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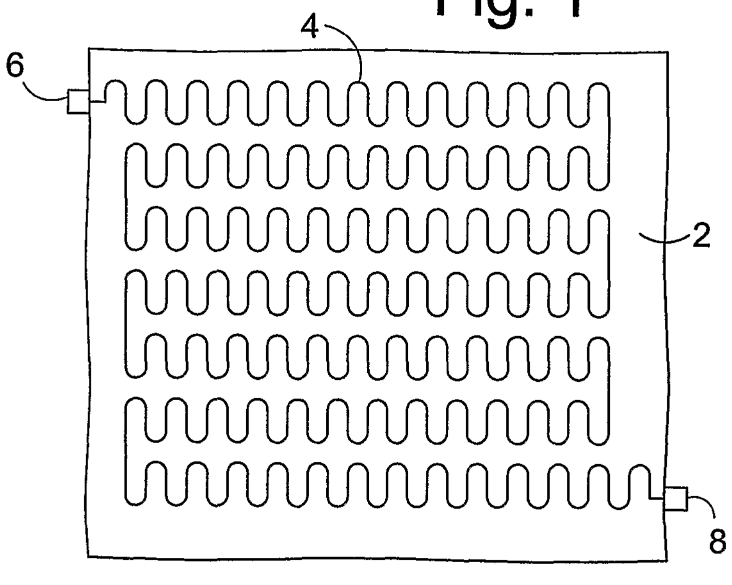
(54) Title: TEMPERATURE SENSOR

Fig. 1



(57) Abstract: A temperature sensor comprises a section of non-stretch fabric (2) in which a length (4) of electrically conductive yarn is confined. The yam has electrical resistance that varies with temperature in a predetermined manner. The yarn follows a tortuous path in the fabric, typically such that the ratio of the square of its length to the area of the fabric section in which it is confined, is at least one hundred. In use, means are provided for measuring the electrical resistance of the yarn in the fabric (2), thereby providing an indication of temperature.

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TEMPERATURE SENSOR

This invention relates to temperature sensors, and particularly to such sensors in the form of a flexible panel which can conform to the surface of a body whose temperature is being measured. Such sensors have use in a variety of applications, including the measurement of the temperature of human or animal body.

Temperature measurement can be accomplished by a variety of means. Typically, such sensors generate a visible signal in response to a temperature change, as a result of a physical or chemical change in response to the change in temperature. It is also known that electrical characteristics of materials can change with temperature, and the present invention is directed particularly at the exploitation of such characteristics.

The present invention seeks to incorporate a temperature sensing mechanism within a fabric. According to the invention a length of electrically conductive yarn is confined in a section of non-stretch fabric, which yarn has an electrical resistance that varies with the temperature in a predetermined manner (ERT yarn). The ERT yarn follows a tortuous path in the fabric such that there is a substantial length of ERT yarn accumulated in the fabric section relative to the dimensions of the fabric section. Typically, the ratio of the square of the length of the conductive yarn in the section to the area of the fabric section is at least one hundred. Preferably, the ratio is at least one thousand and most preferably at least ten thousand.

The length of the ERT yarn can be defined by the resolution requirement of the sensor, the change of its electrical resistance relative to temperature and the gauge of the wire. Care should be taken to prevent contact between different sections of the length of wire as this would effect the performance of the sensor. A change in temperature of the ERT yarn will cause a change in its electrical resistance, which could be determined with a suitable circuit such as a Wheatstone bridge.

In sensors according to the invention, the ERT yarn is preferably confined between two layers defining the fabric section. The purpose of this is of course to prevent the ERT yarn from being exposed on either side of the fabric, although this can be permissible if the ERT yarn is itself insulated. Preferred sensors according to the invention comprise two layers each knitted with nonconductive yarns. The ERT yarn can be coupled directly to one or other of the layers, by individual stitches. Additionally or alternatively, the two layers can be interlinked to create a coherent fabric section holding the ERT yarn. Embroidery techniques can also be used.

The ERT yarn can comprise a plain metallic wire; for example of copper. A preferred conductive yarn comprises nickel coated copper wire. As noted above, the wire may be covered by an electrically insulating coating. Metal coated polymeric yarns could also be used. It is also possible to use conductive non-metallic yarns. Such yarns tend to exhibit smaller changes in electrical characteristics, particularly resistance, in response to changes in temperature.

In order to monitor changes in temperature of a sensor according to the invention, the ERT yarn must of course be part of a circuit with means for measuring its electrical resistance. Such a circuit can be completed by making connections to the ERT yarn ends at peripheral points on the fabric section, and this will normally be the case when the fabric section comprising the sensor is produced separately. However, the sensor may be incorporated in the garment fabric, and rather than have separate connections at the periphery of the fabric section, the circuit, or at least conductors connected to the sensor can also be incorporated in the garment fabric. It is also quite possible to have the ERT yarn extending continuously from the fabric section to complete the requisite electrical circuit. It should be noted in this context that while consideration should be given to the electrical characteristics of the yarn or conductors in the electrical circuit outside of the fabric section, in most applications of the invention specific consideration thereof will not be necessary as the length of yarn within the fabric section will be a sufficient multiple of the length of yarn or conductors in other parts of the circuit for any influence thereof to be ignored.

A fabric including a temperature sensor according to the invention can be used in garments to enable monitoring of the wearer's skin temperature on an occasional or continuous basis while the garment is being worn. This can be of value in medical or surgical situations while a patient is undergoing treatment or by an individual in an exercise regime when temperatures and possibly other bodily characteristics are being monitored. Provision can be made for keeping the sensor close to or in contact with the skin or other surface to be monitored. An adhesive or jelly might be used for example. The sensor can of course also be used to measure ambient temperature, by suspending it in the respective atmosphere. The ERT yarn can be used as the means of suspension.

The invention will now be described by way of example, and with reference to the accompanying schematic drawings wherein:

Figures 1 and 2 each shown in plan view the location of an ERT yarn in a fabric section according to the invention;

Figure 3 shows how a sensor according to the invention can be incorporated in a garment fabric;

Figure 4 shows a simple circuit for monitoring changes in resistance of the ERT yarn in a sensor of the invention;

Figure 5 shows how an ERT yarn may be confined between two knitted layers in a sensor of the invention; and

Figure 6 illustrates a technique for knitting a sensor embodying the invention.

The fabric section 2 in Figure 1 comprises non-conductive and non-stretch yarns such that the section itself is substantially inextensible in any direction. Confined within the fabric section 2 is a length 4 of ERT yarn, which follows a tortuous path within the fabric section between terminals 6 and 8.

The ERT yarn follows multiple sinusoidal paths across one dimension of the fabric section, and the total length of the yarn within the section will be such that the ratio of the square of its length to the area of the fabric section will be at least one hundred, preferably at least one thousand, and most preferably at least ten thousand.

Figure 2 shows a similar view to that of Figure 1, but in this embodiment the ERT yarn follows a more straightforward reciprocating path within the fabric section. The ratio of the square of the yarn length to the area of the fabric section will in this embodiment be closer to one hundred.

Figure 3 shows a T-shirt with a temperature sensor 10 embodying the invention forming an integral part of the garment fabric. Conductors 12 and 14 extend respectively from the terminals 6 and 8 on the sensor to circuit terminals 16 and 18 located in this embodiment at the hem of the garment. A monitoring circuit is completed as described below.

A simple temperature monitoring circuit incorporating a sensor of the invention is shown in Figure 4. Connectors 16 and 18 are connected to a source 20 of electrical power and an ammeter 22, through a switch 24. When the switch is closed, the resistance in the circuit, and thereby of the resistance of the ERT yarn 4 in the sensor 10, can be measured as the ratio of the supply voltage to the ammeter reading. While the conductors 12 and 14 are shown in both of Figures 3 and 4 as separate components, they will normally be extended lengths of the ERT yarn 4. It will be appreciated from Figure 3 that their lengths will be significant in that they extend a substantial part of the entire length of the garment, but relative to the length of ERT yarn 4 within the sensor 10, this length will be small. Depending on the nature of the path followed by the ERT yarn 4 within the sensor 10, this additional length of ERT yarn may either be ignored, or accounted for in calculating changes in the resistance of the ERT yarn in the sensor from the ammeter reading (22).

In sensors according to the invention, the ERT yarn 4 will be confined in the fabric section such that the ERT yarn 4 is not electrically exposed. This is preferably accomplished in sensors according to the invention by confining the

ERT yarn between two layers 26 and 28 of fabric as shown in Figure 5. In this embodiment each layer is itself knitted with non-conductive yarns, with interlinking by cross-over yarns 30. This structure confines, secures and protects the yarn 4 from exposure.

The fabric section defining a temperature sensor according to the invention should be substantially non-extensible in any direction in order to avoid any extension of the ERT yarn confined therein. Any stretching of the ERT yarn will have an additional effect on its resistance, and risk generating an inaccurate temperature reading. Minor flexure of the ERT yarn will not have a significant effect. Thus, when incorporated in a garment, the sensor should be located close to the point at which the temperature is to be monitored, but not in a location where there is likely to be substantial flexure. The position shown in Figure 3, substantially centrally at the upper front or rear of a T-shirt, is appropriate.

A technique of creating such a sensor via the route of computerised flat-bed knitting machine is illustrated in Figure 6. However, the same technique can be used to knit the sensor on non-computerised flat-bed and circular knitting machines as well as on warp knitting machines.

The ERT yarn 32 is accumulated between the courses of an interlock knitted structure. The interlock structure is the most stable basic knitted structure and thus would provide an excellent platform for creating temperature sensors. The main structure 34 for the sensor is a knitted course of alternating odd needles on the front bed and at the same time knitting the alternating even needles on the rear bed, following with a course of alternating even needles on the front bed and at the same time knitting the alternating odd needles on the rear bed. Both of these courses are knitted as tight as possible. In between each of the courses that make up the interlock structure a nickel plated copper wire 32 (ERT yarn) is laid-in without forming a loop. This is followed by another course of ERT laid-in yarn 36 which is made up of numerous ends of the main yarn 34; the reason for this is to fill out any space between the main courses of the base interlock structure. This method of knitting would lock the interlock course in the course direction, especially when this laid-in ERT yarn changes its direction; i.e. when it is laid-in in the opposite direction during the next courses of knitting. The wale or vertical column of stitches direction is also helped to be locked by this laid-in ERT yarn.

Using this method of knitting a combination of the basic interlock structure and laid-in ERT yarn, provides a more stable knitted structure with very little stretch in either the course or the wale direction. This technique gives a good stable structure for holding the nickel plated copper wire in place.

CLAIMS

1. A temperature sensor comprising a section of non-stretch fabric with a length of electrically conductive yarn confined therein, which yarn has an electrical resistance that varies with temperature (ERT) in a predetermined manner, wherein the conductive yarn follows a tortuous path in the fabric.

2. A temperature sensor according to Claim 1 wherein the ratio of the square of the length of the ERT yarn in the fabric section to the area of the fabric section is at least one hundred.

3. A temperature sensor according to Claim 2 wherein said ratio is at least one thousand.

4. A temperature sensor according to Claim 2 wherein said ratio is at least ten thousand.

5. A temperature sensor according to any preceding Claim wherein the fabric section comprises two layers with the ERT yarn confined therebetween.

6. A temperature sensor according to Claim 5 wherein each layer is knitted with non-conductive yarns.

7. A temperature sensor according to Claim 6 wherein the layers are interlinked to create a coherent fabric section.

8. A temperature sensor according to any preceding Claim wherein the ERT yarn comprises copper.

9. A temperature sensor according to Claim 8 wherein the conductive yarn is nickel coated copper wire.

10. A temperature sensor according to any preceding Claim wherein the ERT yarn extends from the fabric section to terminals for connection to a source of electrical power to complete an electrical circuit.

11. A temperature sensor according to Claim 10 wherein the circuit includes means for measuring the electrical resistance of the ERT yarn between the terminals.

12. A garment fabric including a temperature sensor according to any preceding Claim as an integral part thereof.

13. A garment comprising a fabric according to Claim 12.

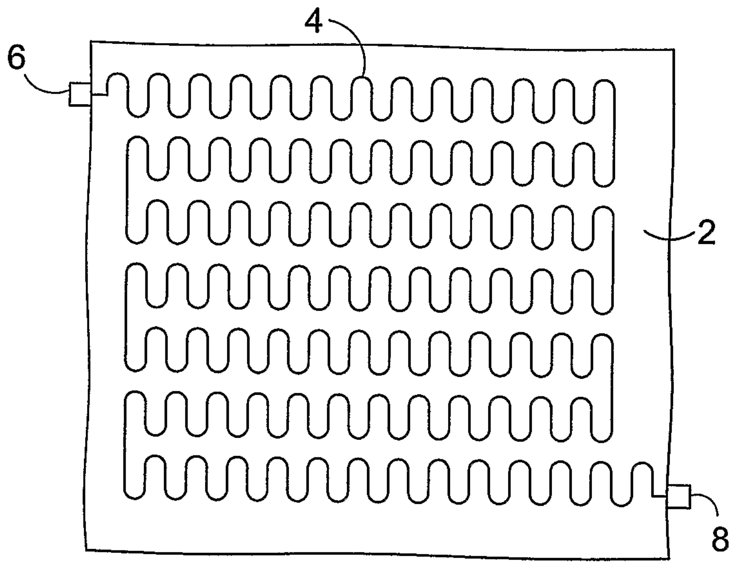

Fig. 1

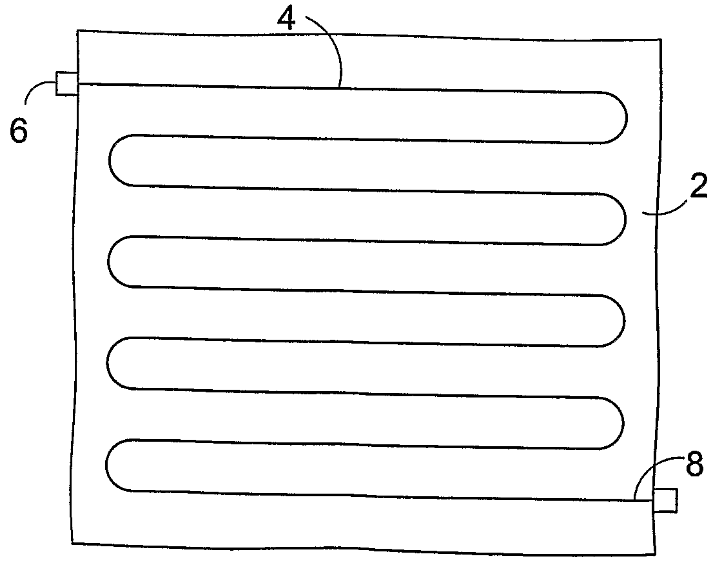

Fig. 2

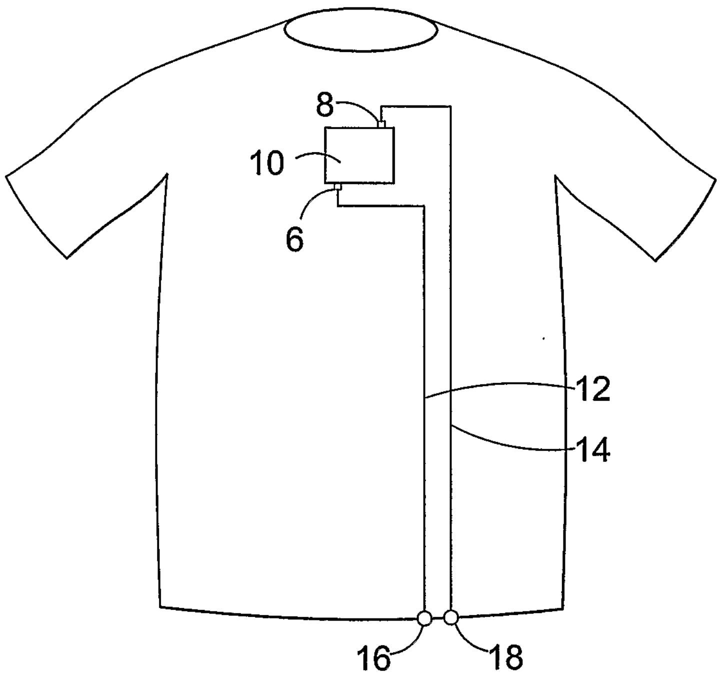

Fig. 3

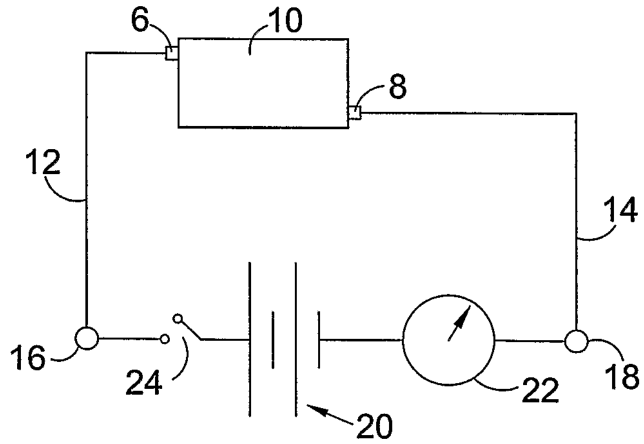

Fig. 4

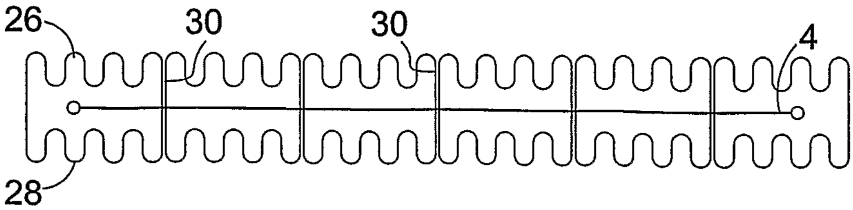

Fig. 5

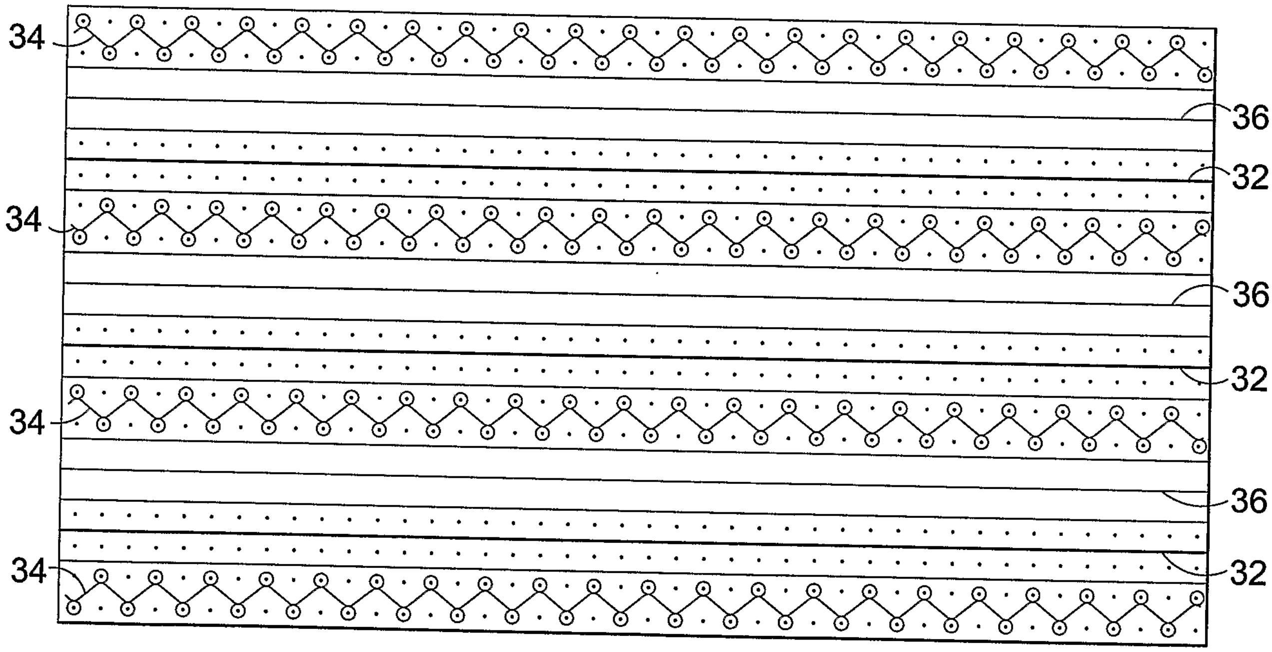

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2008/002242

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01K1/14 G01K7/16 G01K13/00 A41D1/00 A41D13/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01K A61B A41D D03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 199 27 686 A1 (DEOTEXIS INC) 22 March 2001 (2001-03-22) abstract; figures 1,4 columns 1-4 column 5, lines 52-54 -----	1-13
X	GB 1 361 358 A (VYZUMNY USTAV ORGANICKYCH SYNTEZ) 24 July 1974 (1974-07-24) columns 1-3; figures -----	1-13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2008/002242

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