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54 **Electrical devices comprising PTC elements.**

57 A laminar electrical heater in which at least one of the electrodes is in the form of an elongate element forming part of a fabric and which comprises a PTC element, e.g. of a conductive polymer, to render the heater self-regulating. Preferably the heater is prepared by weaving together (a) a first elongate element comprising a first electrode (1) and a layer (11) of PTC conductive polymer surrounding that electrode, and (b) a second elongate element comprising a second electrode (2). The resulting fabric can if desired be laminated to a sheet of a ZTC (3) conductive polymer. A shrinkable fabric heater can be made by incorporating a heat-shrinkable non-conductive filament (4) into the fabric, perpendicular to both electrodes, and is useful for example for enclosing splices in telephone cables.

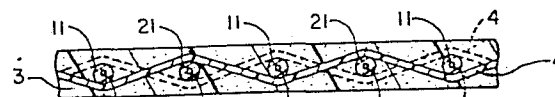


FIG. 1

BACKGROUND OF THE INVENTIONField of the Invention

This invention relates to fabrics having useful electrical properties.

5 Introduction to the Invention

Compositions which have a positive temperature coefficient of resistance ("PTC compositions") are known. They can be composed of ceramic material, eg. a doped barium titanate, or a conductive polymer material
10 eg. a dispersion of carbon black or other particulate conductive filler in a crystalline polymer. The term PTC is generally used (and is so used in this specification) to denote a composition whose resistivity preferably increases by a factor of at least 2.5 over a
15 temperature range of 14°C or by a factor of at least 10 over a temperature range of 100°C, and preferably both. The term switching temperature (or T_s) is generally used (and is so used in this specification) to denote the temperature at which a sharp increase in resistivity
20 takes place, as more precisely defined in U.S. Patent No. 4,237,441. Materials, in particular conductive polymer compositions, which exhibit zero temperature coefficient (ZTC) behavior are also known. In electrical devices which contain a PTC element and a ZTC ele-
25 ment, the term ZTC is generally used (and is so used in this specification) to denote an element which does not exhibit PTC behavior at temperature below the T_s of the PTC element; thus the ZTC element can have a resistivity

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which increases relatively slowly, or which is substantially constant, or which decreases slowly, at temperatures below the T_g of the PTC element. Materials, in particular conductive polymer compositions, which exhibit negative temperature coefficient (NTC) behavior are also known. For further details of conductive polymer compositions and devices comprising them, reference may be made for example to 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, 4,017,715, 4,072,848, 4,085,286, 4,117,312, 4,177,376, 4,177,446, 4,188,276, 4,237,441, 4,238,812, 4,242,573, 4,246,468, 4,250,400, 4,255,698, 4,242,573, 4,271,350, 4,272,471, 4,276,466, 4,304,987, 4,309,596, 4,309,597, 4,314,230, 4,315,237, 4,318,881, 4,330,704, 4,334,351, 4,352,083, 4,361,799, 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 and 4,442,139, J. Applied Polymer Science 19, 813-815 (1975), Klason and Kubat; Polymer Engineering and Science 18, 649-653 (1978), Narkis et al; German OLS Nos. 2,634,999, 732,792, 2,746,602, and 2,821,799; and European published patent application Nos. 38,713, 38,714, 38,718, 63,440, 67,679, 68,688, 74,281, 87,884, 92,406, 96,492, 84,302,717.8, 84,301,650.2 and the European applications corresponding to U.S. Serial Nos. 493,390, 524,958, 535,499 and 534,913.

SUMMARY OF THE INVENTION

There are serious limitations in the known techniques for making electrical devices which contain PTC and/or ZTC elements composed of ceramic or conductive polymer materials. Ceramic materials are brittle and

are difficult to shape, particularly when large or complex shapes are needed. Conductive polymers can be manufactured in a wider variety of shapes, but especially with PTC materials, close control is needed to
5 ensure adequate uniformity; it is yet more difficult, if not impossible, to produce a predetermined variation in properties in different parts of an article. In addition, the physical strength of laminar conductive polymer devices is often less than is desirable. When a
10 heat-shrinkable PTC conductive polymer article is required, there is the difficulty that when a PTC conductive polymer sheet is rendered heat-shrinkable (by stretching the cross-linked sheet above its melting point and then cooling it in the stretched state), the
15 PTC of the heat-shrinkable sheet is often substantially smaller than that of the original sheet; this limits the stretch ratio that can be employed and, therefore, the available recovery.

We have now discovered that improved PTC devices
20 can be prepared by incorporating at least one of the electrodes into a fabric. Thus in one aspect, the invention provides a fabric which is suitable for use as an electrical heater and which comprises an ordered array of interlaced elongate elements, said
25 fabric comprising (1) a first elongate electrode which forms at least part of one of said interlaced elongate elements; (2) a second electrode; and (3) a PTC element through which current passes when the first and second electrodes are connected to a source
30 of electrical power.

Particularly useful devices can be prepared by making use of an elongate element which comprises an

elongate electrode and a resistive element which electrically surrounds the electrode; this elongate element is converted into a fabric which can be incorporated into an electrical system or device. A
5 wide range of such elongate elements can be easily produced in a uniform manner, and through the use of known fabric-manufacturing techniques, such as weaving, knitting and braiding, they can be converted
10 into fabrics which are completely uniform or which vary in a desired predictable way. Other elongate elements can be included in the fabric to provide or enhance desired properties such as strength or heat-recoverability or other thermally induced response.

15 In a preferred embodiment, the invention provides an electrical device which comprises

(1) a first elongate element which comprises

- (i) a first elongate electrode and
- (ii) a first PTC element, preferably an elongate PTC conductive polymer element;
20 and

(2) a second electrode which is spaced apart from the first electrode;

the first and second electrodes being connectable to a source of electrical power to cause current to
25 pass through the PTC element; and the first elongate element forming part of a fabric in which the first elongate element is interlaced with at least one other elongate element to form an ordered array of interlaced

elongate elements. In one preferred embodiment of such devices, the PTC element (which may be a single elongate PTC element or a plurality of discrete PTC elements spaced apart along the length of the electrode) electrically surrounds the first electrode, i.e. the device is so constructed and arranged that, when the electrodes are connected to a power source, substantially all the current passing between the electrodes passes through the PTC element, at least at some temperatures between room temperature and the equilibrium operating temperature of the device, and preferably at all temperatures. In another preferred embodiment, the device comprises a third electrical element, preferably a ZTC conductive polymer element, through which current flows when the electrodes are connected to a power source; preferably substantially all the current passing between the electrodes passes through the third electrical element, at least at some temperatures between room temperature and the equilibrium operating temperatures of the device, and preferably at all temperatures.

Particularly useful devices are those which comprise an element, preferably a non-conductive element, which is thermally responsive and which is heated when current is passed through the device. Such devices can be recoverable, either as a result of passing current through the device or as a result of some other action. For example, very useful heat-shrinkable articles comprise a woven fabric comprising spaced-apart first and second elongate electrodes running in one direction, and heat-shrinkable non-conductive elongate elements running in the other direction, the fabric being impregnated or coated with a heat-softenable ZTC

conductive polymer. When the article is powered, the heat generated by Joule heating causes the ZTC material to soften and the non-conductive elements to shrink, thus shrinking the fabric in the direction of the non-conductive elements and drawing the electrodes closer together.

The invention also includes processes in which a recoverable article of the invention as described above, especially one containing non-conductive heat-shrinkable filaments in the fabric, is used to cover a substrate, the process comprising:

- (A) placing the device adjacent the substrate;
- (B) recovering the device against the substrate, and
- (C) passing current between the electrodes to effect a desired change in the non-conductive element.

Step (C) can be carried out before, simultaneously with, or after, step (B), and the recovery of the device can be effected by passing current between the electrodes or by some other means.

In another embodiment, the PTC element is a substantially continuous laminar element which is composed of a conductive polymer.

BRIEF DESCRIPTION OF THE DRAWING

The invention is illustrated in the accompanying drawing, in which the Figures are diagrammatic, partial,

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cross-sectional views of devices of the invention; in particular,

Figure 1 is a side view of a heat-shrinkable device;

Figure 2 is a side view of the device of Figure 1
5 after it has been powered to effect shrinkage;

Figure 3 is a plan view of the device of Figure 1;

Figure 4 is a side view of another heat-shrinkable
device;

Figure 5 is a plan view of a device similar to
10 that shown in Figure 1 and 2, but in which the
electrodes are differently arranged and the ZTC
element coats but does not fill the fabric;

Figure 6 is a side view of another device similar
15 to that shown in Figures 1 and 2 but in which one
of the electrodes is woven into one fabric and the
other electrode is woven into another fabric, and
the two fabrics are secured together by the ZTC
element;

Figure 7 is a side view of a device similar to
20 that shown in Figure 1 in which only one of the
electrodes is coated with a PTC element; and

Figure 8 is a side view of another device of the
invention.

DETAILED DESCRIPTION OF THE INVENTION

The invention will chiefly be described herein by reference to the preferred devices of the invention, in which there are two (or more) electrodes, at least one of the electrodes being an elongate electrode forming part of an elongate element which (i) comprises the electrode and a PTC conductive polymer element electrically surrounding the electrode and (ii) forms part of the fabric.

However, the invention includes similar devices in which some other type of PTC element electrically surrounds the electrode (provided of course that it permits conversion of the element into the fabric). In addition, the invention includes fabrics comprising at least one elongate element which comprises (a) an elongate metal element and (b) a conductive polymer element which substantially surrounds the elongate metal element and which may be ZTC or NTC element, for example such a fabric which further comprises another electrode which is electrically separated from the first electrode not only by the ZTC or NTC element but also by a PTC element, preferably a conductive polymer PTC element. It should be understood, therefore, that the following detailed description also applies, mutatis mutandis, to such other embodiments of the invention.

In the preferred devices of the invention, at least one of the electrodes is an elongate electrode, usually of metal, e.g. copper or nickel-coated copper, for example a solid or stranded wire, which is electrically surrounded by a PTC conductive polymer element. Usually the PTC element will be melt-shaped, preferably melt-extruded, preferably so that it physically surrounds

the electrode as a uniform coating throughout its length. However, other methods of forming the PTC element, e.g. dip-coating, and other geometric arrangements, are possible. For example the PTC element can vary in thickness and/or resistivity radially and/or longitudinally. Alternatively, the PTC element can alternate radially and/or longitudinally with polymeric elements which are electrically insulating or which have a resistance which is much higher than the resistance of the PTC element at room temperature, so that at least when the device is at relatively low temperatures, substantially all the current between the electrodes passes through the PTC element (it is to be noted that the broad definition of the devices of the invention does not exclude the possibility that at temperatures close to and above the T_g of the PTC element, a substantial part of the current does not pass through the PTC element). The PTC element can be in direct physical contact with the electrode or can be separated therefrom by a layer of ZTC material, for example a low resistivity conductive polymer. The dimensions of the PTC element and the resistivity and other properties of the PTC composition should be correlated with the other elements of the device, but those skilled in the art will have no difficulty, having regard to their own knowledge (e.g. in the documents referenced herein) and the disclosure herein, in selecting suitable PTC elements. Suitable polymers include polyethylene and other polyolefins; copolymers of one or more olefins with one or more polar comonomers e.g. ethylene/vinyl acetate, ethylene/acrylic acid and ethylene/ethylacrylate copolymers; fluoropolymers, e.g. polyvinylidene fluoride and ethylene/tetrafluoroethylene copolymers; and polyarylene polymers,

e.g. polyether ketones; and mixtures of such polymers with each other and/or with elastomers to improve their physical properties.

5 The other electrode in the preferred devices is preferably another elongate electrode which forms part of the same fabric as the first elongate element (as is usually preferred) or part of a different fabric. The second electrode can be the same as or different from the first electrode. Electrical contact
10 between the first and second electrodes can be achieved in any suitable way. For example, the second electrode can be in contact with the first PTC element; or it can be electrically surrounded by a second PTC element which has the same T_g as the first PTC element and
15 is in physical contact with a third electrical element as described above; or it can be in direct physical contact with a third electrical element as described above. Alternatively the second electrode can be an elongate electrode which is not interlaced to form part
20 of a fabric, or it can be a laminar electrode, e.g. a metal foil, apertured metal, or vapor-deposited metal electrode.

The third electrical element, when present (as is preferred), preferably comprises a ZTC conductive
25 polymer. It can be of uniform composition or can comprise discrete sub-elements; for example it may be desirable to coat an electrode or a PTC element surrounding an electrode with a first ZTC conductive polymer in order to provide improved electrical and
30 physical contact to a second ZTC conductive polymer. The third electrical element can fill or bridge the

interstices of the fabric(s), thus providing a continuous laminar element. Alternatively, the third electrical element can be coated onto the fabric(s) so that apertures remain in the fabric. In another embodiment, part (or all) of the third electrical element is provided by an elongate element which is interlaced with at least one other elongate element to form part of the fabric(s), with the remainder (if any) of the third element being coated on or otherwise united to the fabric to provide desired electrical contact between the elongate elements. The third electrical element can be thermally responsive, e.g. heat-shrinkable. The dimensions of the third electrical element and the resistivity and other properties of the ZTC conductive polymers preferably used for it should be correlated with the other elements of the device, but those skilled in the art will have no difficulty, having regard to their own knowledge (e.g. in the documents referenced herein) and the disclosure herein, in selecting suitable ZTC elements. When the device is recoverable, the ZTC element preferably has low viscosity at the recovery temperature so that it impedes recovery as little as possible. Suitable polymers for the ZTC material include copolymers of ethylene with one or more polar copolymers, e.g. ethyl acrylate and vinyl acetate.

The first elongate element (and the other elongate elements) can be formed into a fabric by any method which results in an ordered array of interlaced elongate elements. Weaving is the preferred method, but knitting, braiding etc. can be used in suitable cases. The density of the weave (or other form of interlacing)

can be selected in order to provide the desired power output or shrinkability (when the fabric incorporates shrinkable elements as described below) or other property. Similarly, the density of the weave can be varied from one area to another to provide a desired variation, eg. of at least 10% or at least 25%, in one or more properties from one discrete area (which may be, for example, at least 5% or at least 15% of the total area) to another. Triaxial weaving can be employed.

In order to pass current through the device, the electrodes must of course be connected to a power source, which may be DC or AC, e.g. relatively low voltage, e.g. 12, 24 or 48 volts. The various components of the device must be selected with a view to the power source to be employed. When the electrodes are elongate electrodes, they may be powered from one end or from a number of points along their lengths; the former is easier to provide, but the latter results in more uniform power generation.

The device may include, at least in selected areas thereof, a non-conductive element which provides desired properties, particularly a non-conductive element which is thermally responsive and which is heated when current is passed between the electrodes, or a non-conductive element, e.g. of glass fibers, which provides stiffness or other desired physical properties. The non-conductive element can be, for example, a heat-recoverable, e.g. heat-shrinkable, element. Such heat-recoverable elements can for example be composed of an organic polymer (which can be cross-linked) or a memory metal alloy. Other useful thermally responsive

members include a layer of a hot melt adhesive or a mastic; a thermochromic paint; or a component which foams when heated. The non-conductive element can be an elongate element which forms part of the fabric(s) incorporating the elongate electrode(s), e.g. a continuous monofilament or multifilament yarn or a staple fiber yarn. Suitable heat-shrinkable elements can be composed of, for example, a polyolefin, e.g. high, medium or low density polyethylene; a fluoropolymer, e.g. polyvinylidene fluoride; a polyester, e.g. polyethylene terephthalate or poly butylene terephthalate; or a polyamide, e.g. Nylon 6, Nylon 6,6, Nylon 6, 12, Nylon 11 or Nylon 12. The element is preferably capable of unrestrained recovery to less than 50%, preferably less than 35%, especially less than 25% of its stretched dimension.

An especially preferred embodiment of the invention is a heat-shrinkable device which is useful, for example, for protecting joints between elongate substrates such as telephone cables, and which comprises:

(1) a first elongate electrode which comprises

(i) a first elongate electrode composed of metal and

(ii) a PTC element composed of a PTC conductive polymer composition;

(2) a second elongate element which comprises a second elongate electrode composed of a metal;

- (3) a heat-shrinkable elongate element which shrinks when heated to a temperature T_{shrink} and which is composed of an electrically insulating polymeric composition;

5 said first, second and heat-shrinkable elongate elements having been woven together to form a fabric; and

- (4) a ZTC electrical element which is composed of a ZTC conductive polymer composition;

10 the first and second electrodes being connectable to a source of electrical power to cause current to flow through the ZTC element and to cause shrinkage of the heat-shrinkable element, and the PTC element being positioned so that, when the electrodes are connected to a power source, substantially all the
15 current passing between the electrodes passes through the PTC element.

The first and second elements generally run in one direction in the fabric (which may be the warp or the weft, depending on the ease of weaving), with the heat-shrinkable element running at right angles thereto. This
20 enables the first and second elements to accommodate to shrinkage of the heat-shrinkable element by moving closer together, without longitudinal shrinkage.

25 The first and second elements can be powered from one end, in which case they will normally have a serpentine shape. Alternatively the fabric can be woven so that the electrode is or can be exposed at regular intervals along the fabric, eg. each time it

changes direction, thus permitting the exposed ends to be bussed together by some bussing means which permits the desired shrinkage to take place. Generally, the exposed ends of the first electrodes will be joined together along one edge of the fabric and the exposed ends of the second electrode will be joined together along the opposite edge of the fabric.

In these devices, it is important that the heat generated in the conductive polymer elements is sufficient to raise the heat-shrinkable elements to their shrinkage temperature. In order to ensure that there is adequate heating of the ZTC element before the PTC element shuts off, it is preferred that the resistance of the ZTC element is greater than, preferably at least 1.2 times, the resistance of the PTC element(s) at all temperatures between 0°C and T_{shrink} . When the ZTC element forms a continuous laminar element (as is usually preferred in order to protect the substrate against which the device is to be recovered), this usually means that the resistivity of the ZTC composition is greater than, preferably at least twice, the resistivity of the PTC composition at all temperatures between 0°C and T_{shrink} .

In these devices, it is preferred that the PTC conductive polymer composition has a first resistivity ρ_1 and comprises a first polymeric component which contains at least 50% by volume of a crystalline polymer having a first melting point T_1 , the ZTC conductive polymer composition comprises a polymeric component which contains at least 50% by volume of a thermoplastic polymer having a softening point T_2 and a resistivity

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ϵ_2 ; wherein

$$T_1 > T_{\text{shrink}} > T_2,$$

and

$$\epsilon_2 > \epsilon_1 \text{ at all temperatures between } 0^\circ\text{C and } T_{\text{shrink}}.$$

5

10

It is also preferred that $(T_1 - T_2)$ is at least 30°C , particularly at least 50°C , and that $(T_1 - T_{\text{shrink}})$ is at least 10°C , preferably at least 20°C . We have obtained good results when the polymer in the PTC composition is polyvinylidene fluoride, the polymer in the ZTC composition is a copolymer of ethylene, eg. an ethylene/ethyl acrylate polymer, and the heat-shrinkable element comprises polyethylene.

15

20

The thermal properties of the device and of the surroundings are important in determining the behavior of the device. Thus the device can comprise, or be used in conjunction with, a thermal element which helps to spread heat uniformly over the device, eg. a metal foil layer, or which reduces the rate at which heat is removed from the device, eg. a layer of thermal insulation such as a foamed polymer layer.

25

Referring now to the drawing, Figure 1 is a partial cross-sectional side view of a device of the invention, showing electrodes 1 of one polarity, each surrounded by a PTC conductive polymer element 11, and parallel electrodes 2 of opposite polarity, each surrounded by a PTC conductive polymer element 21. The electrodes are

woven into a fabric with heat-shrinkable non-conductive filaments 4 at right angles to the electrodes, and the fabric is impregnated or coated with ZTC conductive polymer element 3.

5 Figure 2 is a partial cross-sectional side view of the device of Figure 1 after it has been powered to cause shrinkage of the filaments 4 and softening of the ZTC element 3.

10 Figure 3 is a partial cross-sectional plan view of a device as shown in Figure 1. The electrodes 1 are connected at one end to a bus bar connector 12 which runs along one edge of the fabric and does not prevent shrinkage of the filaments 4 when they are heated. Similarly the electrodes 2 are connected at one end to
15 a bus bar connector 22 which runs along the opposite edge of the fabric and does not prevent shrinkage of the filaments 4 when they are heated. The ZTC element 3 completely fills the interstices of the fabric.

20 Figure 4 is similar to Figure 1 and shows the same elements 1, 2, 3, 4, 11 and 21, and in addition shows elongate elements 6 which are woven into the fabric parallel to the PTC elements and are composed of a hot melt adhesive 15 which melts at the shrinkage temperature of the filaments 4. Also shown in Figure 4 is an
25 electrically insulating polymeric backing 7 which softens at the shrinkage temperature of the filaments 4.

Figure 5 is a partial cross-sectional plan view of another device of the invention which is similar to that shown in Figures 1 and 3, but in which the electrodes

follow a serpentine path and are powered from one end,
and the ZTC element 4 coats the fabric but does not
fill its interstices, leaving a plurality of voids 41.

Figure 6 is a partial cross-sectional side view
of another device of the invention which is similar to
that shown in Figures 1 and 2 except that the electrodes
1 are woven into one fabric with half of the heat-shrink-
able filaments 4, while the electrodes 2 are woven into
a second fabric with the other half of the heat-shrinkable
filaments 4. The fabrics are secured to each other by
the ZTC conductive polymer element.

Figure 7 is a partial cross-sectional side view of
another device of the invention which is very similar
to that shown in Figure 1 but in which there is no
PTC coating around the electrodes 2.

Figure 8 is a partial cross-sectional side view of
another device of the invention which comprises electrodes
1 and 2 embedded in a PTC element 11 to form a self-
limiting strip heater preferably having an outer
insulating jacket (not shown). The strip heater is
woven into a fabric with heat-shrinkable filaments 4.

For further details of techniques for preparing
fabrics and for using heat-shrinkable fabric materials,
and of heat-responsive materials which can be incorporated
into or form part of fabrics, reference may be made to
U.K. Patent Applications Nos. 8,300,217, 8,300,218,
8,300,219, 8,300,220, 8,300,221, 8,300,222, 8,300,223
and 8,322,004 (Case Nos. RK 167, 176, 177, 178, 179,
181 and 205, and MPO790) filed by Raychem Limited on

January 6, 1983 and August 16, 1983 and Application No. 8,305,639 filed by N.V. Raychem S.A. on March 1, 1983, Case No. B089. The disclosures of these applications is incorporated herein by reference.

5 The invention is illustrated by the following Example.

EXAMPLE

A satin weave fabric was prepared using the following elongate elements:-

- 10 1. a 24 AWG (diameter 0.064 cm) nickel-coated copper stranded wire conductor having a uniform melt-extruded coating thereon, about 0.008 inch (0.02 cm) thick, of a PTC conductive polymer composition which had a resistivity of about 40 ohm.cm at 25°C and over 500 ohm.cm at 130°C, and
15 which comprised carbon black dispersed in polyvinylidene fluoride;
2. a monofilament which is about 0.01 inch (0.025 cm) in diameter and which is composed of a polyamide hot melt adhesive; and
- 20 3. a high density polyethylene about 5 grams per denier monofilament which had been drawn down about 20 to 30 times immediately after extrusion, and which was therefore heat-shrinkable, with a Tshrink of about 128°C.

25 The weft of the fabric was composed of elements (1) and (2), there being three elements (2) between each of the elements (1), and the elements (1) being 0.3 inch (0.76 cm)

apart (center-to-center). The warp of the fabric was composed of elements (3) at a frequency of 72 filaments per inch.

5 The fabric was then irradiated to a dosage of 12-17 Mrad, thus cross-linking PTC conductive polymer and the polyethylene.

10 The irradiated fabric was laminated under heat and pressure to a 0.03 inch (0.076 cm) thick sheet of a conductive polymer composition which had a resistivity of about 80 ohm.cm at 25°C and about 200 ohm.cm at 140°C [i.e. it was ZTC compared to the PTC composition of element (1)], and which comprised carbon black dispersed in a very low crystallinity ethylene/ethyl acrylate copolymer. At the same time, the opposite face of the fabric was laminated to 15 a 0.011 inch (0.028) thick layer of an insulating polymeric composition.

The resulting product had a cross-section similar to that shown in Figure 4. The electrodes followed a serpentine pattern similar to that shown in Figure 5.

20 When the electrodes were connected to a 36 volt DC power source, the fabric heated to a temperature of about 130°C, at which temperature the polyethylene filaments had reached their shrinkage temperature, and the hot-melt adhesive filaments and ZTC layer had softened; the fabric 25 therefore shrank in the transverse direction to about 33% of the original transverse dimension.

EPC and JapanCLAIMS

1. A fabric which is suitable for use as an electrical heater and which comprises an ordered array of interlaced elongate elements, said fabric comprising

5 (1) a first elongate electrode which forms at least part of one of said interlaced elongate elements;

(2) a second electrode; and

(3) a PTC element through which current passes when the first and second electrodes are connected to a source of electrical power.

2. A fabric according to Claim 1 wherein the second electrode is an elongate electrode which forms at least part of one of said interlaced elements.

3. A fabric according to Claim 1 or 2 wherein at least one of the elongate elements comprises (a) an elongate electrode and (b) a PTC element which is in the form of a layer surrounding that electrode and which is composed of a
5 conductive polymer.

4. A fabric according to Claim 3 which further comprises

(4) a substantially continuous laminar element which is composed of a ZTC conductive polymer and through which current passes when the electrodes
5 are connected to a source of electrical power.

5. A fabric according to Claim 3 or 4 wherein one of said interlaced elongate elements is an element which is electrically non-conductive and is thermally reponsive.

6. A fabric according to claim 5 which comprises

(1) a first elongate element which comprises

(i) a first elongate electrode composed of metal and

(ii) a PTC element which electrically surrounds the first electrode and which is composed of a PTC conductive polymer composition;

(2) a second elongate element which comprises

a second elongate electrode composed of a metal;

(3) a heat-shrinkable elongate element which shrinks when heated to a temperature T_{shrink} and which is composed of an electrically insulating polymeric composition;

said first, second and heat-shrinkable elements forming a fabric prepared by weaving the first, second and heat-shrinkable elements together; and

(4) a ZTC electrical element which is composed of a ZTC conductive polymer composition;

the first and second electrodes being connectable to a source of electrical power to cause current to flow

through the ZTC element and to cause shrinkage of the heat-shrinkable element.

7. A fabric according to claim 6 wherein at all temperatures between 0°C and T_{shrink} of the heat-shrinkable element, the resistance of the ZTC element is greater than the resistance of the PTC element.

8. A fabric according to claim 6 or 7 wherein the PTC conductive polymer composition has a first resistivity ρ_1 and comprises a first polymeric component which contains at least 50% by volume of a crystalline polymer having a melting point T_1 , the ZTC conductive polymer composition has a second resistivity ρ_2 comprises a polymeric component which contains at least 50% by volume of a thermoplastic polymer having a softening point T_2 ; and

10 $T_1 > T_{\text{shrink}} > T_2,$

and

$\rho_2 > \rho_1$ at all temperatures between 0°C and T_{shrink} .

9. A fabric according to claim 8 wherein $(T_1 - T_2)$ is at least 30°C and $(T_1 - T_{\text{shrink}})$ is at least 10°C .

10. A process for covering a substrate which comprises

(A) placing adjacent the substrate a recoverable fabric which comprises

(1) a first elongate element which comprises

5 (i) a first elongate electrode and

(ii) a PTC element surrounding the first
electrode;

10 (2) a second elongate element which is
interlaced with the first elongate ele-
ment to form an ordered array of
interlaced elongate elements;

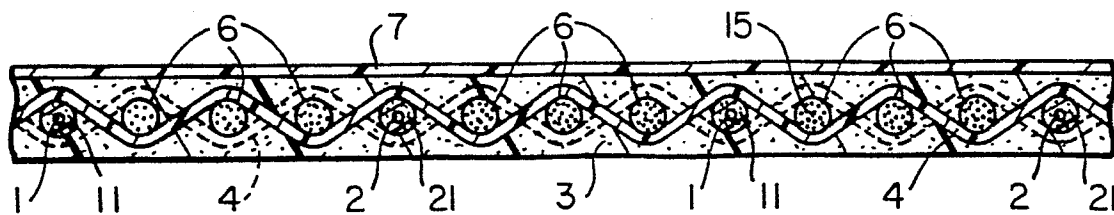
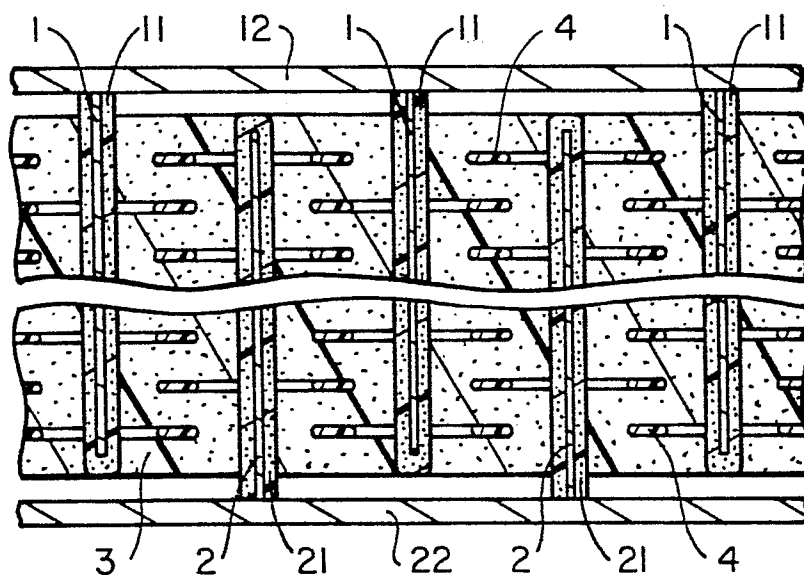
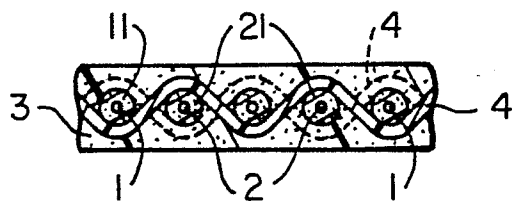
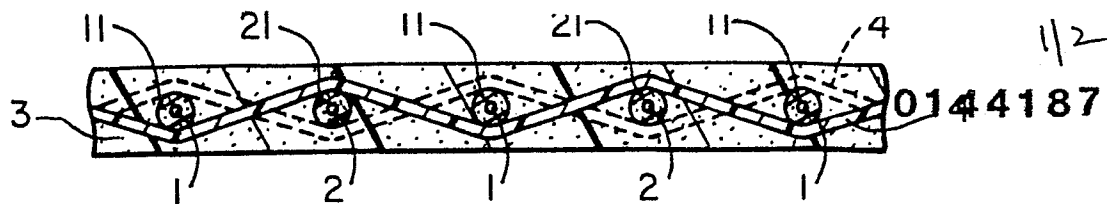
(3) a second electrode;

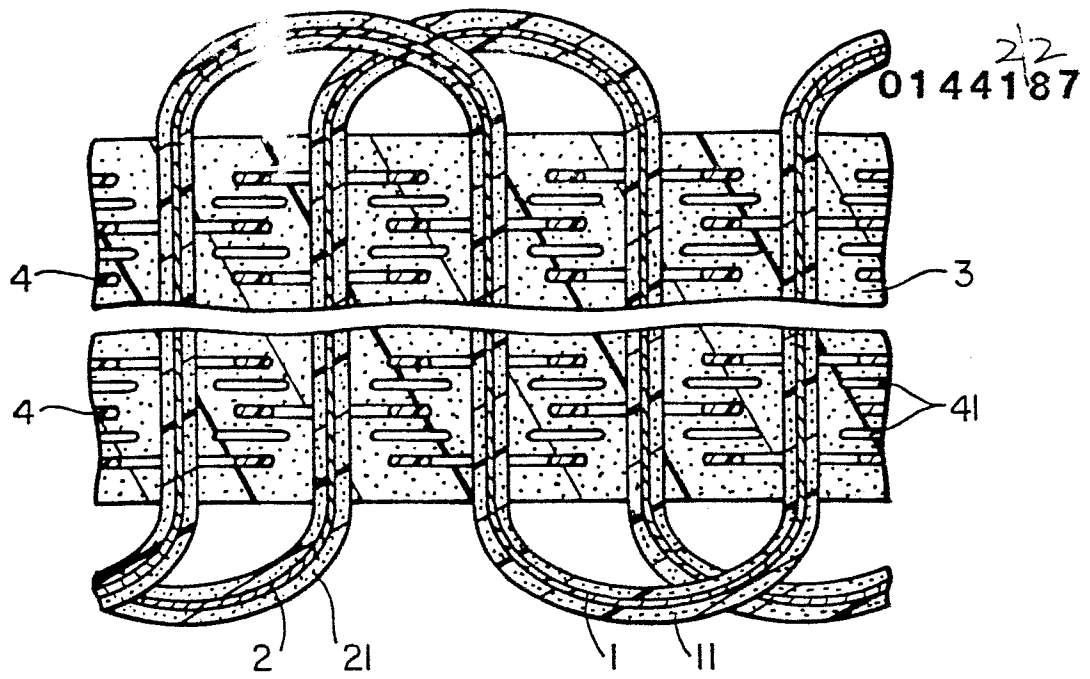
15 the first and second electrodes being connectable
to a power source to cause current to pass through
the PTC element; and

(4) an element which is thermally responsive
and which is heated when current is
passed between the electrodes;

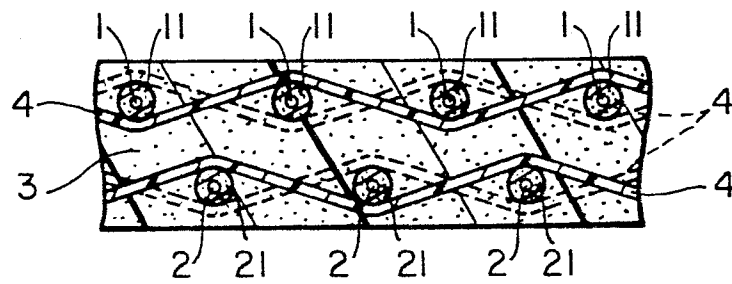
20 (B) recovering the device against the substrate;
and

(C) passing current between the electrodes to
effect a desired change in the thermally
responsive element.

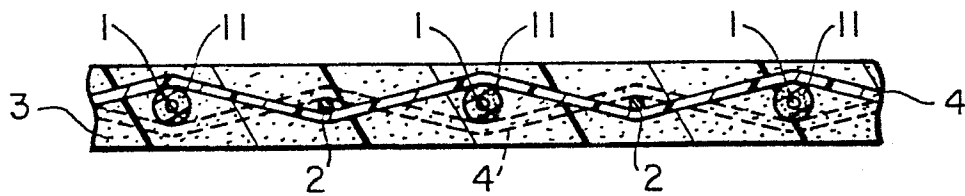




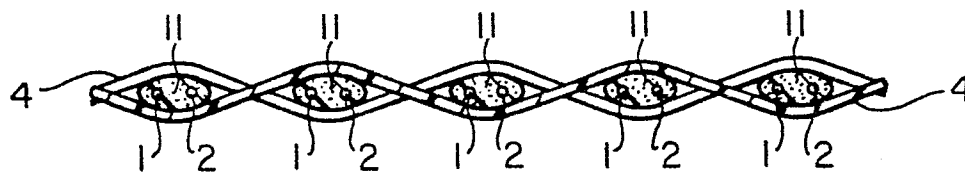
FIG_5



FIG_6



FIG_7



FIG_8



European Patent
Office

EUROPEAN SEARCH REPORT

0144187

Application number

EP 84 30 7984

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
Y	FR-A-1 567 627 (GULTON INDUSTRIES INC.) * Page 2, lines 4-14; page 3, lines 1-8, 16-23, 26-33, 40-43; page 4, lines 1-20, 32-44; page 12; page 13, lines 1-4; figures 1-3 *	1,5,6	H 05 B 3/14 H 05 B 3/34
A	---	2,3,10	
Y	FR-A- 938 257 (SAFEWAY HEAT ELEMENTS) * Page 1, lines 1-5, 53; page 2, lines 25-53; figures 1-4 *	1,5,6	
A	---	4,10	TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
A	FR-A-2 415 935 (RAYCHEM CORPORATION) * Page 1, lines 1-5; page 3, lines 35-39; page 4, lines 1-12; page 5, lines 20-32; page 6, lines 14-23; page 9, lines 31-39; page 10, lines 1-3; page 11, lines 15-32; page 12, lines 1-14, page 17, lines 13-25, 36-39; page 18, lines 1-14; figures 1-8 *	1,3,4, 6-8,10	H 05 B 3/00

-/-			
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 13-02-1985	Examiner PIERRON
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	FR-A-2 335 022(RAYCHEM CORPORATION) * Page 4, lines 19-35; page 6, lines 14-22, 27-37; page 7, lines 1-6, 11-20, 29-37; page 8, line 1 *	1, 4, 6-8	
A	FR-A-2 489 644 (MARVAD ELECTRO-TEXTILE LTD.) * Page 2, lines 15-16, 22-34; page 3, lines 10-22; page 4, lines 4-9, 27-29; figure 1 *	1, 2, 10	
			TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 13-02-1985	Examiner PIERRON
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			