Oct. 14, 1941. G. L. PEARSON 2,258,958

CONDUCTIVE DEVICE

Filed July 13, 1939

FIG. 1

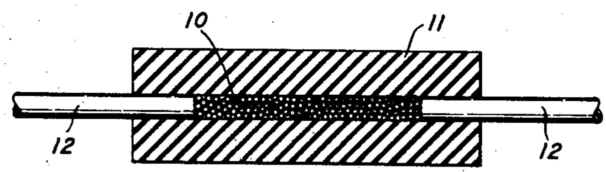


FIG. 2

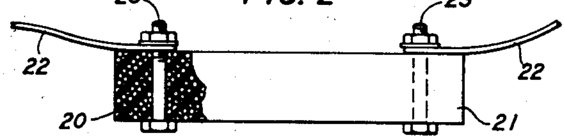


FIG. 3

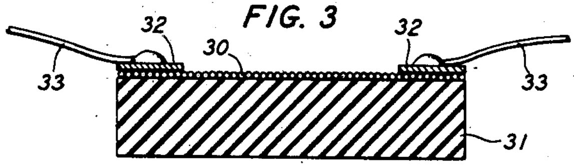
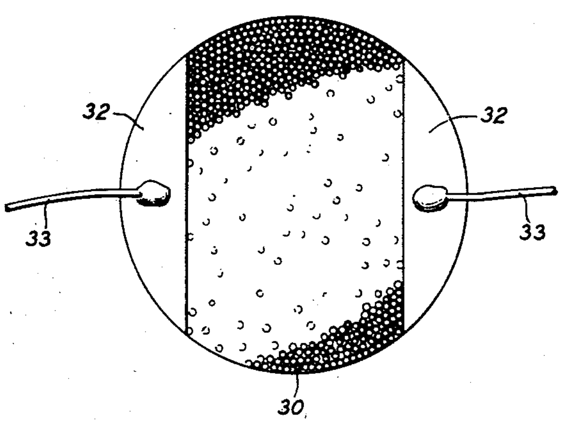


FIG. 4



INVENTOR
G. L. PEARSON
BY
Walter C. Kiesel
ATTORNEY

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CONDUCTIVE DEVICE

Gerald L. Pearson, Towaco, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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9 Claims. (Cl. 201—72)

This invention relates to electrically conductive devices and more particularly to such devices having a high temperature coefficient of resistance.

In the regulation and control of electrical current for various purposes, it is often advantageous to employ circuit elements whose conductance varies as a function of the applied voltage or current. Resistor elements, the resistance of which is highly dependent upon temperature, are illustrative of such devices. The so-called semiconductors, which have resistance values intermediate those normally associated with conductors and insulators, in most cases have a high negative temperature coefficient of resistance at ordinary temperatures. Circuit elements made from such materials have therefore been used for voltage and current regulation. Materials ordinarily classed as conductors in most cases have a positive temperature coefficient of resistance. The value of this coefficient is low as compared with that of the negative coefficient materials. For example, iron does not double in resistance for less than 70° C. rise in temperature at any point below 500° C. Such materials, therefore, are not available for circuit elements which must have a wide range of resistance variation.

One object, therefore, of this invention is to produce a conductive device having a high temperature coefficient of resistance.

A further object of this invention is the production of a resistor unit having a high positive resistance-temperature coefficient.

One feature of this invention resides in a conductive device comprising a plurality of conducting particles supported by a body of non-conductive material, whereby adjacent particles are in mutual contact, the particles and body having widely divergent thermal coefficients of expansion.

In accordance with another feature of this invention, the conductive device comprises conducting particles suspended in an insulating tube, the particles and tube having widely separated thermal coefficients of expansion.

A further feature of this invention resides in a conductive device comprising conducting particles having a low thermal expansion coefficient and supported by a matrix having a high thermal coefficient of expansion.

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

Fig. 1 is a sectional view of one type of conductive unit illustrative of this invention;

Fig. 2 is a sectional view of another illustrative embodiment of this invention; and

Figs. 3 and 4 are respectively a section and a plan view of a further form of conductive unit illustrating this invention.

Certain parts shown in the drawing have been purposely exaggerated to better illustrate the invention. For example, the spherical conducting particles which may be very small, often being in the order of 3.5 mils diameter, have been shown out of proportion in the interests of clarity.

The conductive units may, in accordance with this invention, comprise conducting particles suspended in an insulating body or matrix which has a coefficient of thermal expansion widely different from that of the particles. The particles are so suspended by the body or matrix that each is in contact with the particles thereadjacent. That is, the mutual contact is such that variations in pressure change the contact resistance between particles in a manner similar to that found in a carbon granule type microphone. A variable resistance, interparticle contact of this type is sometimes called a microphonic or modulating contact.

The relation between the coefficients of thermal expansion of the particles and supporting body determines the sign of the temperature coefficient of resistance of the device. With particles of low thermal coefficient and a supporting body or matrix of high thermal coefficient, the device has a positive resistance-temperature coefficient. Conversely, with high expansion particles and a low expansion matrix, the resistance-temperature coefficient is negative. The value of the resistance-temperature coefficient or half temperature is a function of the difference between the thermal expansion coefficients of the conductive and non-conductive elements. The term "half temperature" may be defined as the temperature range over which the resistance doubles or is reduced by half its original value. The temperature range over which the half temperature is measured should be specified. It is convenient in many cases to employ the range 0 to 25° C. for half temperature measurements and such range will be understood in this application unless otherwise specified.

Referring now to the drawing and particularly to Fig. 1, 10 designates a plurality of conducting granules enclosed in a tube 11 of insulating material. Conductors 12, which serve as terminals or electrodes for the unit, are sealed into the ends of tube 11 to complete the enclosure. If the device is to have a negative resistance-temperature coefficient, the particles 10 should have a high and tube 11 a low thermal expansion coefficient. For example, the particles may be of carbon and the tube of quartz. To obtain a positive temperature coefficient of resistance, low expansion conductive particles, such as carbon coated quartz spheres and a high expansion tube, made for example of soft glass, may be used. Conductors 12 should have a thermal expansion coefficient as close to that of the tube 11 as possible. For soft glass tubes, platinum conductors are suitable. In view of the difficulty of sealing metals to quartz, other methods may be employed for securing conductors 12 thereto. The sealing-in is a convenient method of securing the conductors to the tube, so that there is no appreciable relative movement therebetween. The conductors 12 may be secured to the tube 11 by cementing and like means in situations where such methods are more satisfactory than sealing-in.

Where conductors 12 are sealed in the tube 11, the temperature of the device at the time of sealing-in the second conductor, determines the initial pressure on the enclosed particles. Since the temperature at which a high resistance-temperature coefficient is evident, is a function of the initial pressure, said pressure should be adjusted in accordance with the characteristics desired in the completed unit.

Other conductive units of the type illustrated in Figs. 2, 3 and 4 may be made by maintaining a plurality of conducting particles in microphonic contact by a matrix of plastic material. The so-called organic plastics, most of which have a high thermal expansion coefficient, provide suitable matrix materials for high positive resistance-temperature coefficient conductive devices. However, these materials must have a sufficiently high resistance to cold flow to return to their original dimensions at the end of successive heating and cooling cycles. This is necessary in order to obtain stable conductive units. Some of such materials are metal stearates, for example, aluminum stearate, phenol resins, methyl methacrylate, cellulose acetate, cellulose nitrate and the polystyrenes.

One form of positive resistance-temperature coefficient unit of the plastic matrix type is illustrated in Fig. 2. Here the conducting particles 20 are molded into a matrix 21 of insulating material. Circuit connections may be made to the unit in various ways. In the illustrated embodiment, conductive leads 22 are attached to the unit by bolts 23 which serve as electrodes. The leads may also be molded in the material or melted in by the application of heat. Among the materials giving satisfactory results in devices of this form, are iron filings in an aluminum stearate matrix. Various types of iron, in finely divided form, may be used. For example, a 36 per cent nickel steel known as Invar and having a very low thermal expansion coefficient has been used successfully. The iron filings may be mixed with powdered metal stearate and the material molded into a block or disc. Other particle and matrix materials having suitable characteristics may also be employed in this manner.

Units of the type shown in Figs. 3 and 4 may be made by securing conducting particles to the face of a block of insulating material. A positive resistance-temperature coefficient device may be made by attaching a layer of low thermal expansion coefficient conducting particles, such as carbon coated quartz spheres, 30 to the surface of a body of organic plastic material 31. One method of doing this is to spread a layer of the spheres over one face of the plastic body and embed them therein by the application of heat and pressure. Metal electrodes 32 may be applied to the spaced portions of the layer of spheres 30. The electrodes may be applied by any suitable method, for example, by means of a metal spray such as a Schoop spray. Conductors 33 may be attached to the electrodes 32 by solder or like means. Another method of applying the layer 30 is to mix a quantity of the coated spheres with some of the plastic material dissolved in a solvent and to apply the resulting mixture to a surface of the plastic body. The conductive portion of this type of unit comprises essentially a single layer of conducting spheres in which adjacent spheres are substantially mutually tangent.

Half temperatures of the order of 3 to 5° C. may be obtained in positive resistance-temperature coefficient devices made in accordance with this invention. Such devices may be used for regulation and like applications in a manner similar to that employed with negative resistance-temperature coefficient means of various types. In general, the positive coefficient units are connected in series to accomplish the same results as negative coefficient units connected in parallel and vice versa.

Various particle and matrix combinations not specifically indicated in the foregoing description may be employed in carrying out this invention. For example, carbon particles if used with a high expansion matrix such as one of the before-noted plastics would give a positive resistance-temperature coefficient device; iron filings may be attached to the surface of a plastic body instead of being molded therein or carbon coated quartz spheres may be incorporated throughout a plastic matrix.

Although this invention has been disclosed with reference to specific embodiments thereof, it is to be understood that various modifications therein may be made without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A conductive device comprising a plurality of conducting particles embedded in a body of insulating material, whereby voids among said particles are filled with said material, said particles being held in mutual, microphonic contact by said material, said material having a thermal expansion coefficient widely different from that of said particles.

2. A conductive device having a high positive resistance-temperature coefficient comprising a plurality of conducting particles, and a plurality of electrodes secured to a body of insulating material having a high thermal expansion coefficient as compared with that of said particles, each particle being embedded in said material, said particles being held in mutual, microphonic contact between the electrodes by said material.

3. A conductive device having a high positive resistance-temperature coefficient comprising a plurality of particles of iron, a matrix of aluminum stearate, and a plurality of electrodes, the matrix maintaining the electrodes in spaced re-

lation and supporting the particles so that contiguous particles are in mutually contacting relation and the particles adjacent said electrodes are in contact therewith.

4. A conductive device having a high positive resistance-temperature coefficient comprising a plurality of carbon coated quartz spheres, a matrix of organic plastic material having a high thermal expansion coefficient and high resistance to cold flow, and a plurality of electrodes, the matrix maintaining the electrodes in spaced relation and supporting the spheres so that contiguous spheres are in mutually contacting relation and the spheres adjacent said electrodes are in contact therewith.

5. A conductive device having a high positive resistance-temperature coefficient comprising a plurality of carbon coated quartz spheres, a matrix of cellulose acetate plastic, and a plurality of electrodes, the matrix maintaining the electrodes in spaced relation and supporting the spheres so that contiguous spheres are in mutually contacting relation and the spheres adjacent said electrodes are in contact therewith.

6. A conductive device having a high positive resistance-temperature coefficient comprising a plurality of carbon coated quartz spheres and a matrix of cellulose acetate plastic, the matrix having a layer of spheres attached to one surface thereof so that contiguous spheres are in mutually contacting relation, and electrodes attached to spaced portions of said layer.

7. A high resistance-temperature coefficient conductive device comprising conductive particles and insulating material having widely divergent thermal expansion coefficients, said material embedding said particles in mutually contacting relation and filling voids thereamong, whereby the interparticle contact pressure varies with temperature to vary the resistance of said device.

8. A conductive device comprising a plurality of conducting particles embedded in organic plastic, insulating material, said material occupying voids among the particles, said particles being held in mutual microphonic contact by said material, said material having a very high thermal expansion coefficient as compared to that of the particles.

9. A high resistance-temperature coefficient conductive device comprising conducting particles, embedded in an insulating material so that adjacent particles are in mutual contact and voids among the particles are filled with said material, said insulating material having a thermal expansion coefficient greatly different from that of the particles, whereby the interparticle contact pressure and hence resistance varies widely with changes in temperature.

GERALD L. PEARSON.