed on a flat surface and a layer of oxide material applied thereto. The oxide should be finely divided and may be applied as a powder or a paste. The paste has been found to be preferable. Small amounts of water may be mixed with the powdered oxide to form the paste. It is preferable, however, to employ a binder, such as sodium silicate. It has been found that spacers made of an insulating solid aid in maintaining a uniform thickness of body 10. For this reason, rods 12 of glass or like material may be inserted at intervals in the oxide. A second electrode 11 is then placed over the oxide layer and the assembly pressed sufficiently to bring the electrodes in contact with the spacers

glass

2

2,278,072

12. In units of the type illustrated in Figs. 1 and 2 spacer rods of from 3 to 10 mils diameter have been employed. If desired, the electrodes 11 may be flattened to remove major surface irregularities before using, in order to insure a more uniform thickness of the unit.

If the oxide has been applied as a paste, the units are dried after assembly. It is not necessary to heat treat the units to obtain a positive temperature coefficient of resistance. However, heat treatment does aid in producing a more dense, rugged unit. The temperature of heat treatment may be from 300 to 700° C. but should not go above 700° C. Conductive leads, such as wires 13 of nickel, platinum or other suitable material, may be welded or otherwise secured to each electrode 11.

Units of the type shown in Figs. 1 and 2 and about 1 centimeter square with an electrode spacing of from 3 to 10 mils have a cold resistance of from 25,000 to 50,000 ohms. The half resistance interval or half temperature is from 3 to 5° C. within the range 0 to 100° C. The half resistance interval or half temperature may be defined as the temperature interval over which the resistance doubles or decreases to one-half.

By modification of the foregoing method of fabrication, other units, such as illustrated in Figs. 3, 4, 5 and 6, may be produced. The unit shown in Fig. 3 comprises a body 10 of pressed semiconductive material having electrodes 11 of pressed metallic powder. In the making of such a unit a layer of powdered chromic oxide material is placed between two layers of metallic powder, such as permalloy dust (over 30 per cent nickel, remainder iron) and subjected to sufficient pressure to form a self-sustaining body. The oxide and metal particles interengage to bond the electrode portions 11 firmly to the body 10. Conductive leads 13 may be soldered or otherwise secured to the electrodes 11.

In Figs. 4 and 5 are shown units which are made by pressing finely divided oxidic material into a self-sustaining body 10. For the type shown in Fig. 4, a metallic paste, such as silver paste, is applied to two portions of body 10, and conductors 13 are embedded therein. Sufficient heat is applied to convert the paste to metal electrodes 11 firmly bonding the conductors 13 to the unit.

In the units illustrated in Fig. 5, the electrodes 11 are applied to the body 10 by evaporation or plating of metal, such as silver or gold. The conductors 13 may then be applied to the electrodes by solder or equivalent means.

In Figs. 3, 4 and 5, the thickness of the conducting layers or electrodes 11 has been shown exaggerated in the interest of clarity of illustration. These electrodes, particularly in the forms shown in Figs. 3 and 5, are ordinarily made quite thin.

As indicated with respect to the units illustrated in Figs. 1 and 2, heat treatment is not required to produce units having a relatively high positive resistance-temperature coefficient. However, where heat treatment is desirable from other considerations, such as mechanical strength, the temperature should be kept below 700° C. A suitable range is 300 to 700° C.

As illustrated in Fig. 6, units may also be made in bead form. For this type of unit, the finely divided oxide material is made into a paste, preferably with a sodium silicate binder. The paste is formed into a bead 20 on uniformly spaced

wires 21. The wires 21 preferably are of platinum or other conductive material that will not be affected by heat treatment. The beads are dried and then preferably given a heat treatment in air. The temperature range as for the other units may be from 300 to 700° C. but should not go above 700° C.

As has been stated heretofore, the chromic oxide is preferably mixed with a binder material, such as sodium silicate. It has been found that the binder insures a more rugged unit than is ordinarily possible without a binder. However, the binder is not necessary to obtain a positive resistance-temperature coefficient. Units made with no binder and with sodium silicate binder up to 25 per cent all have the positive resistance-temperature coefficient.

By making suitable circuit changes, units having a high positive temperature coefficient of resistance may be employed to perform the same function as negative resistance-temperature coefficient devices. In general, the positive coefficient unit is connected in series to perform the same function as a negative coefficient device in parallel or vice versa. For some regulating purposes, a positive coefficient device may be used with a negative coefficient device with good results. An advantage of the positive coefficient material is its inherent ability to prevent the formation of "hot spots," which must be avoided in negative coefficient units.

A "hot spot," as the name implies, is a portion of a resistor unit that in use attains a higher temperature than the surrounding portions. This may be, for example, due to non-uniformity of the resistance material. In the case of negative resistance-temperature coefficient material, the resistance is reduced at the "hot spot," due to the high temperature. The resulting greater flow of current further raises the temperature thereby further lowering the resistance. In the absence of exterior current limiting means the "hot spot" condition may become so bad as to permanently change the character of the resistance material or even destroy it. In a positive resistance-temperature coefficient material, the "hot spots" are self-limiting since the resistance goes up with increase in temperature.

Although specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A high positive resistance-temperature coefficient resistor unit comprising a body of finely divided, pressed chromic oxide heat treated in air at a temperature below 700° C., and electrodes attached to spaced portions of said body.

2. A resistor having a high positive temperature coefficient of resistance and comprising a thin body of untreated chromic oxide, two metallic electrodes on opposite faces of said body, and insulating means embedded in said body for maintaining separation between said electrodes.

3. A resistor having a high positive temperature coefficient of resistance and comprising a body of pressed, finely divided, chromic oxide between two metallic electrodes, and a plurality of glass rods embedded in said body for maintaining separation between said electrodes.

4. A resistor having a high positive temperature coefficient of resistance and comprising

chromic oxide heat treated at a temperature between room temperature and 700° C.

5. The method of making a positive resistance-temperature coefficient resistor unit that comprises forming a body from finely divided chromic oxide, and heat treating said body in air at a temperature below 700° C.

6. The method of making a high positive resistance-temperature coefficient resistor unit that comprises mixing finely divided chromic oxide and sodium silicate to a paste, applying the paste to a reticulated metallic sheet, inserting a plurality of insulating spacer members into the paste and applying another reticulated metallic sheet thereto, pressing the assembly, drying, and heat

treating in air at a temperature between 300 and 700° C.

7. The method of making a positive resistance-temperature coefficient resistor unit that comprises mixing finely divided chromic oxide to a paste with sodium silicate, applying the paste to a sheet electrode, inserting solid insulating spacers into the paste, applying another sheet electrode over the paste and spacers, pressing to consolidate the assembled elements, drying in air, heat treating in air at a temperature below 700° C. and applying a conductive lead to each electrode.

HAROLD L. B. GOULD.
BURTON A. KINGSBURY.