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(56) Documents Cited:
WO 2017/081087 A1
CN 106969861 A
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(58) Field of Search:
INT CL **A43B, A61B, G01L**
Other: **WPI, EPODOC**

(54) Title of the Invention: **A force sensitive resistor**
Abstract Title: **A force sensitive resistor for a shoe sole**

(57) A force sensitive resistor 10 is provided comprising: a flexible bottom layer 8 of a first material, comprising a first conductive element attached to the bottom layer 8 (see electrodes 12 and 14 in figure 3) and this may be formed by printing with conductive ink. A spacer ring 18 is attached to the bottom layer 8 and surrounds the first conductive element and extends away from the bottom layer 8. A flexible top sensor layer 19 made of a second material is attached across the spacer ring 18 and also comprises a second conductive element facing the first conductive element. The flexible top sensor layer 19 is moveable relative to the flexible bottom layer 8 to vary the resistance of the force sensitive resistor 10. The Young's Modulus of the first material is less than the Young's Modulus of the second material. The flexible bottom layer may form the bottom layer of a shoe sole.

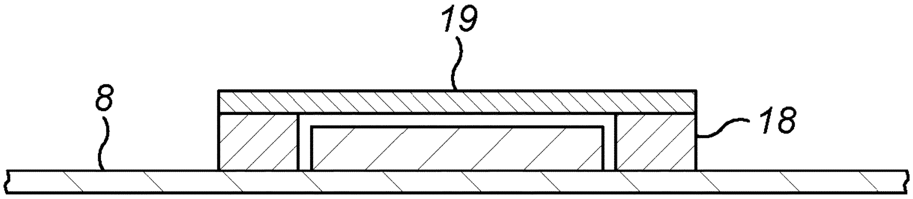

FIG. 3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

28 09 18

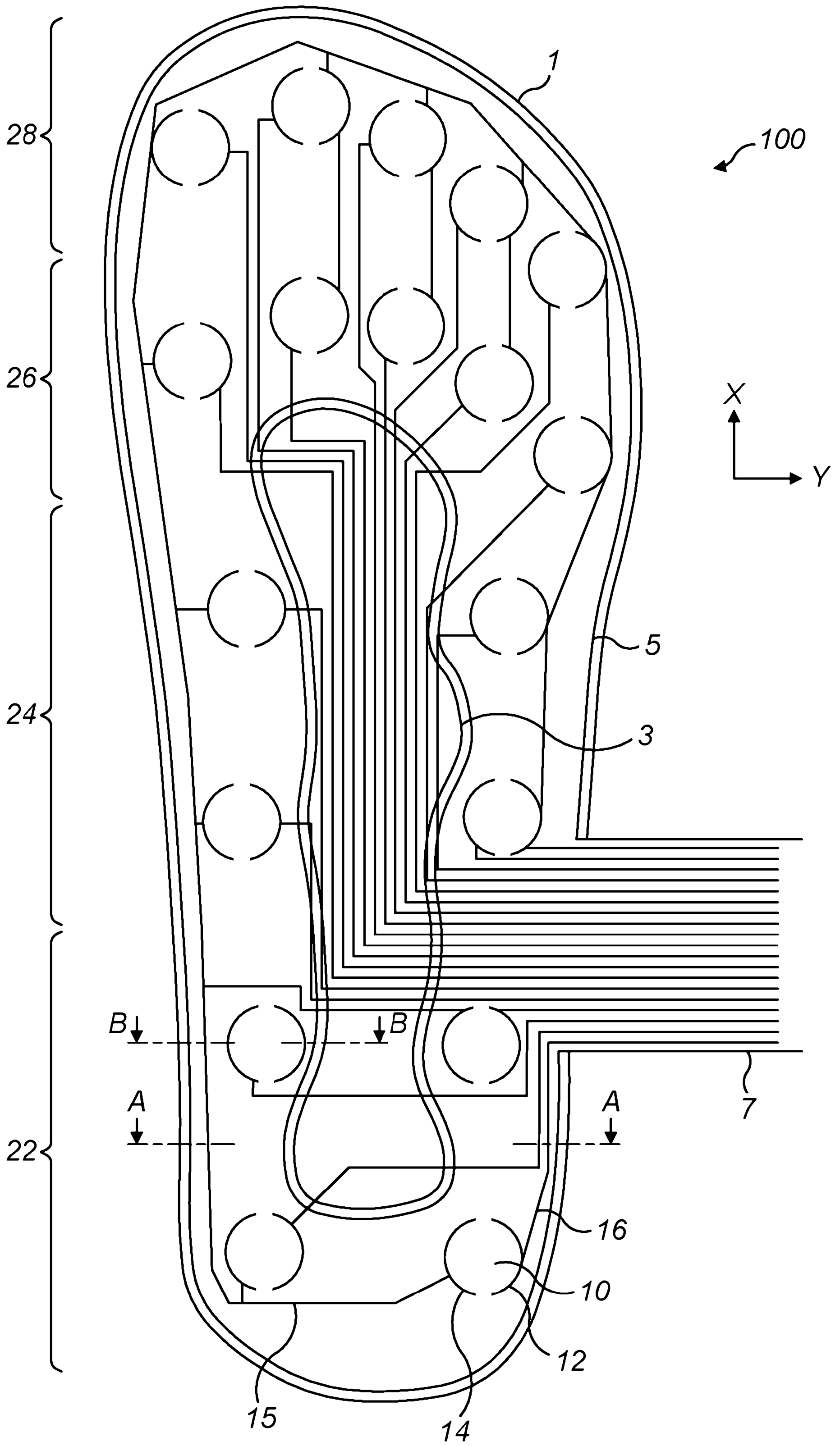

FIG. 1

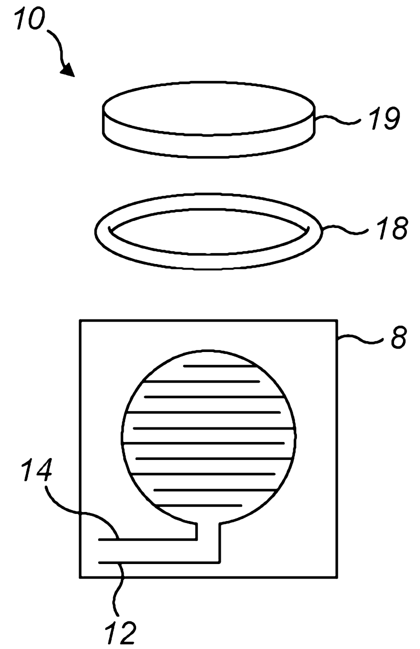

FIG. 2

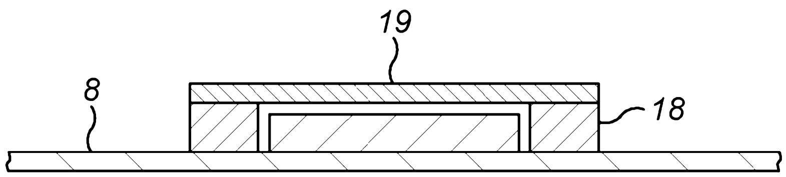

FIG. 3

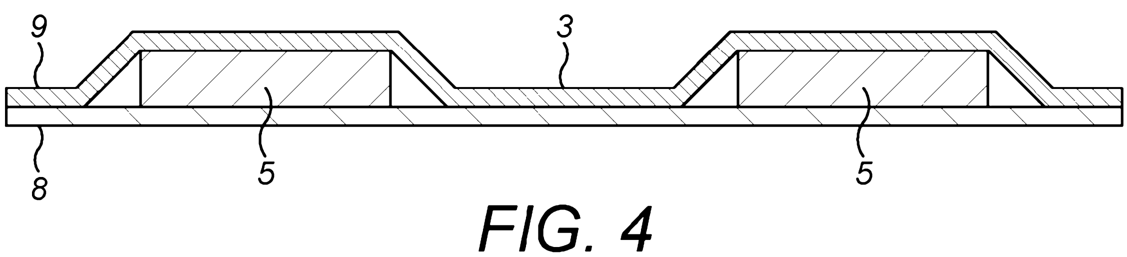

FIG. 4

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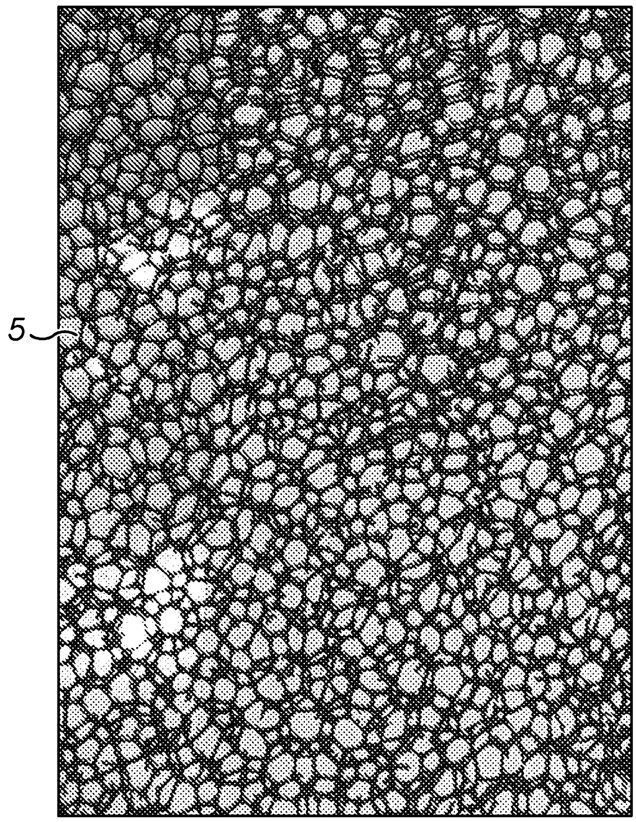

FIG. 5

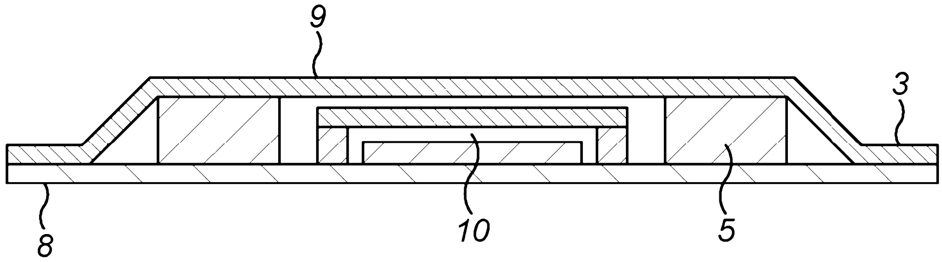

FIG. 6

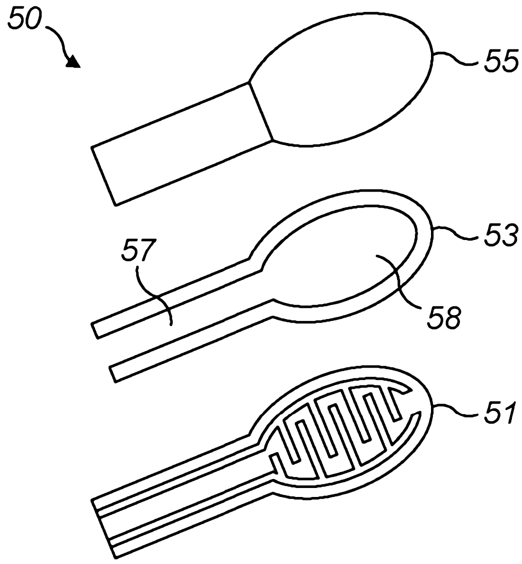

FIG. 7
Prior Art

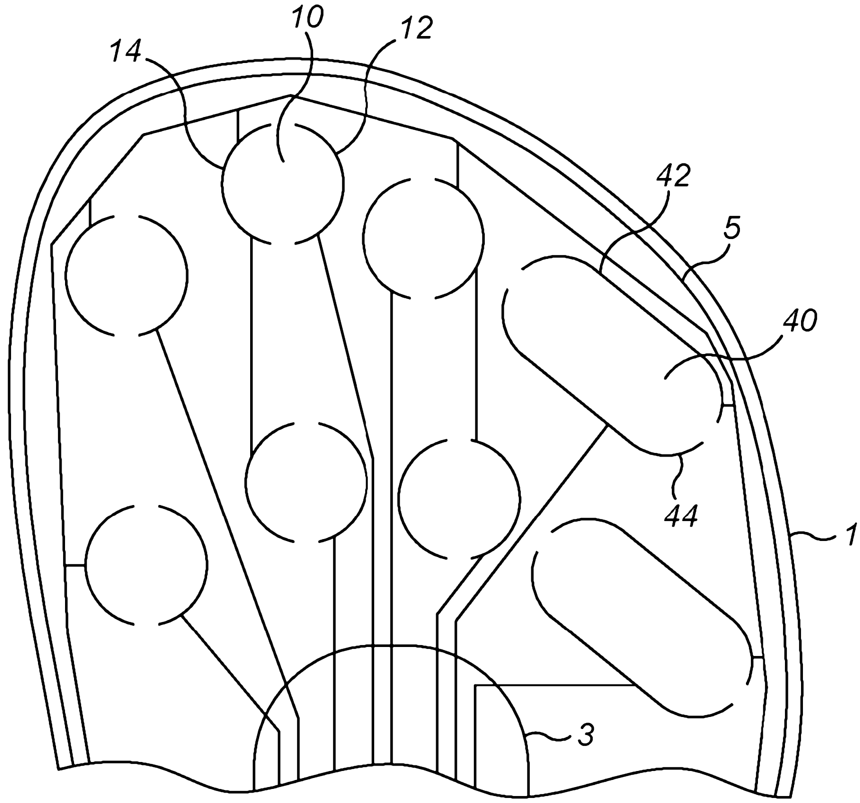

FIG. 8

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28 09 18

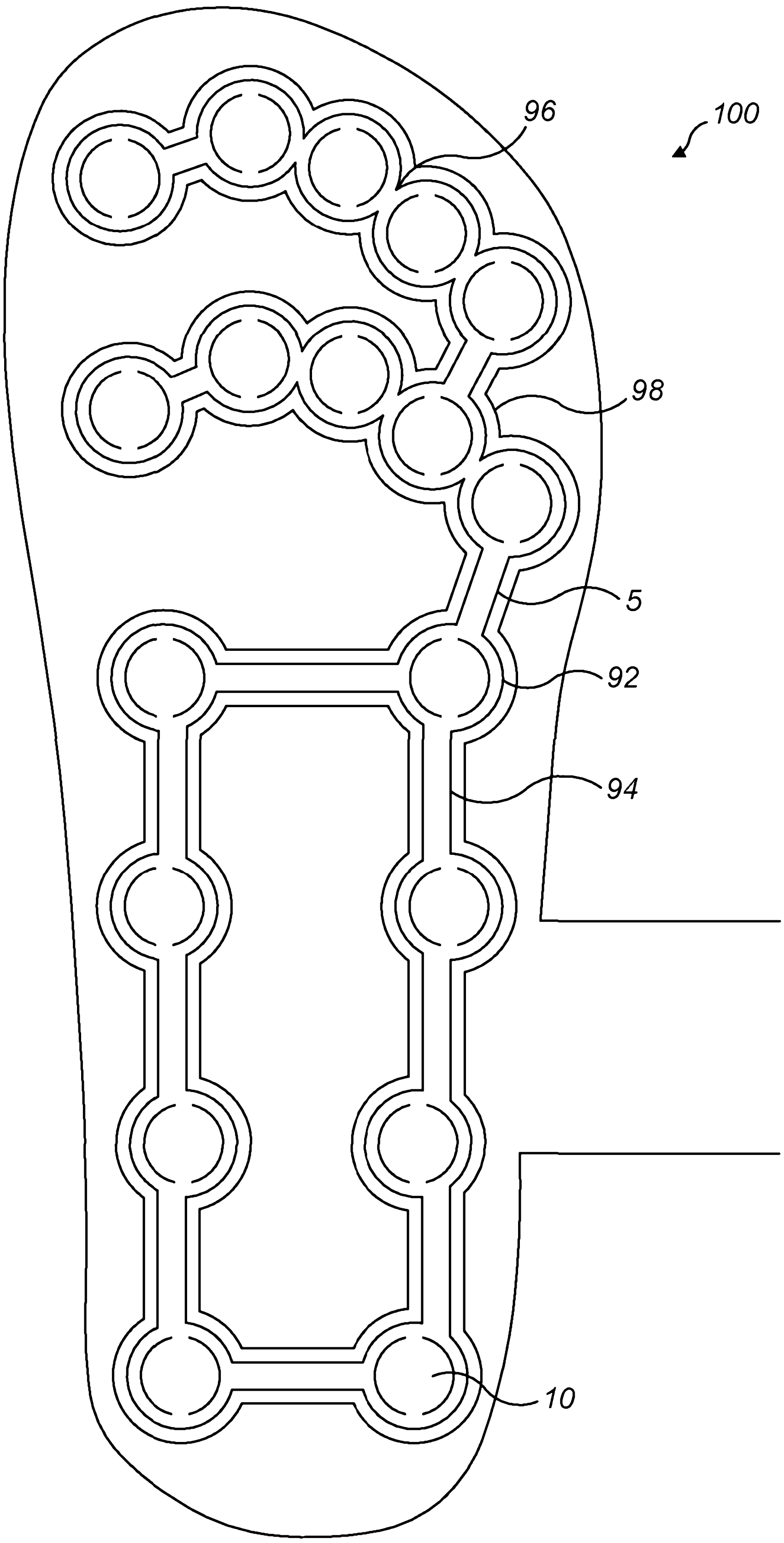

FIG. 9

A FORCE SENSITIVE RESISTOR

The present invention relates to a force sensitive resistor for use with stretchable materials.

Traditionally, force sensitive resistors are provided with a lower conductive member formed on a first substrate, and an upper conductive member formed on a second substrate. A spacer element is mounted between the first and second substrates. As the conductive members are moved toward and away from each other the resistance of the force sensitive resistor is altered. In this manner the force applied to the resistor can be determined by the change in the resistance. The substrates are required to be relatively stiff and resist stretching as otherwise the data from the force sensitive resistor will be corrupted.

This is particularly relevant as force sensitive resistors are often used in environments which receive significant forces and deformations. In particular, force sensitive resistors are being used in so-called "smart" clothing. This includes soles for shoes which are used to generate data regarding the user's gait, pressure distribution and/or pronation.

With the invention of conductive inks, the ability to print electrical circuits directly on to materials has been developed. It is possible to directly print one of the conductive members onto the surface where the force is to be detected. However, as the material stretches and flexes the data will become unusable. There is therefore a need to develop a system that allows direct application of a force sensitive resistor to a flexible and stretchable surface.

A force sensitive resistor is provided according to the present invention according to claim 1. The force sensitive resistor comprising: a flexible bottom layer of a first material, comprising a first conductive element attached to the bottom layer; a spacer ring attached to the bottom layer, the spacer ring surrounding the first conductive element and extending away from the bottom layer; and a flexible top sensor layer of a second material attached across the spacer ring comprising a second conductive element facing the first conductive element, the flexible top sensor layer being moveable relative to the flexible bottom layer to vary the resistance of the force sensitive resistor, characterised in that the Young's Modulus of the first material is less than the Young's Modulus of the second material.

This locally limits the amount of flexion of the lower layer in the region surrounding the first conductive element. In this way, accurate data can be obtained from a force sensitive resistor provided on a flexible and stretchable layer.

Preferably, the first conductive element is formed of a conductive ink printed onto the flexible bottom layer.

A sole is provided according to claim 3, comprising a force sensitive resistor according to claim 1 or 2, wherein the bottom layer of the sole is the flexible bottom layer of the force sensitive resistor.

The invention will now be described in detail, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a top schematic view of a shoe insole comprising a number of force sensitive resistors according to the invention;

Figure 2 is an exploded schematic, part plan, part perspective, view of a force sensitive resistor according to the invention;

Figure 3 is a side sectional view of the force sensitive resistor of Figure 2;

Figure 4 is a sectional view along the line A-A of Figure 1;

Figure 5 is a view of a cushioning material for use in the sole of Figure 1;

Figure 6 is a sectional view along the line B-B of Figure 1;

Figure 7 is an exploded schematic view of a force sensitive resistor according to the prior art;

Figure 8 is a top schematic view of a shoe insole comprising a number of force sensitive resistors according to a further embodiment of the invention; and

Figure 9 is a top schematic view of an alternative sole insole comprising a number of force sensitive resistors according to the invention.

The sole (or insole) 100 shown in Figure 1 is formed of upper and lower flexible and stretchable layers 8, 9 (shown in Figure 4) which are sealed in a water and air tight manner around their outer edge. In particular, the layers 8, 9 may be sealed by means of heat or sonic welding. The sole 100 may be a separate, removable component, or may be integrated with a shoe. The sole 100 is shaped for a human foot and the embodiment of Figure 1 defines two reference directions; a longitudinal direction X extending from a heel region 22 towards the back of the sole 100 to a toe region 28 towards the front of the sole 100, and a lateral direction Y extending from the inner side to the outer side of the sole 100. While the sole shown in Figure 1 is for a right foot, it is appreciated that a mirror version of this sole would be suitable for a left foot. Alternatively, the sole 100 may be usable for either foot by turning the sole 100 over.

Moving from the heel region 22 in the longitudinal direction, the sole 100 has a midfoot region 24, a forefront region 26 and a toe region 28. In use, the heel region 22 supports the user's heel, the midfoot region 24 supports the user's arch, the forefront region 26 supports the user's forefront and the toe region 28 supports the user's toes.

The sole 100 is provided with a number of force sensitive resistors 10 arranged across the sole 100. An exemplary force sensitive resistor 10 is shown in Figure 2. Conductive ink is printed on the bottom layer 8 in a pattern for a force sensitive resistor 10. This conductive ink forms electrodes 12, 14. These electrodes 12, 14 are substantially semi-circular with prongs 13 extending in alternating rows between the electrodes 12, 14. This forms a first conductive element. The prongs 13 have been omitted from the rest of the Figures for clarity, but they are present in each force sensitive resistor 10.

A spacer ring 18 is provided surrounding the first conductive element. A top sensor layer 19 is provided across the spacer ring 18. The top sensor layer 19 is flexible and comprises a second conductive element. Typically, the top sensor layer is formed from PET. The first and second conductive elements may be moved relative to one another in order to vary the resistance of the force sensitive resistor 10 as the user runs.

As the conductive ink is printed directly onto the stretchable lower layer 8, the output of the force sensitive resistor 10 may be altered when the lower layer 8 flexes and stretches and hence the results from the resistor 10 cannot be practically used. In order to address this, the upper sensor layer 19 is stiffer than the lower layer 8. This provides the localised region of the lower layer 8 with enhanced strength, on which the first conductive element is printed. In particular, this is achieved by the upper sensor layer 19 having a higher Young's modulus than the lower layer 8. This locally limits the ease of stretching of the lower layer 8 in the region of the first conductive element within the spacer 18. As such, the first conductive element may be printed directly on to the lower flexible layer 8 whilst still obtaining useful data.

As shown in Figure 1, the lower layer 8 is provided with printed conductive tracks connected to the electrodes 12, 14 of the force sensitive resistor 10. As shown, there may be a single ground track 15 to which each force sensitive resistor 10 is connected. This reduces the space required for the tracks. Each force sensitive resistor 10 is also provided with its own data track 16. The sole is provided with a tab 7 which provides a pathway for the conductive tracks 15, 16 to an external CPU and control system (not shown). The tab 7 is integral with the bottom layer 8 and is likewise flexible and stretchable. While the present figures are shown with an external CPU and control system, this is not necessarily the case, and the CPU and control system may be integral with the sole 100 or provided in another layer designed to be contained within the shoe with the sole 100.

The upper and lower flexible layers 8, 9 of the sole 100 are also sealed in a water and air tight manner across a portion of the central region of the sole 100. This forms a central sealed region 3 on the sole which may extend across the heel region 22, the midsole region 24 and the forefront region 26.

As shown in Figure 4, which is a schematic view along A-A as shown on Figure 1. Between the outer seal and the central sealed region 3, a compressible material 5 is provided. The compressible material 5 is designed to not seal to either of the upper and lower flexible layers 8, 9. In particular the layers 8, 9 should not sonic weld to the compressible material 5. The compressible material 5 is free between the upper and lower flexible layers 8, 9. In particular, the upper and lower flexible layers 8, 9 are not bonded to the compressible material 5. This leaves the compressible material 5 free to move in the gap between the layers 8, 9. As the compressible material 5 is substantially continuous, it is held in position by the central sealed region 3 as shown in Figure 1.

The compressible material may be any suitable material. In particular embodiments it is a foam material, with either an open cell or closed cell arrangement. Figure 5 shows an exemplary open cell foam which may be used with the present invention. High resilience to deformation is necessary to ensure that the sole 100 is not permanently deformed in use. The material 5 may form the main support material of the sole 100, or an additional cushioning material may also be provided for enhanced comfort. The material 5 is selected to have a higher melting point than the material of the first and second layers 8, 9 such that the layers 8, 9 will seal to one another around the material 5 without sealing to the material 5.

As shown in Figure 6 which is a sectional view along B-B, in preferred embodiments the material 5 is provided with cutaway sections substantially aligned with the force sensitive resistors 10. Air is able to flow through the material 5. This allows the entirety of the sole 100 to be sealed around its outer edge. Typically, prior art force sensitive resistors 50 as shown in Figure 7 which are formed of first conductive element 51, spacer 53 and second conductive element 55. The spacer 53 is provided with a vent pathway 57 extending from the spacer chamber 58 extending from the spacer chamber 58. The spacer chamber 58 is provided between the conductive elements.

As the conductive elements are moved towards and away from one another, the volume of the spacer chamber 58 is varied. Accordingly, air which is held in the spacer chamber 58 must be expelled via the vent pathway 57 otherwise the prior art force sensitive resistor 50 may rupture. As such, in prior art soles without the air permeable compressive material 5 of the present invention, a vent pathway must be provided from the force sensitive resistor 50 to the atmosphere outside of the sole 100. While efforts are made to minimise these vent pathways, they represent pathways via which moisture may ingress and damage the sole 100.

By providing the air permeable material 5, these vent pathways are no longer necessary. The air displaced by movement of the force sensitive resistors 10 can be distributed across the sole 100 without risking rupture. This allows the entire sole 100 to be sealed to the atmosphere, which ensures better moisture resistance than known systems.

Figure 9 shows an alternative embodiment of a sole 1. The wiring of the earlier embodiments is not shown in from this Figure for ease of understanding. The wiring of this embodiment is substantially the same as described with the other embodiments. In this embodiment, the compressible material 5 does extend generally across the sole but instead is concentrated in regions around the force sensitive resistors 10 in circular regions 92 surrounding each force sensitive resistor. As the compressible material 5 has a higher melting point than the material of the sole, a seal 98 will be formed around the shape of the compressible material 5.

In the embodiment of Figure 9, connecting portions 94 of compressible material 5 join the circular sections 92 to form a continuous region of compressible material 5. In the toe and forefront regions 28, 26 the circular sections 92 may have some degree of overlap 96.

In the embodiment shown in Figure 9, the compressible material 5 is continuous across all of the force sensitive resistors. However, this is not necessarily the case. In other embodiments particular regions may each have their own discrete regions of compressible material 5. For example, there may be one discrete region in the toe region 28, one discrete region in the forefront region 26 and two discrete regions down either side of the sole in the heel and midfoot regions 22, 24. Alternatively, each force sensitive resistor 10 may have its own discrete sealed section of compressible material 5. There may also be a combination of individual discrete sealed sections and discrete regions of compressible material 5. For example, the toe and forefoot regions 28, 26 may each have their own discrete region of compressible material 5, while the force sensitive resistors 10 in the heel and midfoot regions 22, 24 may be in individual discrete sealed sections of compressible material.

The force sensitive resistors 10 are distributed throughout the sole 100. This ensures that a detailed understanding of the user's weight distribution can be calculated, along with information such as the degree of pronation of the user while walking. In particular, as shown in Figure 1, each region 22, 24, 26, 28 comprises an individual sensing area comprising a plurality of force sensitive resistors 10. These force sensitive resistors 10 are generally similar in shape to one another, in that they are each substantially circular. In each of the toe and forefoot regions 28, 26 a row of force sensitive resistors 10 extending laterally Y across the sole 100 are provided. In particular, each row comprises five force sensitive resistors arranged to acquire data regarding each toe and corresponding toe knuckle.

While this arrangement in the toe and forefront regions 28, 26 is ideal it may not be possible in all embodiments. In particular, for soles 100 designed for smaller feet it may not be possible to fit five separate force sensitive resistors 10 across the lateral direction Y. Accordingly, an arrangement such as that shown in Figure 8 may be provided. As shown, the innermost three force sensitive resistors 10 are provided as in Figure 1. However, instead of two separate outer force sensitive resistors 10, a single force sensitive resistor 40 is provided. This force sensitive resistor 40 is elongated in the lateral direction Y to cover the outer part of the toe and forefront regions 28, 26. This elongated force sensitive resistor 40 is substantially rectangular with rounded ends in Figure 8. However, any suitable shape may be used. The force sensitive resistor 40 is provided with electrodes 42, 44 and functions as the circular force sensitive resistors 10 described above. It has been identified that the data from the individual outer toes is not of as much interest as the inner regions. Accordingly, the data from the outermost toes can be combined while still being useful for analytics.

Across the heel and midsole regions 22, 24 two longitudinal rows of force sensitive resistors 10 are provided. One row is on the inner side of the sole and the other row is on the outer side, with the sealed central region 3 provided between these rows. At least one force sensitive resistor 10 is provided in each row in each of the heel and midsole regions 22, 24. Preferably, if the sole 100 is big enough, each row has two force sensitive resistors 10 in each of the heel and midsole regions 22, 24.

By providing force sensitive resistors 10 in this arrangement a high quality of data can be obtained that provides a lot of information regarding the weight distribution and pronation of the user.

CLAIMS:

1. A force sensitive resistor comprising:

a flexible bottom layer of a first material, comprising a first conductive element attached to the bottom layer;

a spacer ring attached to the bottom layer, the spacer ring surrounding the first conductive element and extending away from the bottom layer; and

a flexible top sensor layer of a second material attached across the spacer ring comprising a second conductive element facing the first conductive element, the flexible top sensor layer being moveable relative to the flexible bottom layer to vary the resistance of the force sensitive resistor,

characterised in that the Young's Modulus of the first material is less than the Young's Modulus of the second material.

2. A force sensitive resistor according to claim 1, wherein the first conductive element is formed of a conductive ink printed onto the flexible bottom layer.

3. A sole comprising a force sensitive resistor according to any preceding claim, wherein the bottom layer of the sole is the flexible bottom layer of the force sensitive resistor.

Intellectual Property Office

Application No:	GB1710443.1	**Examiner:**	Eamonn Quirk
Claims searched:	1-3	**Date of search:**	19 December 2017

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-3	US2010/077868 A1 (Samsung/Joung) Figure 1, 3A spacer 151, resistor membrane 130, flexible PCB/electrode 120. Paragraphs 0029-0034, 0053.
X	1-3	US4314227 A (Eventoff) Figures 2-4, Col.5 lines 1-61.
X	1-3	US2013/098162 A (Chiou Jin Chern) figures 1,4-5: spacer 30, electrodes 21 and 11. Claim 2.
X	1-3	CN106969861 A (Wu Haibin) see figure 2
X	1-3	WO2017/081087 A1 (Axilum Robotics) Figure 2 and 4, spacer ring 7, contacts 6, 9. Page 5 line 21 - page 8 line 21.
X	1-3	US2006/273417 A1 (Fidelica) Figures 1 and 2, flexible membrane 104, flexible substrate 102, spacer 106

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

A43B; A61B; G01L

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

Intellectual Property Office

International Classification:

Subclass	Subgroup	Valid From
G01L	0001/20	01/01/2006
A43B	0003/00	01/01/2006
A61B	0005/103	01/01/2006
G01L	0001/18	01/01/2006