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METHOD OF MAKING A NON-LINEAR RESISTANCE ELEMENT

Filed Nov. 26, 1962

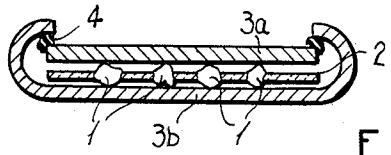

Fig. 1.

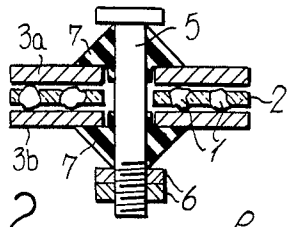

Fig. 2.

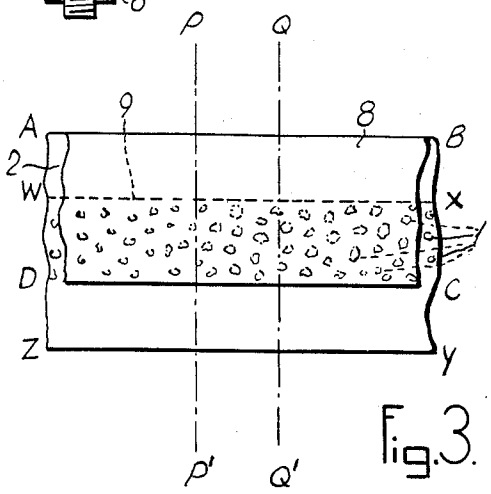

Fig. 3.

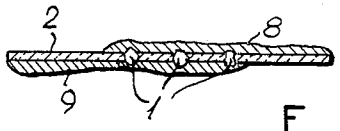

Fig. 4.

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METHOD OF MAKING A NON-LINEAR RESISTANCE ELEMENT

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3 Claims. (Cl. 29—155.71)

This invention relates to non-linear electrical resistance elements, that is, resistance elements which have a non-linear voltage-current characteristic.

Such resistance elements for use with voltages greater than, say, 25 volts are well-known and usually consist of a quantity of discrete particles of silicon carbide or other such non-linear resistance material (that is material the electrical resistance of which varies with variation in applied voltage) in combination with a ceramic binder. One well-known type is known under the registered trade mark "Metrosil" and its electrical characteristic may be expressed in the form:

$$V=KI\beta$$

I and V are the current through and voltage across the resistance element respectively, the index β is characteristic of the material from which the resistance element is made, and the constant K depends upon the shape and size of the resistance element as well as on the material. In practice, the voltage at any current density is proportional to the thickness of the resistance element and the current at any voltage gradient is proportional to the area of the resistance element. The most common form of this type of resistance element is a disc and the lower the voltage, the thinner the disc is required to be.

Resistance elements of this type are usually manufactured by pressing a mixture of granules of silicon carbide or other such material and a ceramic material into the form of a disc which is then sintered. However, such resistance elements designed for low voltage applications are rather fragile. For example, for use at 25 volts the disc may be only 0.02" thick. For very low voltage applications the disc will comprise a single layer of a finite number of silicon carbide or other such granules and this precludes the use of a ceramic binder on the grounds of extreme fragility.

It is an object of the present invention to provide an improved method of manufacturing a non-linear resistance element which is suitable for use with low voltages (e.g. voltages of the order of ¼ to 5 volts).

According to the invention, such method consists in constraining a single layer of granules of silicon carbide or other such non-linear resistance material in a lamina of electrically insulating material with granules exposed at both surfaces of the lamina, and applying to each of these surfaces an electrically conductive member contacting the exposed portions of the granules thereat.

The invention may be performed in a variety of ways, five examples of the preparation of the lamina referred to being as follows:

(1) The granules are spread in a single layer on a lamina of electrically insulating material, such as polythene, which can be penetrated by the granules by application of sufficient pressure to the latter, and pressure is applied in any suitable manner to the granules to cause them to penetrate the lamina to an extent such that portions of the granules are exposed at both surfaces thereof.

(2) A lamina of electrically insulating material, such as polyethylene, which can be made deformable by heating, is placed on a sheet of resilient material such as rubber, the granules are spread in a single layer on the lamina, and a further sheet of resilient material is placed over the layer of granules. The "sandwich" thus constituted is heated until the lamina become deformable and then sufficient pressure is applied to opposite sides of the sandwich to cause the granules to embed themselves in the deformable lamina, except for portions of the granules which are pressed into the sheets of resilient material. These sheets are then removed leaving such portions of the granules exposed at opposite sides of the lamina.

(3) A layer of the granules is held under pressure between two supporting surfaces of rubber or other resilient material, the pressure being such that portions of the granules are embedded therein. A suitable resinous material, such as "Araldite D," is then deposited round the granules, as by vacuum impregnation, and after solidification of the resinous material into a lamina with the granules partially embedded therein, the supporting surfaces are removed leaving those portions of the granules which were pressed into them exposed on opposite sides of the lamina.

(4) A quantity of a suitable material (again such as "Araldite D") is mixed with the granules and then set to form a lamina no thicker than the depth of a layer of the granules. Both surfaces of the lamina are then teased or ground to expose portions of the granules at these surfaces.

(5) A single layer of the granules is contained between two laminae of electrically insulating material having an adhesive substance on their facing surfaces. Sufficient pressure is then applied to the outside surfaces of the laminae for the granules to penetrate them so that portions of the granules are exposed at their outside surfaces. The applied pressure also causes the two laminae to adhere together so that they constitute a composite laminae having portions of the granules exposed at both surfaces thereof.

In each of the foregoing ways the lamina of electrically insulating material containing granules of silicon carbide or other such non-linear resistance material may be prepared in a shape appropriate for incorporation in a voltage dependent resistor, or it may be subsequently cut to a suitable shape or have suitably shaped parts cut or stamped out from it.

To form the final non-linear resistance element the shaped lamina may be constrained between electrodes constituted by rigid electrically conducting pressure plates of brass or other suitable conductive material which contact with the exposed portions of the granules at its opposite surfaces. Alternatively, the surfaces of the lamina may be at least partially covered with a conductive coating constituting the electrodes. Where the lamina is shaped after being formed, such coating may be applied either before or after shaping.

In order that the invention may be more fully understood reference will now be made by way of example to the accompanying drawing in which, on an enlarged scale:

FIGS. 1 and 2 illustrate examples of non-linear resistance elements provided with rigid plate electrodes; and

FIGS. 3 and 4 illustrate examples of non-linear resistance elements provided with electrodes constituted by conductive coatings.

In each of these examples the lamina of electrically insulating material constraining a layer of granules of silicon carbide or other such material would be made in accordance with the invention, for instance by any of the five particular ways just mentioned.

Referring to FIG. 1, a finite number of granules 1 of silicon carbide or other such material are constrained as a single layer in a lamina 2 of electrically insulating material with portions of the granules exposed at both sur-

faces of the lamina 2. The lamina 2 is held between two facing electrical conducting surfaces presented by a pair of juxtaposed rigid metal discs 3*a*, 3*b*, these surfaces contacting the exposed portions of the granules 1. The edges of the lower disc 3*b* are bent over to enclose the lamina 2 and to maintain the metal discs 3*a*, 3*b* in position: the top disc 3*a* and the rim of the lower disc 3*b* are electrically insulated from each other by an annular insulating washer 4. Electrical contact with the resistance element thus formed can be made by conventional means such as spring contacts, tags, etc. (not shown).

The resistance element shown in FIG. 2 also includes a pair of juxtaposed rigid metal discs 3*a'*, 3*b'* between which is clamped a lamina 2 of electrically insulating material constraining a single layer of granules 1 of silicon carbide or other such material. In this instance the lamina 2 and the metal discs 3*a*, 3*b* have a central aperture and the metal discs 3*a*, 3*b* are maintained in position by means of a bolt 5 inserted through the central aperture and locked by nuts 6. Insulating spacers 7 insulate the bolt 5 from the lamina 2 and discs 3*a*, 3*b*.

The voltage resistance characteristic of a non-linear resistance as exemplified in FIGS. 1 and 2 is determined by the number of granules per unit area and the pressure applied by the metal discs. Thus where this lamina constraining the granules is to be prepared, in conformity with the invention, by either of the ways (1) and (2) previously discussed the preparation may be facilitated if the surface of the lamina in which the granules are spaced is previously coated with a viscous substance which will retain the granules in position. Also, in the case of these two examples the granules may be embedded in the lamina by the mechanical pressure applied during assembly to their metal disc electrodes.

As indicated earlier the electrodes of a non-linear resistance element made in accordance with the invention are not necessarily rigid pressure plates, but may be applied to the prepared lamina in the form of a conductive coating. This alternative is illustrated in FIG. 3, in which a lamina 2 of electrically insulating material in strip form has granules 1 of silicon carbide or other such material embedded only along a central portion thereof.

The reference numeral 8 denotes a conductive coating covering the area ABCD on one surface of the lamina 2, and the reference numeral 9 denotes a conductive coating covering the area WXYZ on the other surface. Individual non-linear resistance sheets may then be cut from the strip as shown by the lines PP', QQ'. For any one grade of resistance material the voltage resistance characteristic would be determined by the number of granules per unit area and by the distance between the two lines PP', QQ'.

In section a resistance element thus produced would be as shown in FIG. 4 in which 2 is the lamina of electrically insulating material, 1 is the layer of granules of silicon carbide or other such material constrained therein, and 8 and 9 are the conductive coatings which act as electrodes to which electrical connections may be attached in any known way, for instance, by soldering.

Instead of the lamina strip having granules embedded in a continuous section along its centre, the granules may be embedded there in isolated groups in order to facilitate cutting the lamina up into individual resistance elements.

A non-linear resistance element manufactured in accordance with the invention may be encapsulated in a suitable resin.

Although the term "single layer of granules" has been used throughout the specification by reason that the characteristics of a non-linear resistance element manufactured in accordance with the invention are determined by those granules which have exposed portions of both sides of the lamina of electrically insulating material, it is to be appreciated that in practice some of the exposed granules may overlie others that may be completely embedded within the lamina: the above term is therefore intended to be construed accordingly without departure from the spirit of the invention.

What we claim is:

1. A method of manufacturing a non-linear resistance element comprising the steps of constraining a single layer of discrete granules of a non-linear resistance material in a lamina of electrically insulating material which is sufficiently thin so that each of at least a substantial number of said discrete granules is exposed at both surfaces of the lamina, and applying an electrically conductive member to each of these surfaces to contact exposed portions of the granules thereat, wherein said lamina with said single layer of discrete granules constrained therein is prepared by holding a single layer of the granules under pressure between two supporting surfaces of resilient material, the pressure being such that portions of oppositely facing surfaces of each of at least a substantial number of the granules are embedded in the supporting surfaces, depositing resinous material round the granules, causing the resinous material to set to form the lamina with the granules partially embedded therein, and removing the supporting surfaces to leave those portions of the granules which were pressed into them exposed on opposite sides of the lamina.

2. A method of manufacturing a non-linear resistance element according to claim 1, wherein said granules are silicon carbide granules and wherein each of said two electrically conductive members is a rigid electrically conductive pressure plate pressed into electrical contact with the exposed portions of the granules at the side of the lamina to which it is applied and there secured in position.

3. A method of manufacturing a non-linear resistance element according to claim 1 wherein said granules are silicon carbide granules and wherein said two electrically conductive members are electrically conductive coatings applied over the surfaces of said lamina in electrical contact with the exposed portions of the granules thereat.

References Cited by the Examiner

UNITED STATES PATENTS

2,067,393	1/37	Habann	338—223 X
2,149,827	3/39	Andre	338—21 X
2,282,344	5/42	Ruben	338—20
2,431,326	11/47	Heyroth	252—516
2,707,223	4/55	Hollmann	338—20
2,747,104	5/56	Jacobs	338—17
2,758,256	8/56	Eisler	317—101
2,767,289	10/56	Robinson	338—223
2,777,040	1/57	Kazan	338—17
2,796,505	6/57	Bocciaretti	338—20
2,914,742	11/59	Heath	338—21
2,951,817	9/60	Myers	338—36 X
3,040,282	6/62	Heath	338—21
3,157,735	11/64	Stroup et al.	174—94

FOREIGN PATENTS

959,379	3/57	Germany.

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