Aug. 20, 1968 G. V. DE LIZASOAIN ET AL 3,398,233

ELECTRICAL CONDUCTOR OF FIBERS EMBEDDED IN AN INSULATOR

Filed April 20, 1965

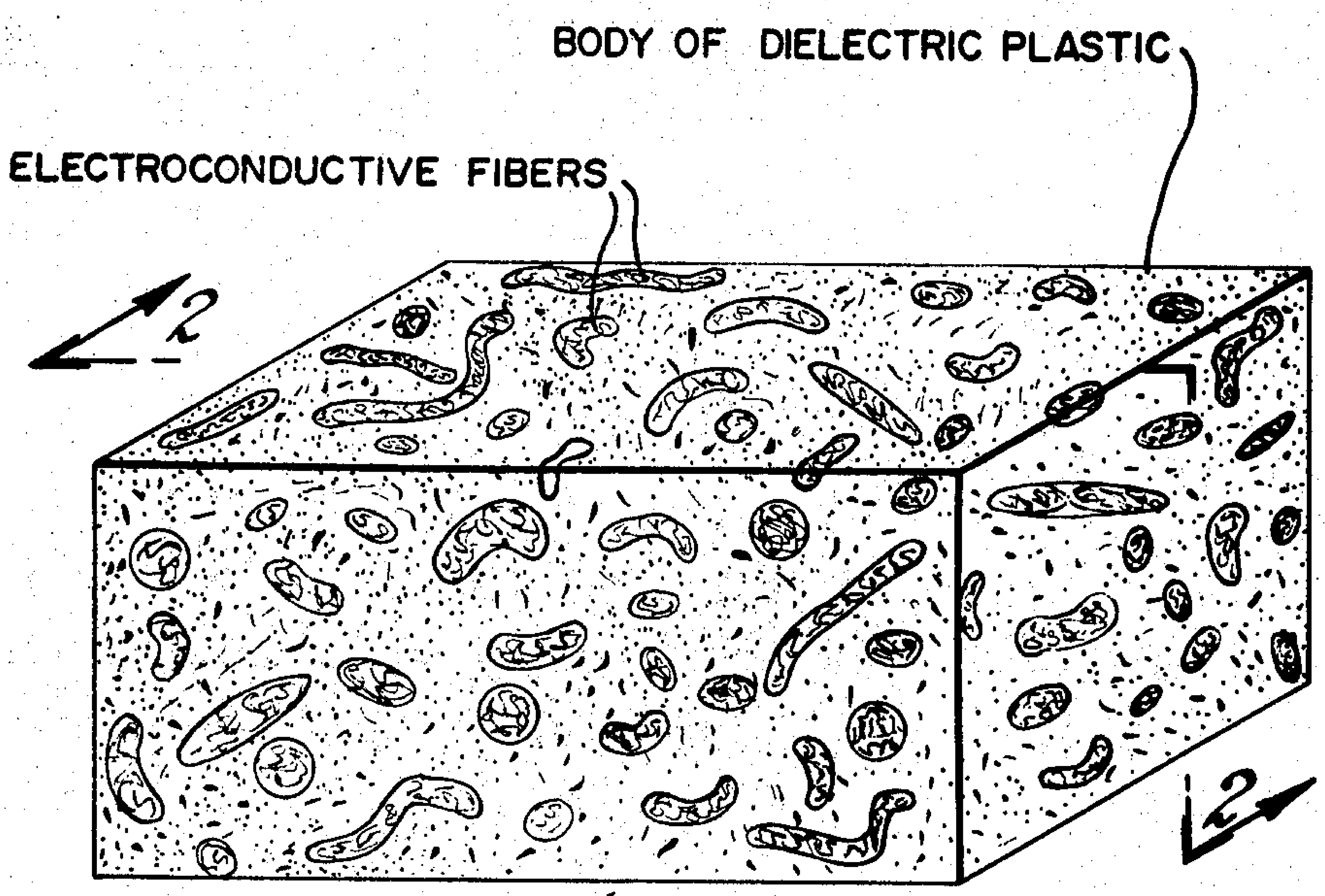

Fig. 1

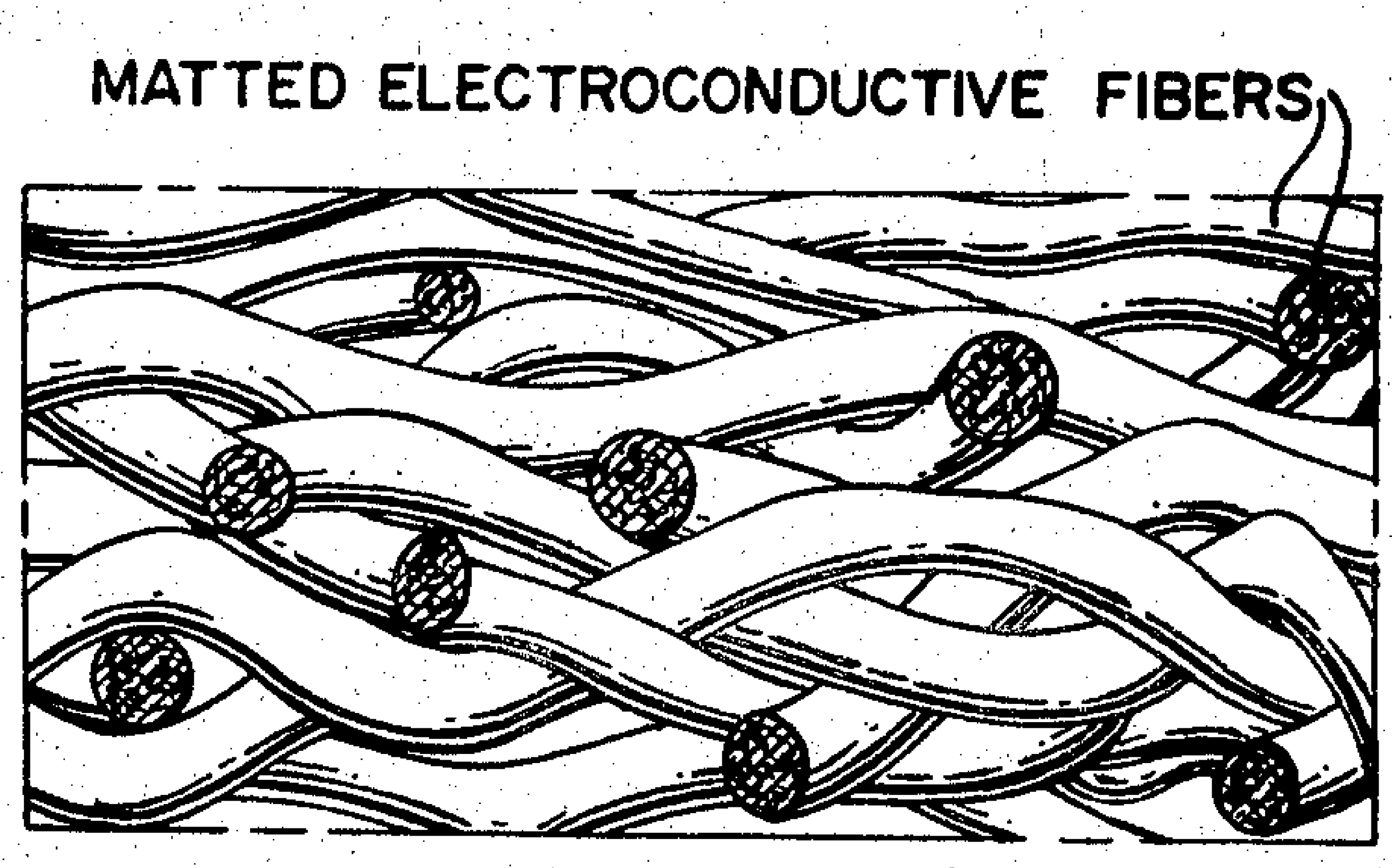

Fig. 2

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ELECTRICAL CONDUCTOR OF FIBERS EMBEDDED IN AN INSULATOR

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Filed Apr. 20, 1965, Ser. No. 449,626
7 Claims. (Cl. 174—110)

The present invention relates to the art of electrical conductors; and deals principally with the class of conductors constituted of electroconductive material embedded in a supporting body of a polymer of the group comprising rubber, elastomers, and flexible or pliable plastics.

As used herein "rubber" means natural, reclaimed, cured, vulcanized, or synthetic rubber, or mixtures and compounds thereof; and "elastomer" means any substance or material having properties similar to any of said rubbers and endowed with the property of what is commonly known as "elastic memory." They are resilient, flexible, and elastic.

At the present time, perhaps the most widely known and used conductors having the properties above noted are the materials generally called conductive rubbers. These are supporting bodies of rubber or dielectric elastomer having embedded therein discrete, minute particles, generally in powder form, of metal or other common electroconductive substances dispersed uniformly throughout the mass of the supporting body in electrical contact. When such bodies are distorted from their original state under compression the electroconductive particles are pressed together in closer contact, which increases conductivity and lowers resistance in conformance with the applied distorting force. Conversely, when they are distorted under tension, as by stretching, the conductive particles tend to move apart and thereby to lower conductivity and increase resistance in conformance with the applied distorting force.

In all prior art conductors of the type above noted of which we are aware, the application of distorting force either increases conductivity with attendant lowering of resistance, or lowers conductivity with attendant increase of resistance, depending upon the character of the applied force, whether it be one of compression or of tension. If the two forces are applied simultaneously, as might occur if a strip of conductor were twisted while under longitudinal compression, the dominant force will control in the areas in which it is exerted, and the electrical behavior of the conductor will be variable and not predictable. Any such conductor subject in use to fortuitous and diverse stresses and strains such as, for example, variable conditions of temperature, atmospheric pressure, and mechanical stress encountered in the operational field of aeronautics, would be useless in electrical indicator and control circuits.

Scientific, technological, and industrial developments have greatly increased the use of electroconductive materials having the property of elastic memory, but they have been limited to applications in which they function primarily as resistance elements in which the impedance factor is dependent upon the particular character of an applied external force to which the element is subjected in use. They do not have the ability to increase electrical conductivity upon the application of any external force regardless of its nature or the manner in which it is applied.

The present invention provides an electrical element

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which has the property of increasing its electroconductivity in conformance with the magnitude of an externally applied force regardless of whether it be of compression or expansion. The element is particularly useful in this respect in the fields of antennas, transducers, amplifiers, variable capacitors, and variable resistors.

The invention also provides an electroconductive plastic material that is flexible, moldable, and capable of esay shaping for conformity with surface characteristics of a support to which it may be applied.

Another object of the invention is the provision of an electroconducitve body possessing the proterty commonly known as elastic memory, and capable of easy cutting into strips or other shapes having uniform thickness, density, and electrical conductivity, and which are of self-sealing, permeable material for line tapping and for passage therethrough of solid conductor leads and connectors.

A further object of the invention is the provision of an electrical element comprising a body of dielectric plastic material having embedded therein a body of uniform density constituted of fibers or filaments of electroconductive material in continuous surface contact, with the plastic material filling completely all spaces between the fibers or filaments in contact therewith and free from adhesion thereto.

Still another object of the invention is the provision of an electrical element as described in the preceding paragraph in which the plastic material has the property commonly known as electric memory and in which the fibers or filaments are free to move individually within and relative to the plastic material in conformity with its movements.

A still further object of the invention is the provision of an electrical conductor constituted principally of metal wool embedded in a supporting body of polymeric material from the group consisting of rubbers, elastomers, and flexible or moldable plastics.

A further object of the invention is the provision of a method of making the electrical elements above described.

Other and incidental objects will be apparent from the following description in conjunction with the accompanying drawings, in which:

FIG. 1 is an enlarged perspective view of an electrical element embodying our invention;

FIG. 2 is a sectional view taken substantially on line 2—2 of FIG. 1, with the plastic supporting body removed.

The prior art has not developed the use of metal wool as an electrical conductor. It has not been considered reliable. It burns out in spots and dangerously overheats in others, thereby presenting irregular and increasing resistance with rise in temperature. It does, however, have advantages of flexibility, light weight, and resistance to breakage under repeated flexing greater than possessed by single and multiple strand wire conductors, wire mesh, and conductors formed of metal strip. Also, its cost is far below that of conventional conductors.

Packing and sealing gaskets made of metal wool in a binder of rubber are known; and it is known to encase pads of metal wool in room-temperature cured silicone rubber to provide heat conductive shock and vibration damper material; but so far as we are aware, prior to the advent of the present invention the art has not produced an electrical conductor made of metal wool, or other matted electroconductive fibers, completely embedded in an insulating body of rubber, polymeric elastomer, or flexible pliable plastics.

In the above noted prior art examples of metal fibers encased in rubber or polymeric elastomer, no problem of electrical behavior or conductivity is involved in their use. The metal fibers are either a mass of metal shavings salvaged in metal cutting and turning operations and thus coated and fouled with oil and dirt, or they are the commercially produced material commonly known as metal wool. In either case, the product is, for reasons heretofore stated, incapable of accomplishing the purposes of this invention.

We have discovered that a mass of matted fibers of commercial metal wool, or other electroconductive fibers, felted into a body of uniform density and completely embedded in a supporting body of dielectric plastic polymeric material from the group consisting of rubbers, elastomers, and flexible plastics, and which is free from adherence to the fibers, provides an electrical element having the properties of flexibility, and/or elastic memory and which is superior in performance to electrical elements made of material commonly known as conductive rubber. It is capable of a wide variety of uses for which conductive rubbers are not suitable.

However, in order to produce a material capable of carrying out the purposes of this invention, certain basic criteria must be observed. There must be homogeneous distribution and continuity of the fibers in the supporting body mass of dielectric plastic polymer, and sufficient points of electrical contact between the fibers to insure good electrical conductivity without overheating, sparking or burning out. There must be no adhesion in the finished product between the material of the surrounding body mass and the fibers; the fibers must be free to move individually within the dielectric body mass under the influence of and in conformity with movements of the body. The fibers must be free at all times to move upon each other in electrical contact.

Following are some illustrative examples of the manner in which the invention is put in practice:

EXAMPLE I

A desired quantity of uncured gum stock silicone rubber is milled with added conventional plasticizing and vulcanizing agents to form a soft and slightly sticky sheet of from about 1/32 to 1/8 inch thickness. A mass of extremely fine fibers of electroconductive material thoroughly cleaned free from grease and dirt, preferably one or more pads of commercial metal wool, is worked by combining into a free standing uncompressed sheet or layer approximately 1/8 inch thick and of a uniform density such that, when viewed against light, no area encompassed by a circle of about 1/16 inch diameter is lacking in fibers.

A piece of desired size is cut from the uncured gum stock rubber sheet and a similar piece is cut from the metal wool layer. The piece of rubber is spread upon a non-adhesive backing film of flexible plastic and covered with the prepared layer of metal wool. A second non-adhesive plastic film then is laid over the layer of metal wool and by light pressure on the film the layer of wool is embedded slightly into the underlying rubber. The press film then is removed and is replaced by a second piece of the rubber entirely covering the exposed face of the metal wool layer. The removed press film or another piece of similar film is then laid over the top of the upper piece of rubber and pressure is applied by a roller, whereby the layer of wool is completely embedded in the mass of rubber comprising the top and bottom sheets. The rolling motion should have a single basic direction and start from the center of the piece toward its extremities. The pressure need not be extreme but should be constant and generally equal. Alternatively, the laminate may be worked by milling between opposed presser rolls, each pass being under increased pressure and reversed in direction.

Application of pressure on the laminate as above described forces the plastic mass of uncured rubber into the interstices of the metal wool, completely filling all spaces between the fibers and in surface contact with the fibers over all areas thereof not actually in electrical contact. At this stage the uncured silicone rubber adheres to the individual fibers with such tenacity that relative movement between them is inhibited.

The preform of rubber and embedded metal wool formed as above described is then molded in a compression molding press under a pressure of at least 40 p.s.i. and cured at an elevated temperature sufficient to melt the rubber and destroy its property of adhesion, thereby freeing it from adhesion to the fibers of the wool. The curing cycle for a sheet of 1/16 inch thickness was twenty minutes at 250° F.

EXAMPLE II

In this example a mass of metallic wool or other electroconductive fibers is prepared as described in Example I, after which it is treated as by spraying, dipping, or in any suitable manner to deposit on the fibers a coating of a nonadhesive release agent such as, for example, silicone grease, wax, soap, or any material that will prevent adhesion of the polymeric body material to the fibers when they are embedded therein. When the fibers are so coated they are embedded in the supporting body material in the manner described in Example I. The polymeric body material may be any polymer from the group consisting of rubbers, elastomers, and flexible plastics, and the preform is shaped and cured as in Example I, it being understood that the time and temperature will depend upon the composition of the body material and the thickness of the product. Some examples of flexible plastics are polyurethane, polyvinyl chloride and polyethylene. Pliable silicone putty and conventional putties.

EXAMPLE III

A mass of metal wool or other electroconductive fibers is prepared as in Example I and placed in a compression mold that has been treated with a release agent. The fiber mass is so placed that it completely fills the mold and will under mild constricting compression be homogeneously distributed, maintaining sufficient points of fiber contact and electrical continuity.

A polymeric material from the group consisting of rubbers, elastomers, and flexible plastics, mixed with a catalyst and a conventional foaming agent, is metered so that the cure commencement time will be sufficient to enable full and uniform distribution of the mix in the mold.

The mix is poured uniformly over the fiber mass in the mold, or entered in the mold in any other manner sufficient to insure that it fills the interstices of the fibers. Alternatively, the polymer mixture may first be poured in the mold and the fiber mass added.

After filling, the mold is capped and its contents are cured in a manner appropriate to the nature of the polymeric material employed. In this process the polymeric mass is foamed into the fiber body under internal pressure in the mold.

In the polymeric material is of such nature that it would, after curing, adhere to the embedded fibers, the fibers must be coated with a release agent before embedding as in Example II.

EXAMPLE IV

A mass of metal wool or other electroconductive fibers is kneaded or otherwise worked uniformly into a body of a putty-like, polymeric material, preferably silicone putty, in such manner that the fibers are distributed homogeneously and in continuity of electrical contact therein.

Broad aspects of invention

It is to be understood that the above examples are illustrative, not restrictive. In its broad aspects, the present invention is a discovery that matted electroconductive fibers of extremely small cross section, and particularly commercial metal wool, if worked to a body of uniform density and embedded in a supporting mass of dielectric plastic material having properties of flexibility, and/or elastic memory, and free from adhesion to the fibers when cured, produces an electrical element that functions in an unobvious and unexpected manner to provide an electrical conductor of far less cost and far greater efficiency than insulated single or multiple strand wire conductors, wire mesh, and metal strip conductors of comparable cross section in conventional use.

Although electroconductive fibers of commercial metal wool are preferred, the invention is not restricted thereto. The fibers need not necessarily be metal. Essential requirements are that they be electroconductive, flexible, light in weight, very small in cross section, and not insulated. Furthermore, it is within the purview of the invention, and intended, that where conditions of use so require the material of the supporting body in which the fibers are embedded may be of thermosetting plastic.

An important aspect of the invention is the fact that the nature of the material constituting the supporting body, and also of any release agent that may be used, is such that it is readily displaceable by the fibers when moving into or at their points of surface contact, and will after such displacement immediately return to complete coverage of all surfaces of the fibers not actually in electrical contact resulting from such movement.

It is to be understood that the external surface of the element may be coated or otherwise covered with insulating material (not shown) where desired.

We claim:

1. An electrical element comprising a homogeneous filamentary structure of uniform density constituted of matted fibers of electroconductive material, said filamentary structure embedded in a supporting body of dielectric plastic, said plastic completely filling all spaces between the fibers and covering the fibers free from adherence thereto.

2. An electrical element as in claim **1**, said fibers being metal wool, and said plastic being a polymer from the group consisting of rubbers and elastomers, and flexible plastics.

3. An electrical element as in claim **1**, said fibers being metal wool, and said plastic being a material of putty-like consistency.

4. An electrical element comprising a mass of metal wool of uniform density, said metal wool embedded in a supporting body of silicone rubber, the silicone rubber completely filling all spaces between the fibers of the wool in surface contact with the fibers and free from adherence thereto.

5. An electrical element comprising a mass of uniform density constituted of matted fibers of electroconductive material, said fibers embedded in a supporting body of dielectric plastic completely filling all spaces between the fibers and normally adhesive with respect thereto, and said fibers having a coating of a material preventing adhesion between the fibers and the plastic.

6. An electrical element as in claim **5**, said fibers being metal wool, and said plastic being a polymer from the group consisting of rubbers, polymers, and flexible plastics.

7. An electrical element comprising a homogeneous filamentary structure constituted of matted fibers of metal wool in continuous electrical contact, the filamentary structure having a uniform density such that no area thereof encompassed by a circle of substantially one-sixteenth inch in diameter is lacking in fibers, said filamentary structure being completely embedded in a supporting body of polymeric plastic material, said body material completely filling all spaces between the fibers and being free from adhesion thereto, whereby the fibers are free to move individually while maintaining electrical contact within and relative to the body material and to each other under the influence of and in conformance with distorting movements of the body material.

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