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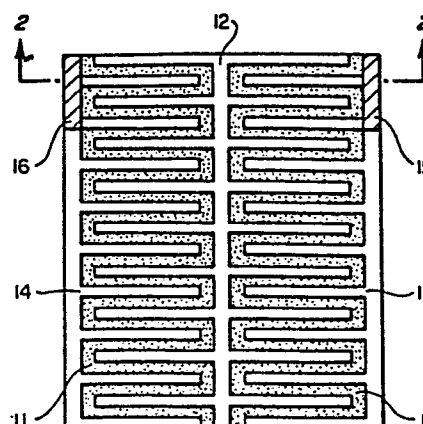
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64 Laminar Conductive polymer devices.

67 Electrical devices, especially self-regulating flexible sheet heaters and circuit protection devices, comprise a laminar element (11) of a melt-shaped PTC conductive polymer, and a plurality of electrodes (12,13,14) which are positioned that the predominant direction of current flow is parallel to the faces of the laminar element (11). The electrodes (12,13,14) are preferably positioned on one face of the laminar element and are applied by a printing process. Preferably the ratio of the average width of the electrodes to the distance between them is at least 0.1:1.



**FIG. 1.**

## BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

This invention relates to electrical devices which contain conductive polymer compositions.

### INTRODUCTION TO THE INVENTION

It is known that polymers, including crystalline polymers, can be made electrically conductive by dispersing therein suitable amounts of carbon black or another finely divided conductive filler. Some conductive polymers exhibit what is known as PTC (positive temperature coefficient) behavior. The terms "composition exhibiting PTC behavior" and "PTC composition" are used in this specification to denote a composition which has an  $R_{14}$  value of at least 2.5 or an  $R_{100}$  value of at least 10, and preferably both, and particularly one which has an  $R_{30}$  value of at least 6, where  $R_{14}$  is the ratio of the resistivities at the end and the beginning of a 14°C range,  $R_{100}$  is the ratio of the resistivities at the end and the beginning of a 100° range, and  $R_{30}$  is the ratio of the resistivities at the end and the beginning of a 30°C range.

Electrical devices comprising conductive polymer elements, in particular heaters, circuit control devices, and sensors, have been described in prior publications and in co-pending, commonly assigned, patent applications. 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, 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,

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#### SUMMARY OF THE INVENTION

We have now discovered that excellent PTC conductive polymer devices can be prepared by shaping, preferably melt-shaping, the PTC conductive polymer into a sheet, and simultaneously or subsequently securing within the sheet and/or on one or both surfaces of the sheet, a plurality of electrodes which are spaced-apart from each other so that the predominant direction of current flow between the electrodes is substantially parallel to the face of the conductive polymer sheet. The size and separation of the electrodes are important in determining the properties of the resulting device. Thus in electrical heaters of the invention, the electrodes appear to act both as current carriers and as heat sinks in a way which minimizes the formation of "hotlines" (i.e. narrow areas over which there is a high voltage gradient) in the PTC element. In circuit protection devices of the invention, the novel design makes it possible, for a conductive polymer composition of

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particular resistivity, to prepare a device which has lower resistance for its size (or smaller size for its resistance) than the known electrode configurations. Furthermore, the current density is less than in conventional designs. In addition, by making use of a device in which the spacing of the electrodes varies from one part of the device to another, the operational dynamics of the device can be changed.

In one aspect the present invention provides an electrical device which comprises

- (1) a laminar element which is at least 0.002 inch (0.005 cm) thick and is composed of a conductive polymer composition which (a) exhibits PTC behavior, and (b) comprises an organic polymer and, dispersed in the polymer, a particulate conductive filler;
- (2) a plurality of electrodes, at least two of which can be connected to a source of electrical power to cause current to pass through the laminar element, and which are dimensioned and positioned so that
  - (a) when current passes between the electrodes, a substantial component (usually at least 75%, preferably at least 90%, particularly at least 95%) of the current is parallel to the faces of the laminar element, and
  - (b) the ratio of the average width of the electrodes, measured parallel to the faces of the laminar element, to the

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average distance between adjacent electrodes between which current passes, measured parallel to the faces of the laminar element, is at least 0.01:1.

The invention further provides a method of heating a substrate which comprises placing a heater as defined above in thermal contact with the substrate, and powering the heater so that it heats the substrate.

The invention further provides an electrical circuit which comprises a circuit protection device as defined above, an electrical load in series with the device, and a power source, the circuit having a normal operating condition in which the device has a low resistance.

#### BRIEF DESCRIPTION OF THE DRAWING

The invention is illustrated in the accompanying drawing, in which

Figure 1 is a plan view of a heater of the invention,

Figure 2 is a cross-section taken on line 2-2 of Figure 1,

Figure 3 is a plan view of another heater of the invention,

Figure 4 is a cross-section through a heater similar to that shown in Figure 3 but having additional insulating and thermally conductive members,

Figure 5 is a plan view of another heater of the invention,

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Figure 6 is a plan view of a circuit protection device of the invention, and Figure 7 is a cross-section taken on line 2-2 of Figure 1.

#### DETAILED DESCRIPTION OF THE INVENTION

It is to be understood that the device of this invention can be part of a larger device which does not meet the definition given above. Thus the invention includes for example a device which comprises (1) a laminar element as defined above and (2) electrodes which in one or more areas are as defined above and in one or more other areas fail to meet the definition given above, e.g. because the electrodes are too far apart.

The laminar element is composed of a PTC conductive polymer composition. Many such compositions are described in the various patents, patent applications and publications referred to above. Preferred compositions for use in this invention comprise carbon black, or a mixture of carbon black and graphite, as the conductive filler. The composition can also contain a non-conductive filler, which may be reinforcing or non-reinforcing, and/or a filler exhibiting non-linear properties. One or more of the fillers can be selected to have a high thermal conductivity.

The polymer preferably comprises at least one thermoplastic crystalline polymer. Particularly useful polymers are olefin polymers, including homopolymers, particularly polyethylene and the polyalkenamers obtained by polymerizing cycloolefins; copolymers of two

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or more olefins; and copolymers of one or more olefins, e.g. ethylene or propylene, with one or more olefinically unsaturated comonomers, preferably polar comonomers, e.g. vinyl acetate, acrylic acid methyl acrylate and ethyl acrylate. Also particularly useful are fluoropolymers (which may be olefin polymers), in particular polyvinylidene fluoride and copolymers of ethylene with tetrafluoroethylene and/or a perfluoro-comonomer. Mixtures of polymers can be used, including mixtures of thermoplastic and amorphous, e.g. elastomeric, polymers. The conductive polymer can be cross-linked, preferably by irradiation, after it has been shaped, or while it is being shaped, into the laminar element. When metal electrodes are applied to a surface of the laminar element, such cross-linking is preferably carried out before the electrodes are applied, since improved adhesion can thereby be obtained. When electrodes containing a polymeric binder are employed, improved results may be obtained by cross-linking after the electrodes have been applied.

In one embodiment, the devices of the invention are self-regulating heaters, and in such heaters, the preferred resistivity of the conductive polymer at room temperature (23°C) will depend upon the dimensions of the laminar element and the power source to be used with the heater, but will generally be in the range from 1 to 500,000 ohm.cm, eg. 100 to 100,000 ohm.cm, preferably 5-50 ohm.cm for very low voltages (up to 6 volts), 50-1,000 ohm.cm for low voltages (4 to 60 volts DC), 1,000 to 10,000 ohm.cm for normal supply voltages of about 110 to 240 volts AC, and 10,000 to 100,000 ohm.cm for voltages of greater than 240 volts AC.

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In another embodiment, the devices of the invention are circuit protection devices, and in such devices, the preferred resistivity of the conductive polymer at room temperature (23°C) will depend upon the desired characteristics of the device, but will generally be in the range from 0.5 to 100,000 ohm.cm, preferably 1.0 to 100 ohm.cm. The resistance of the device at 23°C is preferably from 1 to 1,000, especially from 2 to 100 ohms.

The polymer is preferably melt-shaped, with melt-extrusion usually being preferred. When the melt-shaping method results in a preferred orientation of the conductive particles (as does melt-extrusion), the electrodes are preferably arranged so that current flow between them predominantly follows (e.g. is at an angle of not more than 30°, preferably not more than 15°, to) the direction of orientation (which, in the case of melt-extrusion, is the direction of extrusion).

The laminar element can be very thin, but generally has a thickness of at least 0.002 inch (0.005 cm), preferably at least 0.008 inch (0.02 cm), particularly at least 0.01 inch (0.025 cm). There is no upper limit on the thickness of the laminar element, but for reasons of economy (and in some cases flexibility) the thickness of the element is generally not more than 0.25 inch (0.65cm). When, as is preferred, the electrodes are applied to the same surface of the element, the thickness of the element is usually not more than 0.1 inch (0.25 cm), preferably not more than 0.05 inch (0.13 cm), particularly not more than 0.025 (0.06 cm) inch.

An important feature of the present invention is the size and spacing of the electrodes. The electrodes

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are preferably ribbon-shaped elements secured on the same side of the laminar element, as is preferred, or on opposite sides of the element. It is also possible for ribbon-shaped electrodes to be placed on both surfaces of the conductive polymer element, usually as mirror images to ensure the desired direction of current flow. It is also possible for the electrodes to be within the thickness of the conductive polymer element, e.g. by sandwiching the electrodes between two conductive polymer elements, which can be the same or different.

The electrodes can be secured in or on the laminar element in any convenient way, for example by printing a conductive ink onto the laminar element to form the electrodes, through the use of polymer thick film technology, by sputtering, by a process comprising an etching step, or by using pre-shaped foil electrodes. The electrodes can also be formed on a surface of an insulating laminar element, for example by the techniques noted above or by etching, and the conductive polymer can then be secured to the electrodes and the insulating laminar element, for example by laminating a pre-formed film of the conductive polymer to the insulating element. The electrodes can for example be formed on the reverse side of a printed circuit board. Suitable materials for the electrodes include metals and metal alloys, for example silver, copper, ruthenium, gold and nickel. Electrodes comprising graphite can also be used.

The ratio of the average width of the electrodes, measured parallel to the faces of the laminar element, to the average distance between adjacent electrodes between which current passes, measured parallel to the

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faces of the laminar element, is at least 0.01:1, preferably at least 0.1:1, eg. about 0.25:1, with a preferred upper limit of less than 10:1, particularly less than 5:1, especially less than 3:1. The electrodes are preferably equally spaced from each other. However, variation of the distance between the electrodes is possible and can be desirable. 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 laminar element, is not more than ten times, preferably not more than six times, especially not more than three times the average distance between adjacent electrodes between which current passes, measured parallel to the faces of the laminar element. The total surface area of the electrodes, viewed at right angles to the laminar element, to the surface area of one of the faces of the laminar element is preferably at least 0.1:1.

Preferred patterns for the electrodes include interdigitating comb-like patterns of opposite polarities; a central backbone of one polarity with two comb-like patterns which interdigitate with opposite sides of the backbone and which both have a polarity opposite to the central backbone; and a central backbone with two comb-like patterns which interdigitate with opposite sides of the backbone and which are of opposite polarity to each other, with the backbone being at an intermediate voltage when a DC power supply is used or providing a neutral (which may be a floating neutral) when an AC power supply is used.

The electrodes can be quite thin (and in heaters may be thin enough for resistive heat generated by them

to be significant) and when this is so, the device may comprise bus connectors for the electrodes. These connectors will generally be straight strips of metal which run up one margin, or up a center line, of the heater. The connectors can be added after the electrodes have been applied, or they can be secured to the laminar element and the electrodes applied over both.

The devices of the invention can comprise laminar insulating elements covering the conductive element and electrodes (or, in protection devices, a container which surrounds but is spaced apart from, the PTC element), in order to provide both physical and electrical protection. In a number of the uses for the devices of this invention, an important advantage is that the devices can be flexible, and for such uses, preferred insulating elements are flexible polymeric films. The device can also comprise a coating of an adhesive, which may be for example a pressure-sensitive adhesive optionally covered by a release sheet, or an adhesive which can be activated by heat, e.g. from the device itself.

Especially when the device is a heater, it can also comprise, on part or all of one or both surfaces thereof, and optionally extending therefrom, a thermally conductive member, e.g. a metal foil or a layer of a polymer having thermally conductive particles, e.g. graphite or carbon fibers, disposed therein. If the thermally conductive element is also electrically conductive, it will normally be electrically insulated from the electrodes and the conductive polymer element.

The heaters of the invention have a wide variety of uses, including the heating of handlebars on motorcycles

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and bicycles, the heating of electrical devices, for example batteries, e.g. in vehicles, the heating of pipes and tanks, the heating of antennas, and the heating of electronic components, including printed circuit boards. If desired, the conductive polymer laminar element can be heat-recoverable, preferably heat-shrinkable, so that when the device is powered, the laminar element recovers, e.g. into conforming contact with an adjacent substrate. The electrodes should be arranged so that they do not need to change shape when recovery takes place, or should be such that they can change shape when recovery takes place, for example by reason of apertures, slits, corrugations or other lines of physical weakness in those parts of the electrodes which need to change shape on recovery. Alternatively, the heater is not in itself heat-recoverable, but is secured to a heat-recoverable substrate, e.g. a heat-shrinkable cross-linked polymeric film or other shaped article, having a recovery temperature below the temperature at which the heater controls, so that when the heater is powered, it causes recovery of the substrate, preferably without substantially retarding such recovery. A heater for use in this way can for example comprise a plurality of apertures or slits through the ribbon-shaped electrodes, thus permitting the shape of the heater to be changed, especially when it is hot.

Referring now to Figures 1 and 2, a laminar PTC conductive polymer element 11 carries on one surface thereof an electrode 12 in the form of a central backbone and interdigitating comb-like electrodes 13 and 14. Secured on top of electrodes 13 and 14 are termination pads 15 and 16 of opposite polarity.

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Referring now to Figure 3, a laminar PTC conductive polymer element 11 carries on one surface thereof three parallel bus connector strips, the center connector 16 being of one polarity and the outer connectors 15 being of opposite polarity. Printed on top of the element 11 and the connectors 15 and 16 are electrodes 12, 13 and 14 (the electrodes could also be printed as a continuous pattern, as in Figure 1, instead of a series of strips connected by the bus connectors, but the illustrated embodiment is more economical).

Referring now to Figure 4, this is a cross-section through a heater which has the same electrical components as Figure 3, but which also includes an insulating jacket 17 which surrounds the electrical components and a thermally conductive base member 18, e.g. of metal, which completely covers one surface of the heater and extends outwardly therefrom.

Referring now to Figure 5, this shows a PTC conductive polymer element 11 having printed on one surface thereof interdigitating comb-like electrodes 12 and 13. Underneath the marginal portions of the electrodes are bus connector strips which are not shown in the Figure.

Referring now to Figures 6 and 7, a laminar PTC conductive polymer element 11 carries on one surface thereof interdigitating comb-like electrodes 12 and 13.

The invention is further illustrated by the following Examples.

EXAMPLE 1

A dispersion of carbon black in an ethylene/ethyl acrylate copolymer (commercially available from Union Carbide as DHDA-7704) was melt-extruded into a sheet about 0.04 cm thick and about 46 cm wide. The sheet was irradiated to a dosage of 15 Mrad and the resulting cross-linked sheet was cut into samples 7.5 x 10 cm in size.

Using a commercially available thick film ink comprising silver particles and an elastomer, an electrode pattern as shown in Figure 1 was screen-printed onto one face of a number of samples. The ink was cured at 65°C for 30 minutes. Copper foil termination pads were then secured to the printed electrodes, again as shown in Figure 1, using a conductive adhesive.

Other samples were converted into heaters by securing copper bus connectors, 0.32 cm wide and 0.0075 cm thick to one face of the laminate, and then screen-printing the electrodes on top of the bus connectors and the laminar element (using the same technique as with the previous samples) to give a product as shown in Figure 3.

Finally a cross-linked polyethylene film was laminated to both sides of the samples and the edges of the polyethylene film heat-sealed to prevent delamination. Contact with the copper bus connectors or termination pads was made by cutting a patch from the insulating film and soldering a lead to the exposed copper, or by means of insulation-piercing clips.

EXAMPLE 2

A circuit protection device as illustrated in Figures 6 and 7 was made as follows. A piece of aluminum foil, 0.005 cm thick, was cut into two electrodes of the shape shown in Figure 1, which were then secured to one face of a sheet of conductive polymer, 3.2 x 4.4 x 0.05 cm in dimensions, by heating the foil electrodes and the conductive polymer sheet to 180-200°C in a nitrogen gas environment and applying pressure. The conductive polymer had a resistivity of about 4 ohm.cm at room temperature and comprised about 26.7% by volume of Statex G carbon black dispersed in about 45.9% by volume of Marlex 6003 (a high density polyethylene sold by Philips). The composition was converted into a sheet by extrusion.

The device, which had a resistance at room temperature of about 1 ohm, was tested by connecting it in series with an 80 volt AC power source and a load resistance of about 25 ohms, which resulted in an initial current of about 3.0 amp passing through the device. In about 5 seconds, the resistance of the device rose to about 210 ohms, thus reducing the current to about .380 amps.

CLAIMS

1. An electrical device which comprises

(1) a laminar element which is at least 0.002  
inch (0.005 cm) thick and is composed of a  
conductive polymer composition which (a)  
exhibits PTC behavior and (b) comprises an  
organic polymer and, dispersed in the  
polymer, a particulate conductive filler;

(2) a plurality of electrodes, at least two of  
which can be connected to a source of elect-  
rical power to cause current to pass through  
the laminar element, and which are dimensioned  
and positioned so that

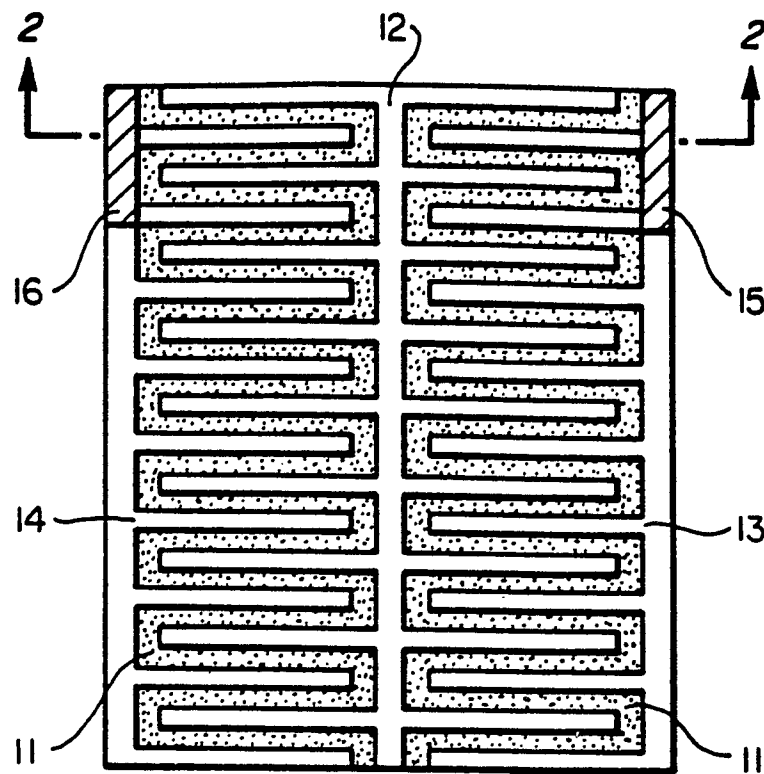
(a) when current passes between the electrodes,  
a substantial proportion of the current is  
parallel to the faces of the laminar  
element, and

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

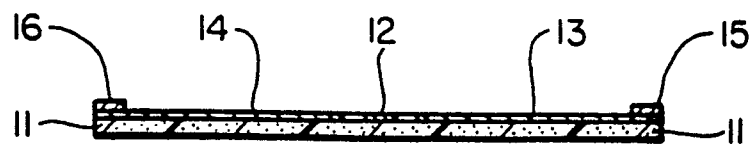
2. A device according to Claim 1 wherein the laminar  
element has a thickness of 0.01 to 0.1 inch (0.025 to  
0.25 cm).

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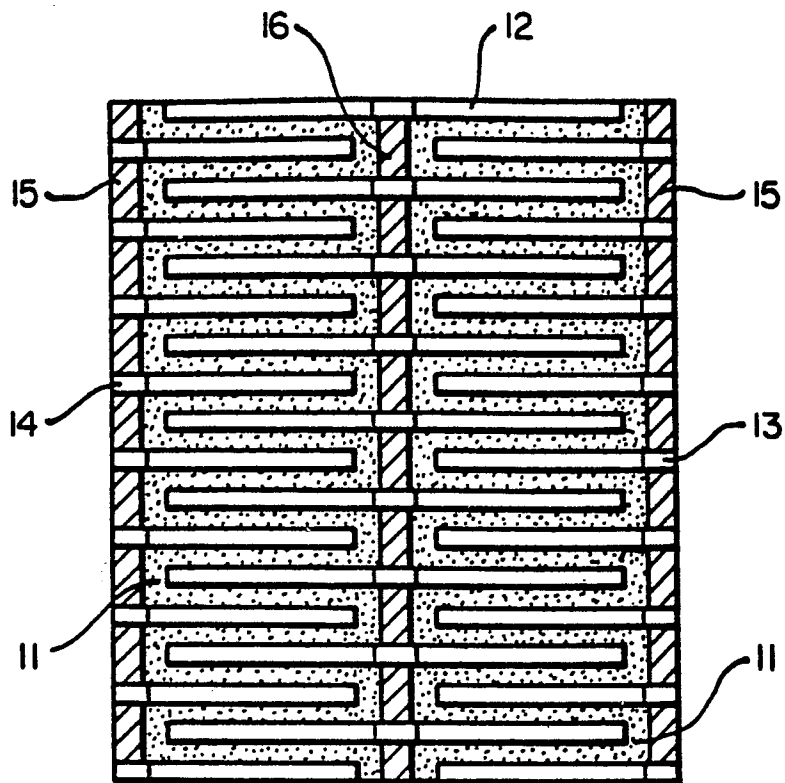
3. A device according to Claim 1 or 2 wherein the conductive polymer composition has been melt-extruded.
4. A device according to Claim 3 wherein the electrodes are so positioned that current passing between the electrodes follows a path which is substantially parallel to the direction of extrusion.
5. A device according to any one of claims 1 to 4 wherein the electrodes have been printed on the same surface of the laminar element.
6. A device according to any one of claims 1 to 5 wherein the electrodes comprise a plurality of parallel bars which are spaced apart from each other by substantially the same distance.
7. A device according to any one of claims 1 to 6 wherein the ratio of the average width of the electrodes to the average distance between adjacent electrodes between which current passes is from 0.1:1 to 5:1.
8. A device according to any one of claims 1 to 7 which is a circuit protection device having a resistance of 2 to 100 ohms and wherein the conductive polymer composition has a resistivity at 23°C of 1 to 100 ohm.cm.
9. A device according to any one of claims 1 to 7 which is a self-regulating heater wherein the conductive polymer composition has a resistivity at 23°C of 100 to 100,000 ohm.cm.
10. A device according to Claim 9 which also comprises a laminar thermally conductive element.



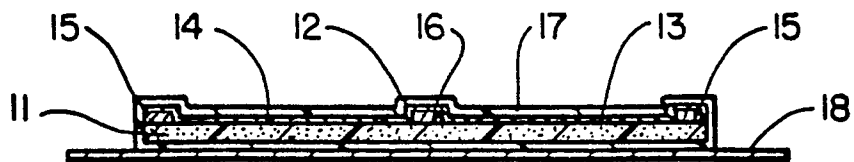
**FIG\_1.**



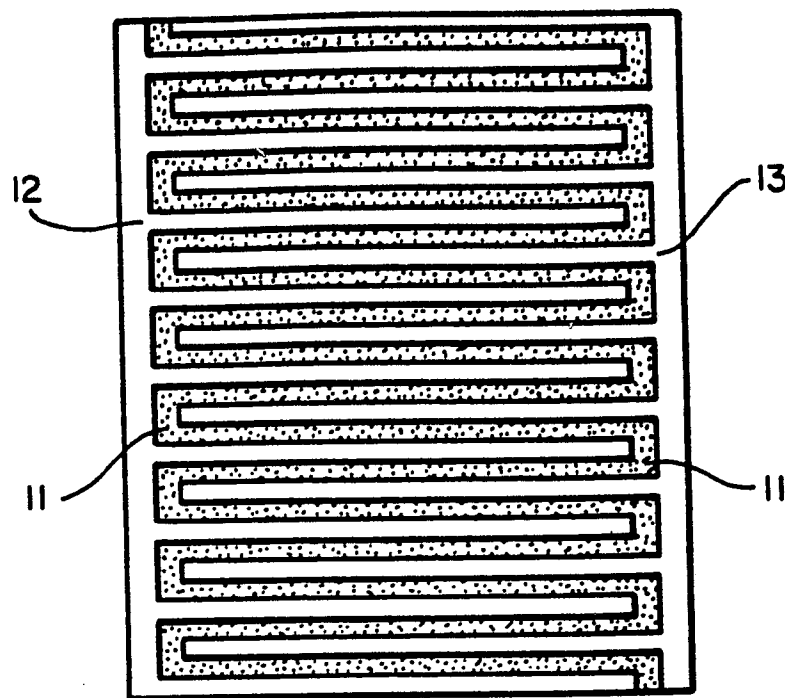
**FIG\_2.**

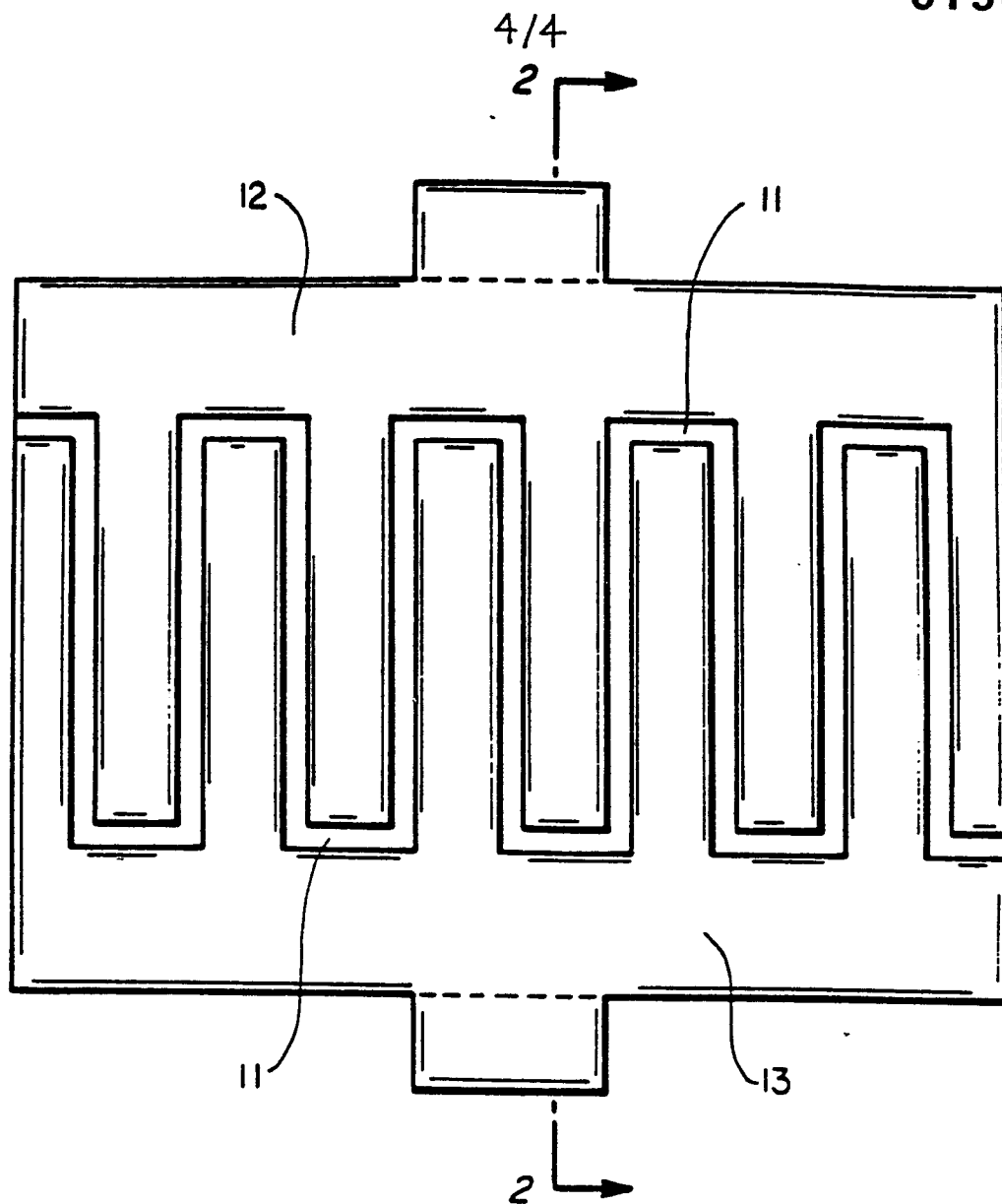


FIG\_3.

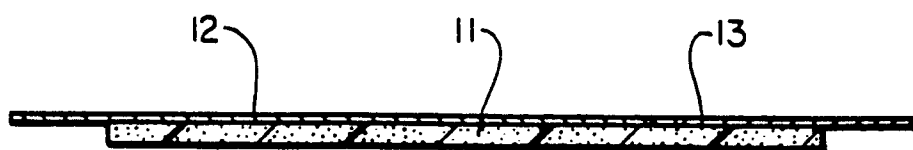


FIG\_4.

**FIG\_5.**



FIG\_ 6.



FIG\_ 7.



| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                    |                                                | EP 85300415.8                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------|------------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Citation of document with indication, where appropriate, of relevant passages      | Relevant to claim                              | CLASSIFICATION OF THE APPLICATION (Int. Cl. 4) |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | US - A - 4 034 207 (TAMADA)                                                        | 1,3,6                                          | H 05 B 3/10                                    |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | * Totality *                                                                       | 4,5,10                                         | H 05 B 1/02                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | --                                                                                 |                                                | H 01 C 7/02                                    |
| D,Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | US - A - 4 426 339 (KAMATH)                                                        | 1,3,6                                          |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | * Abstract; column 1, lines 17-24 *                                                |                                                |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | --                                                                                 |                                                |                                                |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | US - A - 4 037 082 (TAMADA)                                                        | 1,4-6, 10                                      |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | * Column 4, line 56 - column 7, line 6; fig. 3-9 *                                 |                                                |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | --                                                                                 |                                                |                                                |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | DE - A1 - 2 946 842 (SIEMENS)                                                      | 1,4,5                                          |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | * Page 7, lines 10-15; fig. 3 *                                                    |                                                |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | --                                                                                 |                                                |                                                |
| D,A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | US - A - 4 177 446 (DIAZ)                                                          | 1,4,10                                         | TECHNICAL FIELDS SEARCHED (Int. Cl. 4)         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | * Claims 1,2; column 8, line 57 - column 9, line 2; fig. 1 *                       |                                                | H 01 B 1/00                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | --                                                                                 |                                                | H 01 C 7/00                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                    |                                                | H 05 B 1/00                                    |
| D,A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | EP - A1 - 0 087 884 (RAYCHEM)                                                      | 1,3,8                                          | H 05 B 3/00                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | * Abstract; page 6, lines 8-17; page 9, lines 11-18; page 18, lines 3-10; fig. 1 * |                                                |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | --                                                                                 |                                                |                                                |
| D,A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | EP - A1 - 0 038 718 (RAYCHEM)                                                      | 1,9                                            |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | * Page 3, lines 1-22 *                                                             |                                                |                                                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | ----                                                                               |                                                |                                                |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                    |                                                |                                                |
| Place of search<br>VIENNA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                    | Date of completion of the search<br>30-04-1985 | Examiner<br>TSILIDIS                           |
| <p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone</p> <p>Y : particularly relevant if combined with another document of the same category</p> <p>A : technological background</p> <p>O : non-written disclosure</p> <p>P : intermediate document</p> <p>T : theory or principle underlying the invention</p> <p>E : earlier patent document, but published on, or after the filing date</p> <p>D : document cited in the application</p> <p>L : document cited for other reasons</p> <p>&amp; : member of the same patent family, corresponding document</p> |                                                                                    |                                                |                                                |