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Description

This invention relates to electrical devices comprising conductive members having different resistivities.

Many electrical devices, particularly heaters, comprising conductive members having different resistivities are known. Such devices may comprise, for example, a metallic member used in conjunction with a resistive element such as a conductive polymer, i.e. a mixture comprising a conductive filler and an organic polymer (this term being used to include polysiloxanes), the filler being dispersed in the organic polymer or otherwise held together by the organic polymer, or a ceramic. The conductive polymer may exhibit PTC behavior. Documents describing conductive polymer compositions and devices comprising them include U.S. Patents Nos. 2,952,761, 2,978,665, 3,243,753, 3,351,882, 3,571,777, 3,757,086, 3,793,716, 3,823,217, 3,858,144, 3,861,029, 3,950,604, 4,017,715, 4,072,848, 4,085,286, 4,117,312, 4,177,376, 4,177,446, 4,188,276, 4,237,441, 4,242,573, 4,246,468, 4,250,400, 4,252,692, 4,255,698, 4,271,350, 4,272,471, 4,304,987, 4,309,596, 4,309,597, 4,314,230, 4,314,231, 4,315,237, 4,317,027, 4,318,881, 4,327,351, 4,330,704, 4,334,351, 4,352,083, 4,388,607, 4,398,084, 4,413,301, 4,425,397, 4,426,339, 4,426,633, 4,427,877, 4,435,639, 4,429,216, 4,442,139, 4,459,473, 4,481,498, 4,476,450, and 4,502,929; J. Applied Polymer Science 19, 813-815 (1975), Klason and Kubat; Polymer Engineering and Science 18, 649-653 (1978), Narkis et al; and commonly assigned U.S. Serial Nos. 601,424 now abandoned, published as German OLS No. 1,634,999; 732,792 (Van Konynenburg et al), now abandoned, published as German OLS No. 2,746,602; 798,154 (Horsma et al), now abandoned, published as German OLS No. 2,821,799; 134,354 (Lutz); 141,984 (Gotcher et al), published as European Application No. 38,718; 141,988 (Fouts et al), published as European Application No. 38,718, 141,989 (Evans), published as European Application No. 38,713, 141,991 (Fouts et al), published as European Application No. 38,714, 150,909 (Sopory), published as UK Application No. 2,076,106A, 184,647 (Lutz), 250,491 (Jacobs et al) published as European Application No. 63,440, 272,854 and 403,203 (Stewart et al), published as European Patent Application No. 67,679, 274,010 (Walty et al), 300,709 and 423,589 (Van Konynenburg et al), published as European Application No. 74,281, 369,309 (Midgley et al), 483,633 (Wasley), 493,445 (Chazan et al), published as European Patent Application Publication No. 128,664, 606,033, (Leary et al), published as European Application No. 119,807, 509,897 and 598,048 (Masia et al) published as European Application Publication No. 133,748, 524,482 (Tomlinson et al) published as European Application Publication No. 134,145, 534,913 (McKinley), 535,449 (Cheng et al) published as European Application No. 138,424, 84,306,456.9, 552,649 (Jensen et al) published as European Application No. 144,187 and 904,736, published as UK Patent Nos. 1,470,502 and 1,470,503. The application contemporaneously filed with this application (our reference MP0959-COM) corresponding to U.S. Serial No. 650,918 and European Patent Application No. 85300415.8 corresponding to U.S. Serial No. 573,099 (MP0897, Batliwalla et al). The disclosure of each of the patents, publications and applications referred to above is incorporated herein by reference.

Care is required to ensure satisfactory electrical contact, with a minimum of contact resistance, between two members of different resistivities. This is especially true when a large and/or long contact area is needed, as for example in strip heaters and large sheet heaters, where contact is to be made, for example, between a metallic member and a resistive element composed of a conductive polymer. Methods have been proposed for achieving such contact between a metallic member and a resistive element. Some of those methods involve heating the metallic member and the conductive polymer in contact therewith at a temperature above the melting point of the conductive polymer; the molten conductive polymer can be contacted with a suitably preheated metallic member, and/or the metallic member and conductive polymer can be heated after they have been brought into contact. It is also known to coat the metallic member with a highly conductive polymer, e.g., containing a relatively high concentration of silver or graphite, before contacting it with the conductive polymer of the resistive element. Other proposed methods involve the use of conductive adhesives, staples or rivets (or other low resistance connection member).

We have now discovered that if a contact layer, composed of a material whose resistivity is between that of two conductive members having different resistivities is sandwiched between the two conductive members and is bonded to the surface of the highest resistivity member, improved electrical contact between the said two members is achieved.

In accordance with the present invention there is provided an electrical device which comprises:

- (1) a resistive element composed of a first material which has a resistivity at 23° C of 1 to 500,000 ohm.cm;
- (2) a contact layer which is directly bonded to a surface of the resistive element, and is composed of a second conductive material having a resistivity at 23° C which is less than the resistivity at 23° C of the first material; and

(3) a further member which is composed of a third conductive material, preferably a metal, having a resistivity at 23° C which is less than the resistivity at 23° C of the second material, said further member being in direct physical contact with the contact layer and being maintained in such contact substantially only by means of pressure over a connection area which is at least 3.23 cm² (0.5 inch²) in area or which

has at least one dimension greater than 2.54 cm (1 inch),
the components of the device being positioned such that the device can be connected to a source of electrical power so that an electrical path exists from the further member to the resistive element through the contact layer.

With such an arrangement good electrical contact between the resistive element and the further member, that is the lowest resistivity member, can be achieved merely by pressing the further member against the contact layer, even when the connection area is large and/or long and even when the pressure is sufficiently low to allow the further member to be moved relative to the contact layer. In one preferred embodiment the further member provides a connection means for connection, for example to a power supply.

In the devices of the invention, there is preferably no direct physical contact between the resistive element and the further member.

The resistive element in the devices of the invention is preferably composed of a conductive polymer. When the device is a heater, the conductive polymer preferably exhibits PTC behavior, thus rendering the heater self-regulating. The preferred range of resistivity at 23° C depends upon the dimensions of the heater and the power supply to be used, e.g. 5 to 50 ohm.cm for voltages up to 6 volts DC, 50 to 500 ohm.cm for 4 to 60 volts DC, 500 to 10,000 ohm.cm for 110 to 240 volts AC and 10,000 to 100,000 ohm.cm for voltages greater than 240 volts AC. The conductive filler in the conductive polymer usually comprises, and preferably consists essentially of, carbon black.

The contact layer preferably also is composed of a conductive polymer. The contact layer can exhibit PTC, substantially ZTC or NTC behavior in the operating temperature range of the device. The ratio of the resistivity of the resistive layer material to the resistivity of the contact layer material is preferably at least 20:1, preferably at least 100:1, especially at least 1000:1, or even higher, e.g. at least 100,000:1. The contact layer can be applied to the resistive layer by printing a conductive ink thereon, or through use of polymer thick film technology, or by a process comprising an etching step, or in any other way. The contact layer can be present only between the most conductive member and the resistive element, or can extend beyond the connection member, in which case it may act as a preferential current carrier.

In the device according to the present invention, wherein the lowest resistivity member is preferably metal and preferably functions as a connection means, it is preferred that the contact layer extends beyond the lowest resistivity member in which case the contact layer can provide one or more electrodes which extend beyond the connection member.

The electrodes provided by the contact layer are preferably arranged in a manner similar to that disclosed in our copending, Application No. 85300415.8 filed 85/01/22 (EP-A-0158410) corresponding to U.S. Serial No. 573,099 (MPO897), i.e. there are a plurality of ribbon-shaped electrodes which are dimensioned and positioned on a surface of the resistive heating element (in our case the highest resistivity layer) so that

(a) when current passes between the electrodes, a substantial proportion of the current is parallel to the faces of the resistive element, and

(b) the ratio of the average width of the electrodes, measured parallel to the faces of the resistive element, to the average distance between adjacent electrodes between which current passes, measured parallel to the faces of the resistive element, is at least 0.01:1, particularly at least 0.1:1.

Preferably the electrodes are so positioned and dimensioned that, at all points, the distance between adjacent electrodes between which current passes, measured parallel to the faces of the resistive element, is not more than three times the average distance between adjacent electrodes between which current passes, measured parallel to the faces of the resistive element. It is particularly preferred that the ratio of the average width of the electrodes to the average distance between the electrodes between which current passes is from 0.4:1 to 5:1, especially an arrangement in which the electrodes comprise a plurality of parallel bars which are preferably spaced apart from each other by substantially the same distance. Preferably adjacent electrodes are less than 1 inch apart. When the resistive element is conductive polymer which has been melt-extruded, the electrodes are preferably arranged so that the current flows along the direction of extrusion.

The devices of the present invention each provide three components arranged relative to each other so that an electrical path can exist from the component having the lowest resistivity of the three components to the component having the highest resistivity of the three components through the other, intermediate resistivity component. The devices may comprise more than three components of different resistivity.

Where there are more than three components, the components are preferably arranged sequentially in order of their resistivity, so that the electrical contact between any two components is improved by the presence of an intermediate resistivity layer between them. For example, a preferred electrical device comprises four components of different resistivities in which the component having the lowest resistivity of the four comprises a metal connection member for connection to an electrical power source. It contacts a second higher resistivity member, which preferably extends beyond the connection member to provide electrodes, and in turn contacts a third higher resistivity layer, which preferably has the same configurations, but extends slightly beyond the second layer. The third layer in turn contacts a higher resistivity layer which preferably provides a substrate resistive element. The device according to this form of the invention comprises four members of sequentially increasing resistivity.

By arranging one or more intermediate resistivity layers between the members of different resistivities in this way, good electrical contact may be achieved between members having resistivities whose ratios differ by 10^{10} , and even up to 10^{12} .

In preferred devices according to the invention, the contact layer preferably comprises a conductive polymer in which the conductive filler consists of or contains a metal, preferably silver, or a mixture of silver with graphite or silver with graphite and carbon black. In this case the contact layer preferably has a resistivity in the range 2.5×10^{-5} to 1×10^{-3} ohm.cm. In other preferred devices according to the invention, the contact layer preferably comprises a conductive polymer in which the conductive filler consists of graphite and/or carbon black, or a mixture of graphite and/or carbon black with a metal, for example silver, wherein there is more graphite and/or carbon black than silver. In this case the contact layer preferably has a resistivity in the range 0.5×10^{-2} to 0.1 ohm.cm.

Preferred features of the further member in devices according to the invention are now discussed. Particularly in devices wherein the further member preferably provides a connection member, that member is preferably composed of at least one metal, e.g. copper, which is usually preferred for reasons of economy, aluminum, nickel, silver or gold, or a coating of one metal on another, e.g. nickel-coated or tin-coated copper, and is usually a wire or sheet or tape, and may be straight or bent or folded. Generally there are two or more connection members in each device, the members being connectable to a power supply to cause current to pass through the resistive element. Either the connection area between each connection member and a contact layer is at least 3.23 cm^2 (0.5 inch^2), preferably at least 32.26 cm^2 (5 inch^2), e.g. at least 64.52 cm^2 (10 inch^2), in area and can be very much more, or the connection area has at least one dimension greater than 1.26 cm (0.5 inch), preferably greater than 2.54 cm (1 inch) and can be much more, e.g. at least 12.70 cm (5 inch). Preferably the connection member makes substantially continuous contact with the contact layer, but this is not essential.

In the devices according to the invention wherein the further member has a resistivity greater than 1×10^{-5} Ohm cm, and is therefore non-metallic, that member is preferably composed of a conductive polymer. The member can exhibit PTC, substantially ZTC or NTC behavior in the operating temperature range of the device.

The further member has a resistivity less than that of the contact layer but greater than 1×10^{-5} ohm.cm. Preferably the further member has a resistivity in the range 1×10^{-5} to 1×10^{-2} ohm.cm, more preferably in the range 1×10^{-4} to 1×10^{-3} ohm.cm. In a preferred embodiment the resistivity is about 5×10^{-4} ohm.cm.

Where the further member comprises a conductive polymer, it may be applied to the contact layer in the same way that the contact layer is applied to the resistive layer, through the use of polymer thick film technology, or by a process comprising an etching step or it may be applied in any other way.

Devices according to the invention include (i) sheet heaters, e.g. a sheet heater wherein the resistive element is a laminar element comprising spaced-apart substantially flat surfaces to which the contact layers are bonded and in particular include sheet heaters wherein the further members are connection members, the connection members having substantially flat surfaces which are pressed against the respective contact layers, and the contact layers extend beyond the areas of contact with the connection members to provide a plurality of electrodes; and (ii) strip heaters wherein the resistive element is in the form of a strip comprising spaced-apart concave surfaces to which the contact layers are bonded, and the connection members have substantially complementary convex surfaces which are pressed against the respective contact layers.

Devices according to the present invention preferably include a dielectric layer, covering and intimately bonded to at least part of the electrodes. Devices according to the invention, especially devices which are heaters, preferably also comprises a laminar polymeric insulating element which is adjacent to, but not secured to, the electrodes or dielectric layer (if present), or to the electrode bearing face of the resistive element. Preferably the insulating element is arranged in a manner described in the Patent Application No. 85306476.4 (EP 0175550A), filed contemporaneously with this application corresponding to U.S. Serial No.

650,918 (MP0959, Batliwalla et al).

In the device according to the present invention the connection area between the contact layer and the further member is at least 6.45 cm² (1 square inch), preferably at least 32.26 square centimeters, (5 square inches) in area. The connection area preferably has at least one dimension greater than 7.62 cm (3 inches).

An advantage of devices according to the invention is that they can be used in applications where it is necessary for the device to carry a current of at least 5, and in some situations at least 10 Amps.

Embodiments of the present invention will now be described by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a cross-section through a first sheet heater according to the invention,

Figure 2 is a plan view of the resistive element, contact layers and connection members of Figure 1,

Figure 3 is a cross-section through a strip heater of the invention;

Figure 4 is a cross-section through a second sheet heater according to the invention; and

Figure 5 is a plan view of the resistive element contact layers, further members, and connection members of Figure 4.

Referring now to the drawings, Figures 1 and 2 illustrate a heater which comprises a heating element comprising a laminar conductive polymer resistive element 11 having printed on the top surface thereof inter-digitated electrodes 12 and 13 which are composed of a conductive polymer composition containing a metal, e.g. silver, as the conductive filler and having substantially lower resistivity than the conductive polymer in element 11. Bus bars 15 and 16, composed of expanded metal mesh, are folded around marginal portions of the element 11 and the electrodes 12 and 13 respectively, the marginal portions of the electrodes providing the contact layers of the present invention. An insulating jacket is formed around the heating element and bus bars by a polymeric bottom sheet 17 and a polymeric top sheet 18. Sheet 17 is secured to the bottom of the resistive element, to the bottom of the bus bars and to edge portions of the top sheet by a substantially continuous layer of adhesive 21 (as shown), or by melt bonding (not shown). The top sheet is adjacent to, but not secured to, the bus bars, electrodes and resistive element. On top of the top sheet there is a metallic, e.g. copper, foil 19 which is maintained in position by an outer polymeric insulating sheet 20, whose marginal portions are secured to the marginal portions of the sheet 18 by adhesive layers 22 and 23 (as shown), or by melt bonding (not shown). As shown in Figure 2, the electrodes have a width t and a length l , and are separated by a distance d , and the bus bars have a width

x . Typical values for these variables are

t 0.08 - 0.51 cm (0.03 - 0.2 inch)

l 6.35 - 15.24 cm (2.5 - 6.0 inch)

d 0.25 - 0.76 cm (0.1 - 0.3 inch)

x 1.02 - 2.04 cm (0.4 - 0.8 inch)

Figure 3 is a cross-section through a self-regulating strip heater having a constant cross-section along its length. An elongate strip 1 of PTC conductive polymer has concave edges which are coated with contact layers 2 and 3 of a ZTC conductive polymer whose resistivity at room temperature is several times less than that of the PTC conductive polymer. Elongate wires 5 and 6, which may be solid or stranded, are pressed against the contact layers 2 and 3 respectively by means of polymeric insulating jacket 7.

Figures 4 and 5 illustrate a heater similar to that shown in Figures 1 and 2 which comprises a heating element comprising a laminar conductive polymer resistive element 11. Printed on the top surface of the resistive element 11 is an interdigitated pattern of a resistive conductive polymer composition 30 which contains carbon black, or a mixture of graphite and carbon black, as the conductive filler, and has substantially lower resistivity than the conductive polymer in the element 11. Printed over the resistive pattern 30 are interdigitated electrodes 32 which are composed of a conductive polymer containing a metal e.g. silver, as the conductive filler and having lower resistivity than the conductive polymer in the resistive pattern 30. The configuration of the electrodes 32 is identical to that of the underprint layer 30, but the electrodes are narrower than the underprint layer. Thus the layer 30 extends between the electrodes 32 and the resistive element 11 and extends slightly beyond the electrodes 32. Bus bars 15 and 16, as used in the device of Figures 1 and 2 are provided. An insulating jacket in the form of a polymeric bottom sheet 17 and a polymer top sheet 18 which is secured by adhesive 21 or by a melt bond, is also provided as in the device illustrated in Figures 1 and 2, as is a metallic foil 19 which is held in place by polymeric insulating sheet 20 secured to sheet 18 by adhesive layers 22 and 23 or by a melt bond. The width t and length l , of the electrodes 32 are the same as those for the electrodes 12 and 13 illustrated in Figure 1. The width t' and the separation distance d' of the underprint layer 30 are

t' 0.15 - 1.02 cm (0.06 - 0.4 inch)

d' 0.25 - 0.76 cm (0.1 - 0.3 inch)

The invention is further illustrated by the following Examples.

Example 1

A heater as illustrated in Figures 1 and 2 was made in the following way.

The ingredients listed below were compounded together and melt-extruded at 232° C (450° F) as a sheet 0.04 cm (0.0175 inch) thick.

Ingredient	% by weight
Polyvinylidene fluoride ("Kynar")	79.7
Carbon Black (Vulcan XC-72)	10.2
Fillers and other additives	10.1

The sheet was irradiated to a dose of 14 megarads, thus cross-linking the polymer. The resistivity of the cross-linked composition at 23° C was 3,500 ohm.cm. The sheet was then heated and split into strips 18.42 cm (7.25 inches) wide. An electrode pattern as illustrated in Figure 1 was deposited on the strips, by screen-printing a graphite-and-silver-containing composition onto the strip, followed by drying. The resistivity of the printed composition, after it had dried, was about 10^{-4} ohm.cm. The distance (d) between adjacent electrodes was 0.64 cm (0.25 inch); the width (t) of each electrode was 0.16 cm (0.0625 inch); and the length (l) of each electrode was 13.72 cm (5.4 inches).

Bus bars of nickel-coated copper expanded metal, 3.81 cm (1.5 inch) wide, were folded around the edges of the electrode-bearing strip, and the assembly laminated between (A) a bottom sheet of ethylene-chlorotrifluoroethylene copolymer ("Halar") 21.6 cm (8.5 inch) wide and 0.05 cm (0.020 inch) thick, coated on the whole of its top surface with a layer 0.005 cm (0.002 inch) thick of a silicone adhesive sold by Adhesives Research Corporation under the trade name "Arclad", and (B) a top sheet of ethylene-chlorotrifluoroethylene ("Halar") 21.6 cm (8.5 inch) wide and 0.025 cm (0.010 inch) thick, placed in contact with the printed electrodes, which was coated on 1.27 cm (0.5 inch) wide edge portions of its bottom surface with a layer 0.005 cm (0.002 inch) thick of the same adhesive. Lamination was carried out at 52° C (125° F) and 690 KPa (100 psi). There was no adhesive between the top sheet and the bus bars, or between the top sheet and the conductive polymer sheet, or between the top sheet and the electrodes. A sheet of copper, 0.005 cm (0.002 inch) thick and 18.24 cm (7.25 inch) wide, was placed on the exposed surface of the top sheet, and an outer sheet of ethylene-chlorotrifluoroethylene ("Halar"), 21.6 cm (8.5 inch) wide and 0.01 cm (0.005 inch) thick, was placed over the copper sheet and laminated [at 52° C (125° F) and 690 KPa (100 psi)] to the edge portions of the bottom sheet (but not the copper foil), through 1.27 cm (0.5 inch) wide layers of 0.005 cm (0.002 inch) thick "Arclad" adhesive on edge portions of the outer sheet. There was no adhesive between the outer sheet and the copper foil.

Example 2

A heater as illustrated in Figure 4 was made in a same way to the heater illustrated in Figures 1 and 2 as described in Example 1, except that before the electrode pattern was deposited on the strips, an underprint layer comprising a graphite containing composition, having a resistivity of about 0.1 ohm.cm, i.e., intermediate between the resistivity of the resistive element and the electrodes, was deposited on the strips by screen printing, and then dried. The electrodes were then screen printed directly to overlie the underprint layer. The interdigitated portions of the underprint layers were twice as wide as the electrodes. Thus the width (t) of each electrode was 0.16 cm (0.0625 inch) and the width (t') of each of the interdigitated portions of the underprint layer was 0.32 cm (0.125 inch). The distance (d') between adjacent interdigitated portions of the underprint layer was 0.64 cm (0.25 inch).

Claims

1. An electrical device which comprises

- (1) a resistive element composed of a first conductive material which has a resistivity at 23° C of 1 to 500,000 ohm.cm;
- (2) a contact layer which is directly bonded to a surface of the resistive element, and is composed of a second conductive material having a resistivity at 23° C which is less than the resistivity at 23° C of the first material; and
- (3) a further member which is composed of a third conductive material having a resistivity at 23° C which is less than the resistivity at 23° C of the second material, said further member being in direct

physical contact with the contact layer and being maintained in such contact substantially only by means of pressure over a connection area which is at least 3.23 cm^2 (0.5 inch^2) in area or which has at least one dimension greater than 2.54 cm (1 inch),

the components of the device being positioned such that the device can be connected to a source of electrical power so that an electrical path exists from the further member to the resistive element, through the contact layer.

2. A device according to claim 1 wherein the second material has a resistivity at 23°C which is from 10^{-6} to 10^3 ohm.cm and which is such that the ratio of the resistivity at 23°C of the first material to the resistivity at 23°C of the second material is at least 20:1, and wherein the further member is composed of a metal.
3. A device according to claim 1 or 2, which comprises at least two further members in the form of continuous elongate metallic connection members which can be connected to a power source to cause current to flow through the resistive element and which make substantially continuous contact with the resistive element through respective contact layers.
4. A device according to claim 1, 2, or 3, which is a sheet heater wherein the resistive element is a laminar element comprising spaced-apart substantially flat surfaces to which the contact layers are bonded, and the metallic members have substantially flat surfaces which are pressed against the respective contact layers, wherein the contact layers preferably extend beyond the area of contact with the metallic members to provide a plurality of inter-digitated electrodes.
5. A device according to claim 3, which is a strip heater wherein the resistive element is in the form of a strip comprising spaced-apart concave surfaces to which the contact layers are bonded, and the metallic members have substantially complementary convex surfaces which are pressed against the respective contact layers.
6. A device according to any preceding claim, wherein at least one of the first and second materials is a conductive polymer which comprises an organic polymer and, dispersed in the polymer, a particulate conductive filler, which filler preferably comprises at least one of silver, graphite and carbon black.
7. A device according to any preceding claim, wherein the first material is a conductive polymer which exhibits PTC behaviour in the operating temperature range of the device.
8. A device according to any preceding claim, wherein there is no direct physical contact between the resistive element and the further member.

Patentansprüche

1. Elektrische Einrichtung, die folgendes aufweist:

(1) ein Widerstandselement, das aus einem ersten leitfähigen Material besteht, das einen spezifischen Widerstand von $1-500\,000 \text{ Ohm}\cdot\text{cm}$ bei 23°C hat;

(2) eine Kontaktschicht, die mit einer Oberfläche des Widerstandselements direkt verbunden ist und aus einem zweiten leitfähigen Material besteht, das einen spezifischen Widerstand bei 23°C hat, der niedriger als der spezifische Widerstand bei 23°C des ersten Materials ist; und

(3) ein weiteres Element, das aus einem dritten leitfähigen Material besteht, das einen spezifischen Widerstand bei 23°C hat, der niedriger als der spezifische Widerstand bei 23°C des zweiten Materials ist, wobei das weitere Element in direktem physischem Kontakt mit der Kontaktschicht ist und in einem solchen Kontakt im wesentlichen nur durch Druck über eine Anschlußfläche gehalten ist, deren Fläche wenigstens $3,23 \text{ cm}^2$ ($0,5 \text{ inch}^2$) ist oder die wenigstens eine Dimension hat, die größer als $2,54 \text{ cm}$ (1 inch) ist,

wobei die Komponenten der Einrichtung so positioniert sind, daß die Einrichtung an eine Stromversorgung anschließbar ist, so daß durch die Kontaktschicht hindurch ein elektrischer Pfad von dem weiteren Element zu dem Widerstandselement existiert.

2. Einrichtung nach Anspruch 1, wobei das zweite Material einen spezifischen Widerstand bei 23°C hat, der zwischen 10^{-6} und $10^3 \text{ Ohm}\cdot\text{cm}$ liegt und derart ist, daß das Verhältnis des spezifischen

Widerstands bei 23 ° C des ersten Materials zu dem spezifischen Widerstand bei 23 ° C des zweiten Materials wenigstens 20:1 beträgt, und wobei das weitere Element aus einem Metall besteht.

3. Einrichtung nach Anspruch 1 oder 2, die wenigstens zwei weitere Elemente in Form von kontinuierlichen langgestreckten metallischen Anschlußelementen aufweist, die an eine Stromversorgung anschließbar sind, um zu bewirken, daß Strom durch das Widerstandselement fließt, und die durch entsprechende Kontaktschichten hindurch einen im wesentlichen kontinuierlichen Kontakt mit dem Widerstandselement herstellen.
4. Einrichtung nach Anspruch 1, 2 oder 3, die eine flächige Heizeinrichtung ist, wobei das Widerstandselement ein laminares Element ist, das voneinander beabstandete im wesentlichen ebene Oberflächen aufweist, mit denen die Kontaktschichten verbunden sind, und die metallischen Elemente im wesentlichen ebene Oberflächen haben, die gegen die entsprechenden Kontaktschichten gepreßt sind, wobei die Kontaktschichten sich vorzugsweise über den Bereich des Kontakts mit den metallischen Elementen hinaus erstrecken, um eine Vielzahl von fingerartig ineinandergreifenden Elektroden zu bilden.
5. Einrichtung nach Anspruch 3, die eine bandförmige Heizeinrichtung ist, wobei das Widerstandselement die Form eines Bands hat, das voneinander beabstandete konkave Oberflächen aufweist, mit denen die Kontaktschichten verbunden sind, und die metallischen Elemente im wesentlichen komplementäre konvexe Oberflächen haben, die gegen die entsprechenden Kontaktschichten gepreßt sind.
6. Einrichtung nach einem der vorhergehenden Ansprüche, wobei wenigstens entweder das erste oder das zweite Material ein leitfähiges Polymer ist, das ein organisches Polymer und, in dem Polymer dispergiert, einen teilchenförmigen leitfähigen Füllstoff aufweist, der vorzugsweise wenigstens eines der Materialien Silber, Graphit und Ruß aufweist.
7. Einrichtung nach einem der vorhergehenden Ansprüche, wobei das erste Material ein leitfähiges Polymer ist, das im Betriebstemperaturbereich der Einrichtung ein PTC-Verhalten zeigt.
8. Einrichtung nach einem der vorhergehenden Ansprüche, wobei kein direkter physischer Kontakt zwischen dem Widerstandselement und dem weiteren Element besteht.

Revendications

1. Dispositif électrique qui comprend :
 - (1) un élément résistif constitué d'une première matière conductrice qui possède une résistivité à 23° C de 1 à 500 000 ohms.cm ;
 - (2) une couche de contact qui est liée directement à une surface de l'élément résistif et est constituée d'une deuxième matière conductrice ayant une résistivité à 23° C qui est inférieure à la résistivité à 23° C de la première matière ; et
 - (3) un élément supplémentaire qui est constitué d'une troisième matière conductrice ayant une résistivité à 23° C qui est inférieure à la résistivité à 23° C de la deuxième matière, ledit élément supplémentaire étant en contact physique direct avec la couche de contact et étant maintenu dans un tel contact pratiquement seulement au moyen d'une pression sur une zone de connexion qui possède une surface d'au moins 3,23 cm² (0,5 inch²) ou qui possède au moins une dimension supérieure à 2,54 cm (1 inch),les constituants du dispositif étant positionnés de telle sorte que le dispositif puisse être connecté à une source de courant électrique afin qu'il existe un trajet électrique allant de l'élément supplémentaire à l'élément résistif, par l'intermédiaire de la couche de contact.
2. Dispositif suivant la revendication 1, dans lequel la deuxième matière possède une résistivité à 23° C qui est comprise dans l'intervalle de 10⁻⁶ à 10³ ohms.cm et qui est telle que le rapport de la résistivité à 23° C de la première matière à la résistivité à 23° C de la deuxième matière soit au moins égal à 20:1, et dans lequel l'élément supplémentaire est constitué d'un métal.
3. Dispositif suivant la revendication 1 ou 2, qui comprend au moins deux éléments supplémentaires sous forme d'éléments métalliques allongés continus de connexion qui peuvent être connectés à une source de courant pour provoquer le passage d'un courant à travers l'élément résistif et qui assurent un

contact pratiquement continu avec l'élément résistif à travers les couches respectives de contact.

- 5 **4.** Dispositif suivant la revendication 1, 2 ou 3, qui est un dispositif de chauffage sous forme de feuille dans lequel l'élément résistif est un élément laminaire comprenant des surfaces pratiquement plates espacées auxquelles les couches de contact sont liées, et les éléments métalliques possèdent des surfaces pratiquement plates qui sont comprimées contre les couches de contact respectives, les couches de contact s'étendant de préférence au-delà de la zone de contact avec les éléments métalliques pour produire plusieurs électrodes interdigitées.
- 10 **5.** Dispositif suivant la revendication 3, qui est un dispositif de chauffage sous forme de bande dans lequel l'élément résistif est sous forme d'une bande comprenant des surfaces concaves espacées auxquelles les couches de contact sont liées, et les éléments métalliques possèdent des surfaces convexes pratiquement complémentaires qui sont comprimées contre les couches de contact respectives.
- 15 **6.** Dispositif suivant l'une quelconque des revendications précédentes, dans lequel au moins l'une des première et deuxième matières est un polymère conducteur qui comprend un polymère organique et, dispersée dans le polymère, une charge conductrice en particules, charge qui consiste de préférence en au moins un composé choisi entre l'argent, le graphite et le noir de carbone.
- 20 **7.** Dispositif suivant l'une quelconque des revendications précédentes, dans lequel la première matière est un polymère conducteur qui présente un comportement de coefficient de température positif dans la plage de températures de fonctionnement du dispositif.
- 25 **8.** Dispositif suivant l'une quelconque des revendications précédentes, dans lequel il n'existe aucun contact physique direct entre l'élément résistif et l'élément supplémentaire.

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Fig. 1.

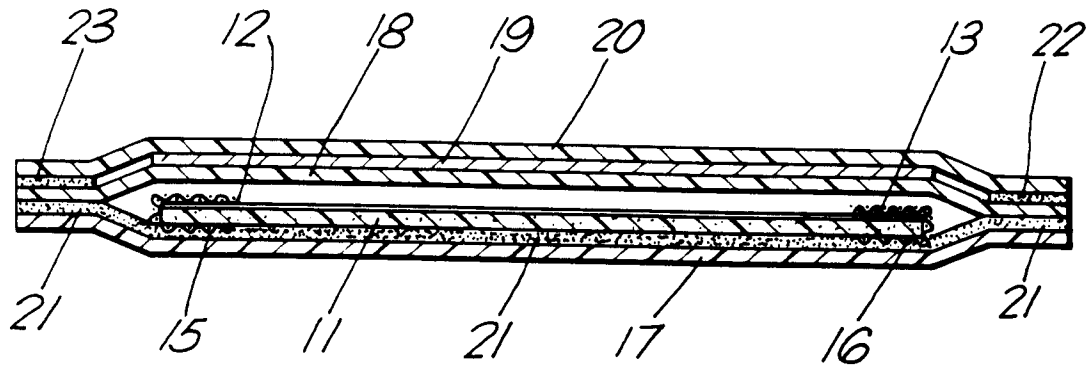


Fig. 2.

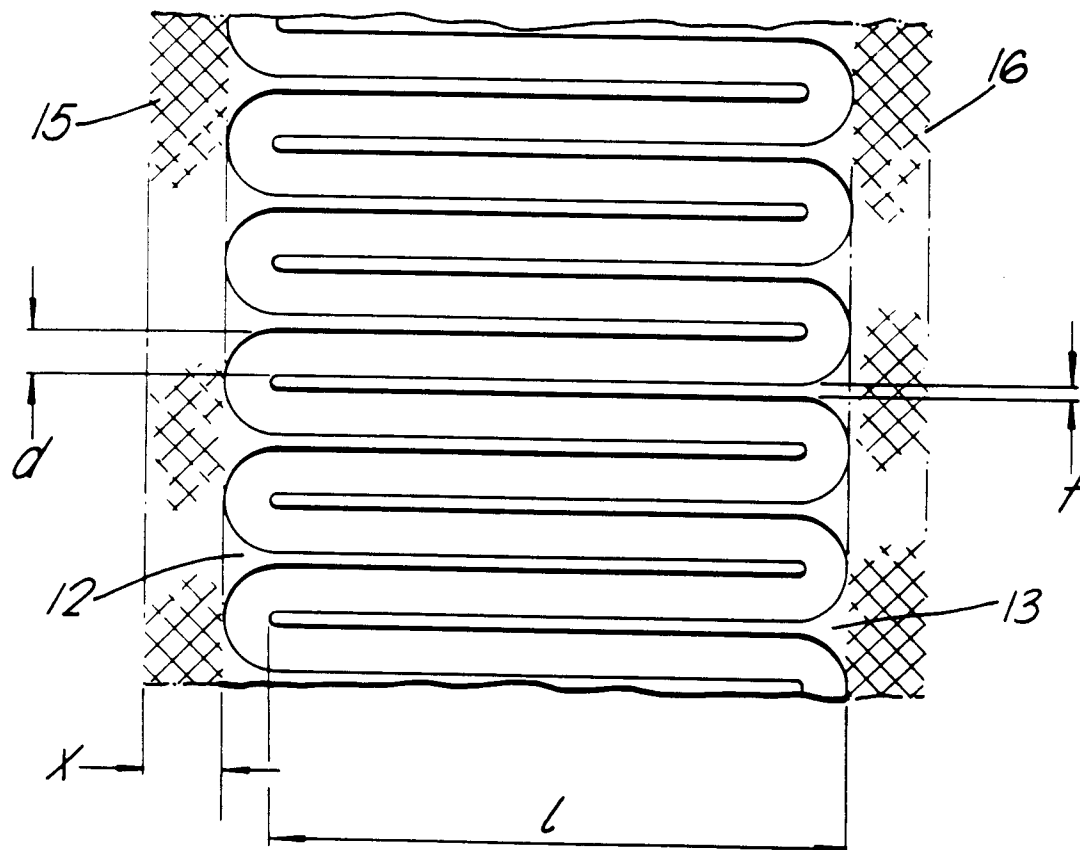


Fig . 3.

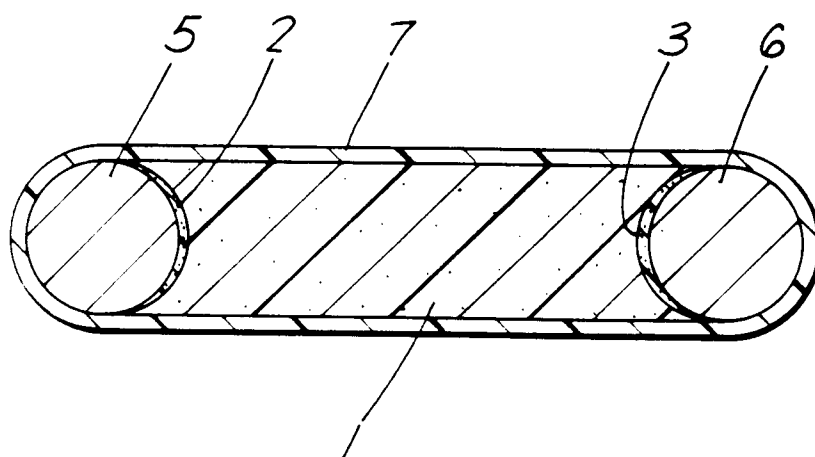


Fig . 4.

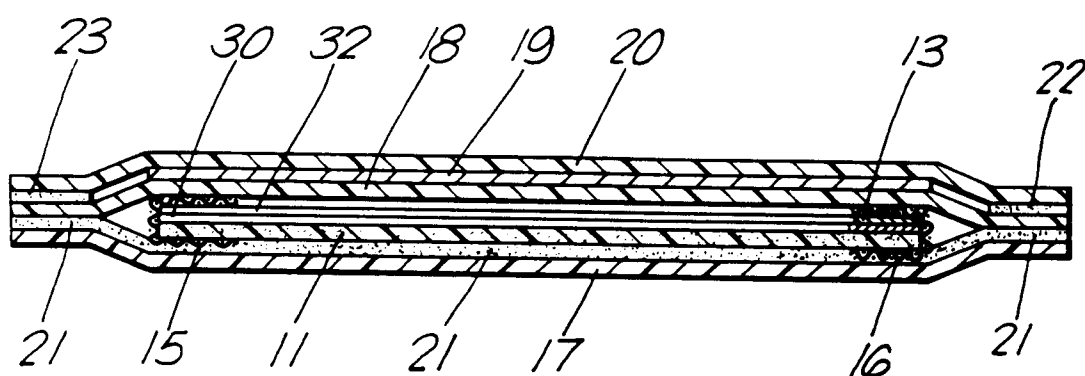


Fig. 5.

