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JP 2007178256 A US 6505521 B1
US 6049080 A US 4315238 A
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(54) Title of the Invention: **Resistance changing detector**
Abstract Title: **Dual action parallel sensor**

(57) A sensor is configured to experience resistance changes in response to an external interaction such as force, pressure or touch. The sensor comprises a first layer of a conductive material (301, 503) attached to a first electrode (304) and a second intermediate layer of a material (302) having a resistance sensitive to said external interaction. A third layer (303) consists of a first set of fingers (504) interdigitated with a second set of fingers (505). The first set of fingers is connected to a second electrode (305) whilst the second set of fingers is attached to a third electrode (306). The first electrode is connected to one of said second electrode or said third electrode to make a parallel connection (507,508) and resistance is measured between said parallel connection and the remaining third or second electrode. A method for constructing such a sensing device for sensing an external interaction is also disclosed.

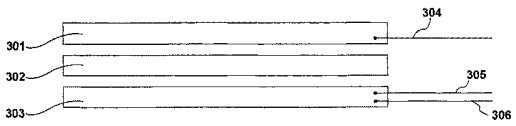

Fig. 3

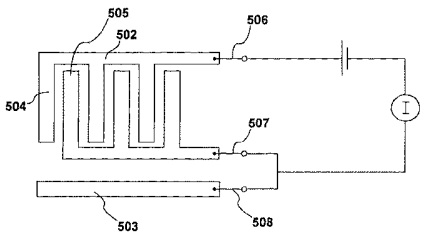

Fig. 5

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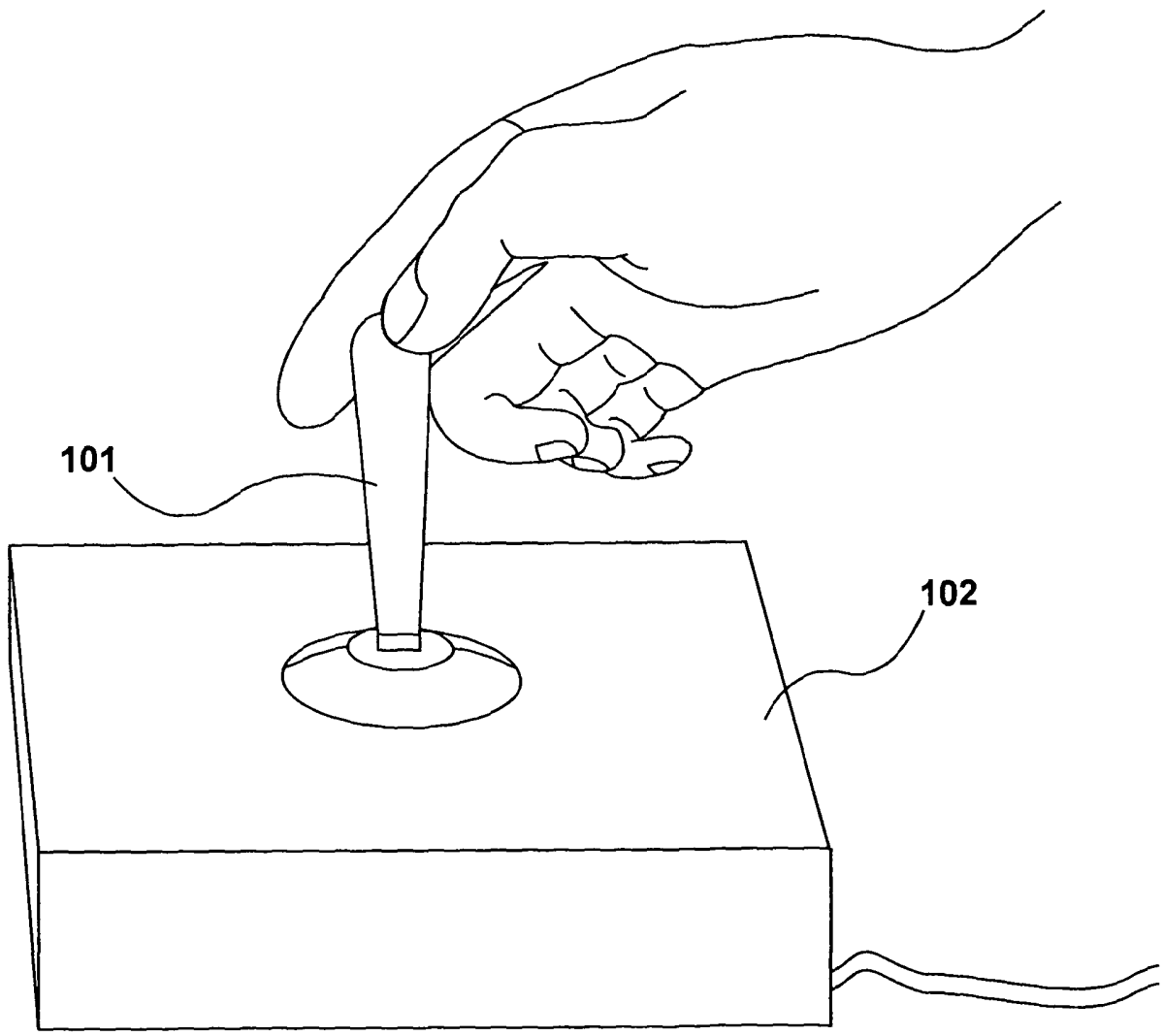

Fig. 1

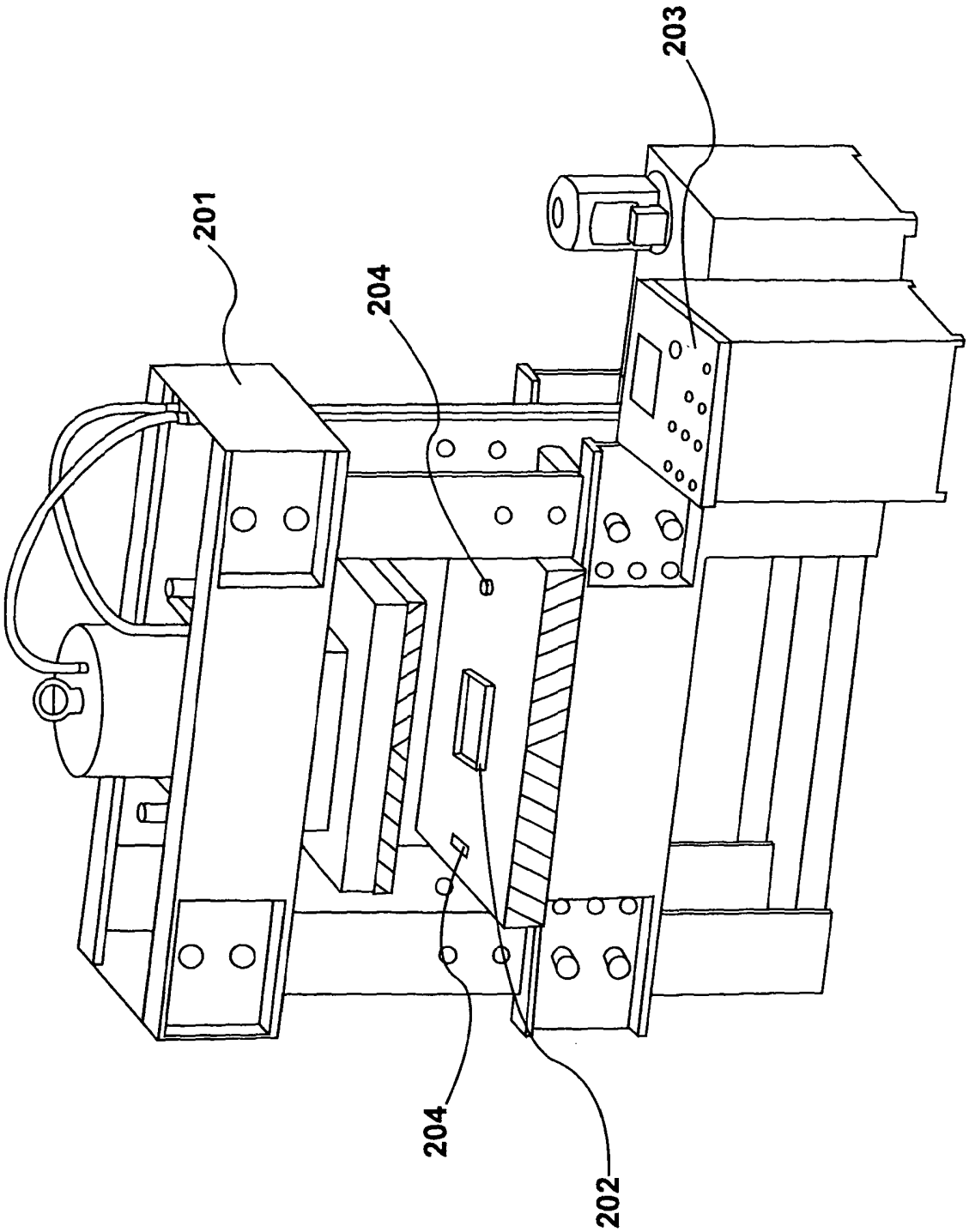

Fig. 2

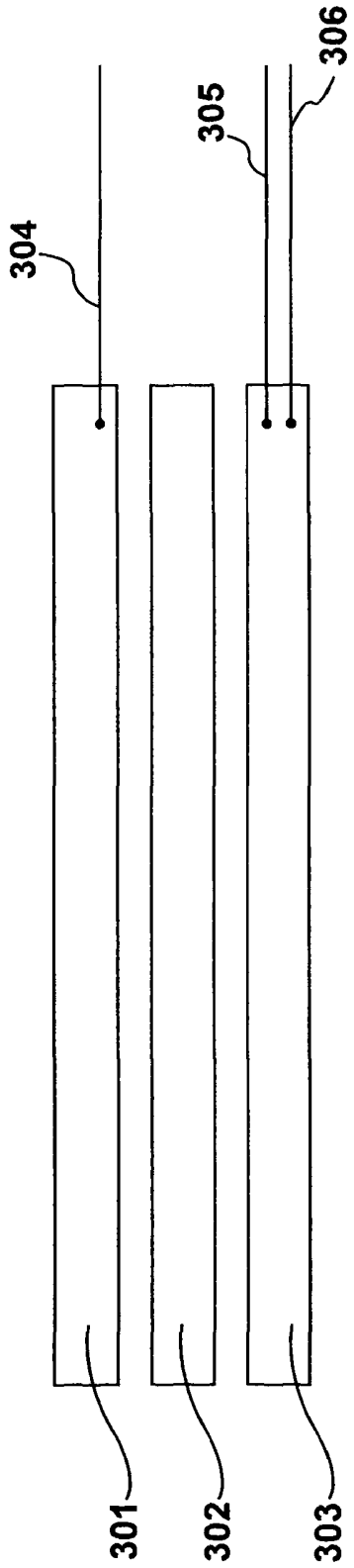

Fig. 3

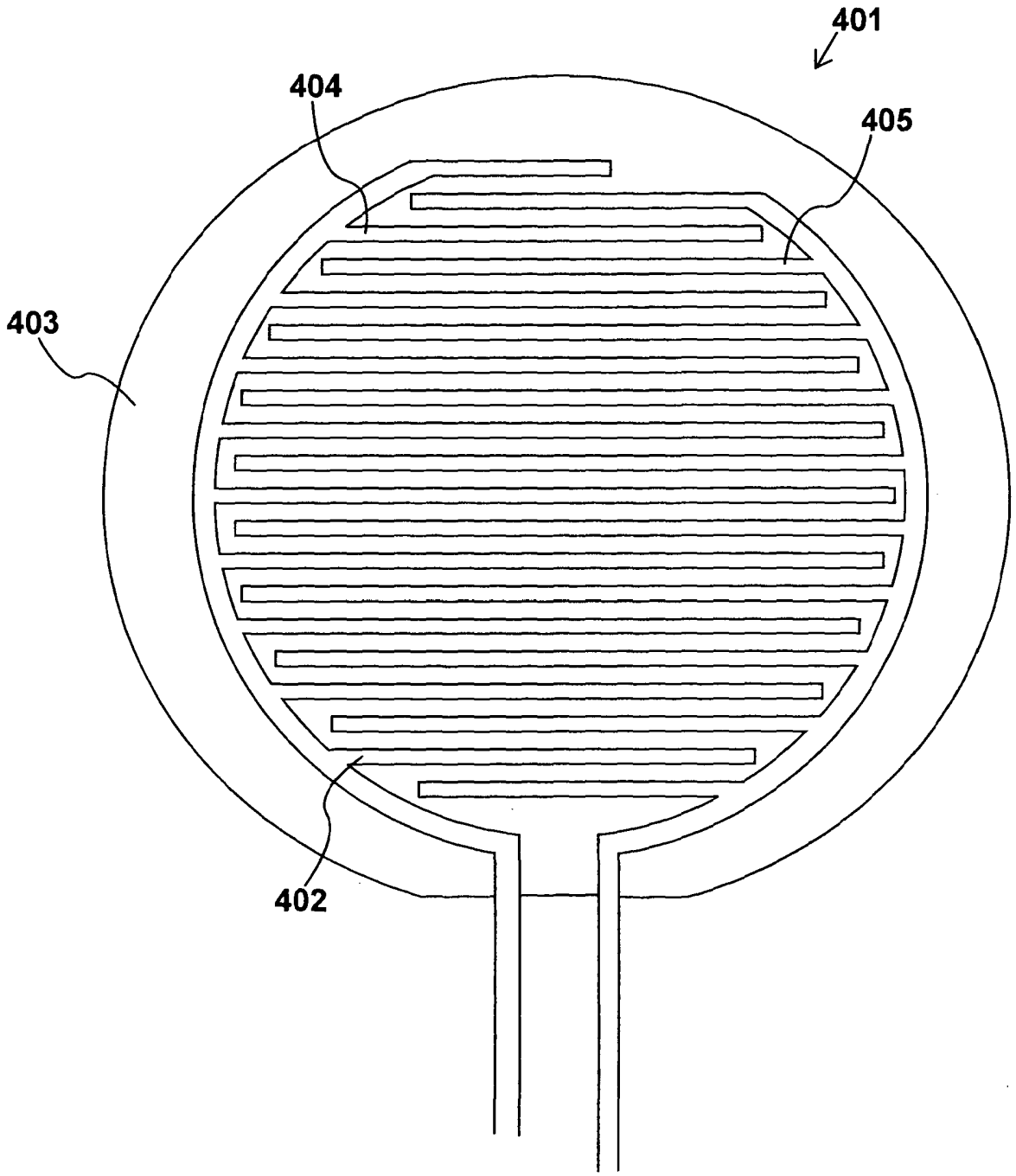

Fig. 4

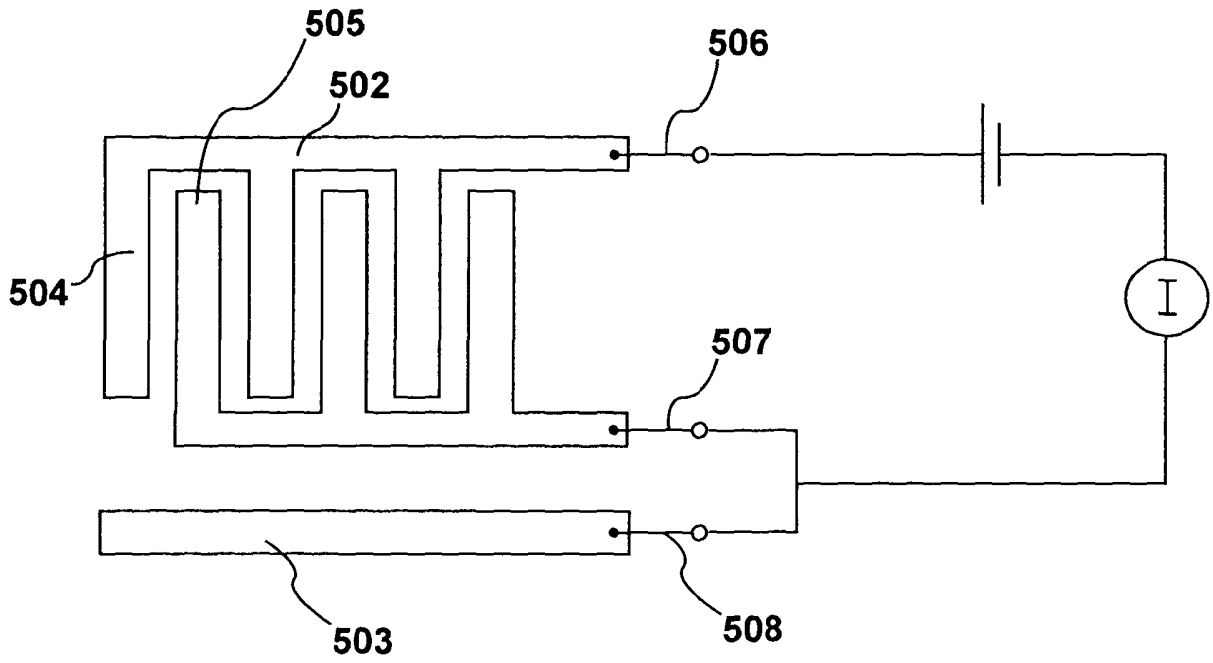

Fig. 5

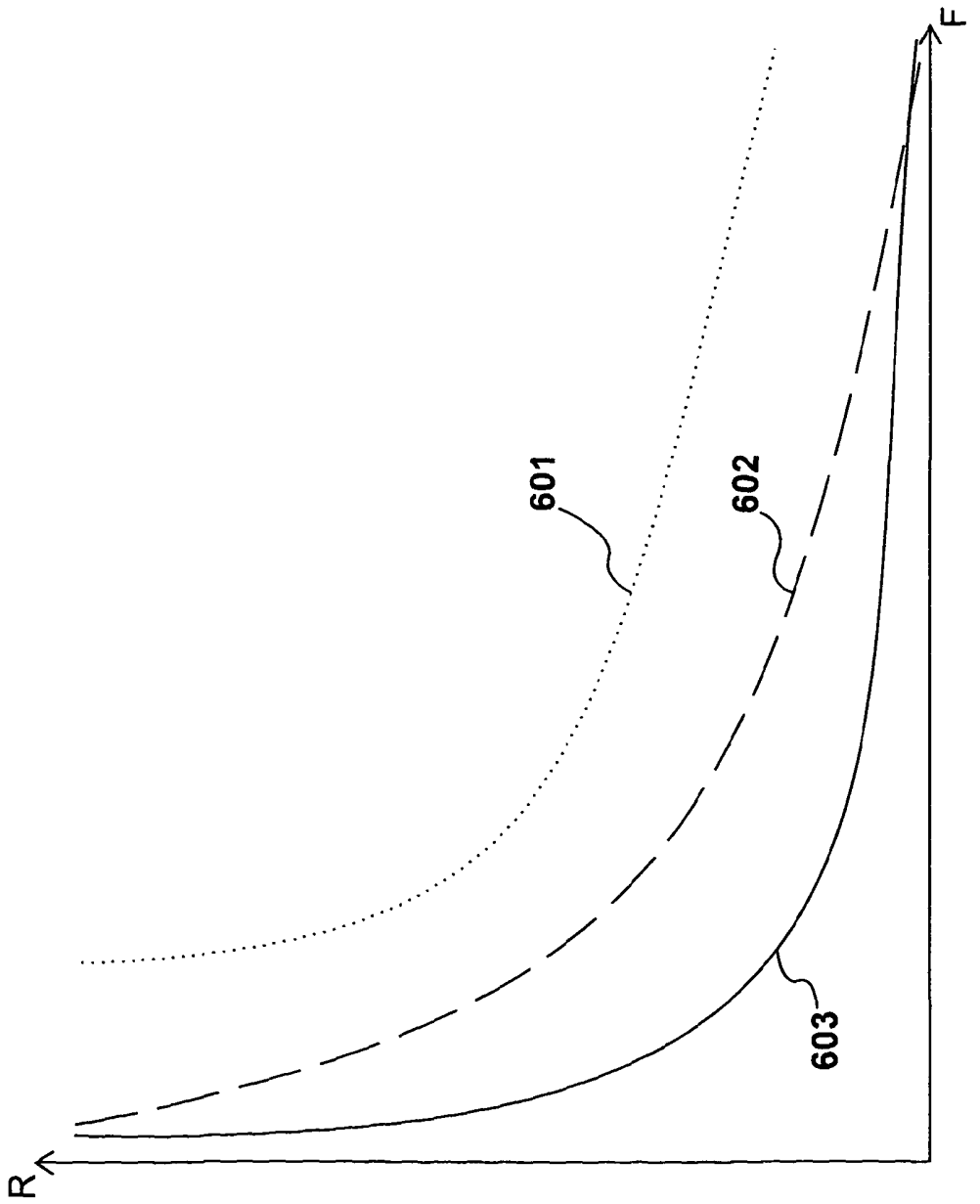

Fig. 6

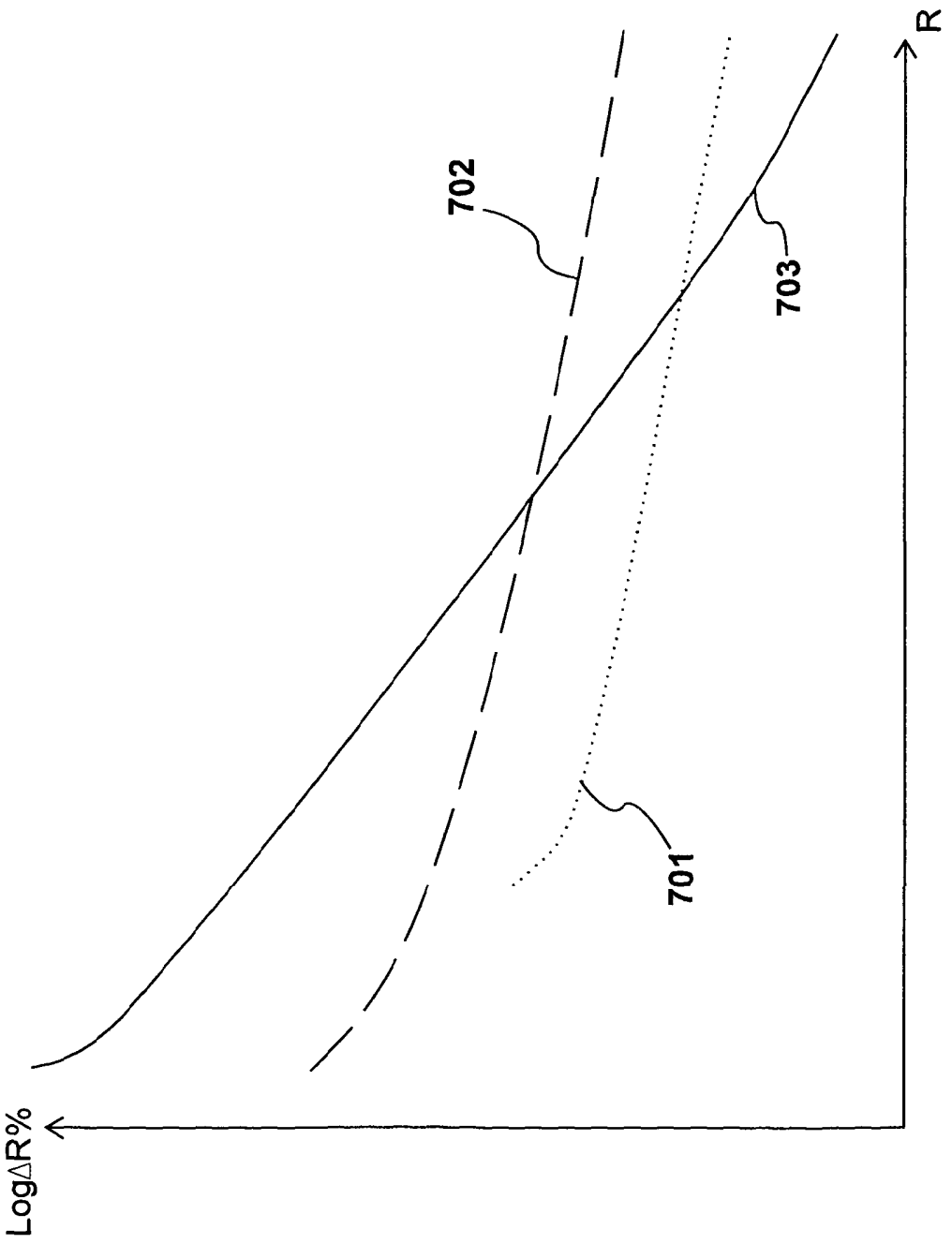

Fig. 7

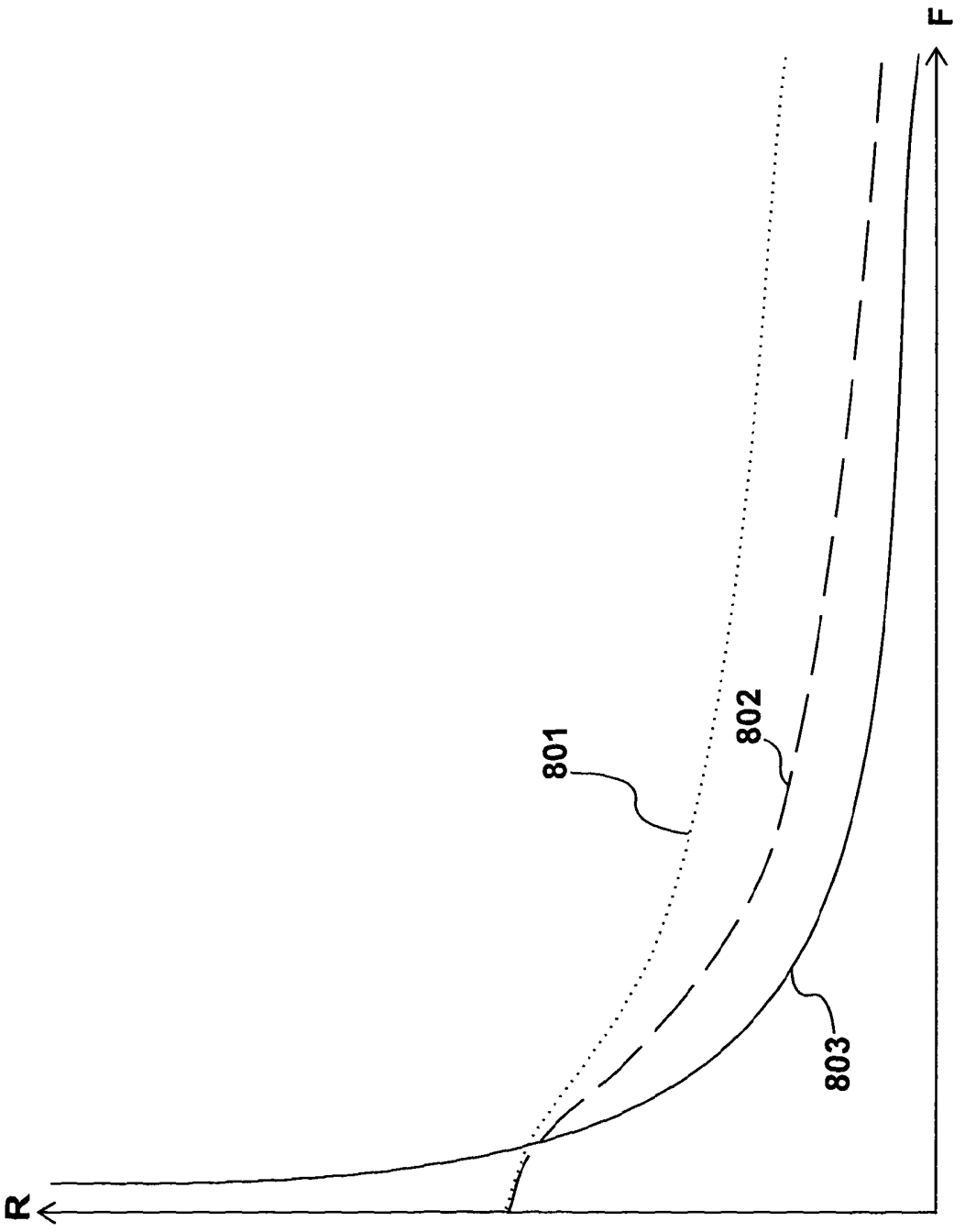

Fig. 8

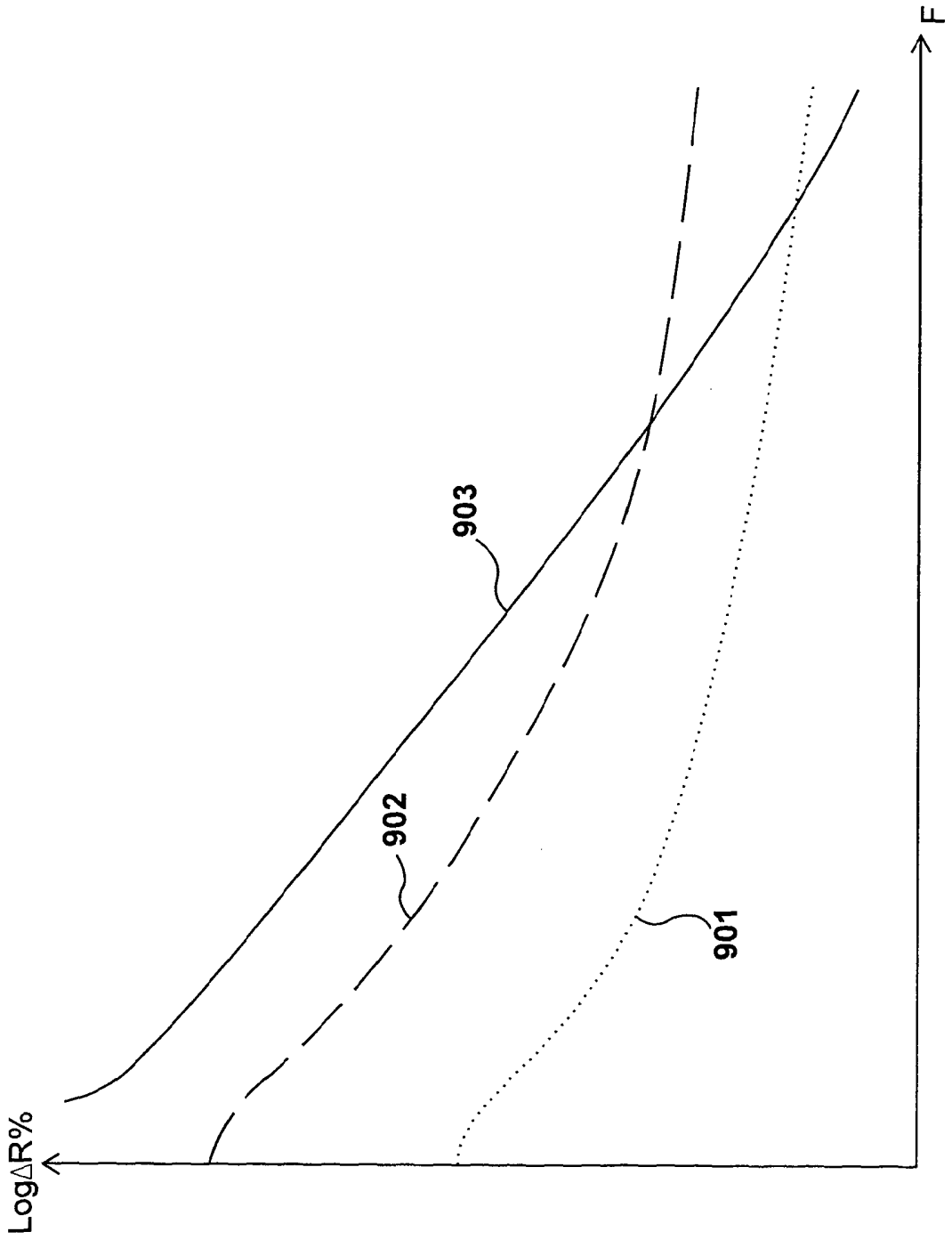

Fig. 9

RESISTANCE CHANGING DETECTOR

CROSS REFERENCE TO RELATED APPLICATIONS

This application represents the first application for a patent directed towards the invention and the subject matter.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a detector or sensor configured to experience resistance changes in response to an external interaction.

The present application also relates to a method of constructing a sensing device for sensing an external interaction by effecting a change in resistance.

2. Description of the Related Art

A sensor configured to experience resistance changes in response to an external interaction is disclosed in United States patent 6 501 465, assigned to the present assignee. The disclosed sensor deploys conductive fabric layers and increasing applied pressure results in a greater degree of conductivity between the layers such that the resistance of the connection may be measured in order to determine the degree of applied pressure. An acknowledged problem with systems of this type is that they exhibit a wide range of responses such that it is difficult to predict the way in which resistance will change and it is therefore difficult to engineer the sensor for a particular application.

An alternative approach is disclosed in US 6 291 568, assigned to the present assignee, in which a quantum tunnelling composite (manufactured by the present applicant) is deployed as a material with variable resistivity in

response to applied pressure. By using a quantum tunnelling composite, it is possible to control the response of the detector more accurately, although in some configurations the response may be very sensitive to relatively small pressures or it may have an extended range while being less sensitive to an initial press.

There are two known methods for measuring a change in resistance. One way is to have an electrode at the top with a second electrode at the bottom and pressure sensing material sandwiched in between. A voltage is applied and changes in current are detected due to varying changes in resistance.

An alternative method is to have alternate electrodes on the bottom, referred to as interdigitated fingers, with the pressure sensitive material on the top. These known methods produce different force/resistance profiles because the first method defines one resistance while the second method provides two. Different paths are taken and accordingly there is a different resistance profile.

BRIEF SUMMARY OF THE INVENTION

According to an aspect of the present invention, there is provided a detector configured to experience resistance changes in response to an external interaction, comprising: a first layer of a conductive material having a first electrode connected thereto; a second intermediate layer of a material having a resistance sensitive to said external interaction; and a third layer consisting of a first set of fingers interdigitated with a second set of fingers; wherein, said first set of fingers has a second electrode attached thereto and said second set of fingers has a third electrode attached thereto; said first electrode is connected to one of said second electrode or said third electrode to make a parallel connection; and resistance is measured between said parallel connection and the remaining third or second electrode.

In an embodiment, the second intermediate layer is fabricated from quantum tunnelling compound. In alternate embodiments, the layer fabricated from quantum tunnelling compound may be directly printed onto the first layer

of a conductive material having a first electrode connected thereto or onto the third layer consisting of a first set of fingers interdigitated with a second set of fingers.

According to a second aspect of the present invention, there is provided a method of constructing a detecting device for detecting an external interaction by effecting a change in resistance, comprising the steps of: defining a first layer of a conductive material; attaching a first electrode to said first layer of a conductive material; defining a second intermediate layer of a material having a resistance sensitive to external interactions; defining a third layer consisting of a first set of fingers interdigitated with a second set of fingers; attaching a second electrode to said first set of fingers and attaching a third electrode to said second set of fingers; connecting said first electrode to one of said second electrode or said third electrode to make a parallel connection; and measuring resistance between said parallel connection and the remaining third or second electrode.

In an embodiment, the second intermediate layer is fabricated from a quantum tunnelling composite. The layer fabricated from a quantum tunnelling composite may be directly printed onto the first layer of a conductive material having a first electrode connected thereto or onto the third layer consisting of a first set of fingers interdigitated with a second set of fingers.

In an embodiment, an external interaction takes the form of a mechanical interaction caused by the application of force or pressure. In an alternative embodiment, the external interaction involves an interaction with a chemical vapour and the detector may be deployed primarily as a safety device for detecting harmful vapours. In an alternative embodiment, the external interaction takes the form of an application of electro-magnetic radiation or ionising radiation.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a perspective view of a manually operable joystick supported by a base unit;

Figure 2 is a perspective view of a press;

Figure 3 shows a representation of the layered structure of a detector embodying an aspect of the present invention;

Figure 4 shows a generalised representation of the sensor according to the invention;

Figure 5 shows a representation of the electronic circuit of the detector according to the invention;

Figure 6 is a graphical representation of the force-resistance profiles for different readings of an embodiment of the detector;

Figure 7 is a graphical representation of the force-resistance profiles for different readings of an embodiment of the detector, on a logarithmic scale;

Figure 8 is a further graphical representation of the force-resistance profiles for different readings of a preferred embodiment of the detector; and

Figure 9 is a further graphical representation of the force-resistance profiles for different readings of a preferred embodiment of a detector, on a logarithmic scale.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Figure 1

An environment that makes use of a detector or a plurality of detector is illustrated in Figure 1. In this example, a manually operable joystick 101 is provided supported by a base unit 102. The joystick 101 is moveable with respect to the base unit 102 and when moved pressure is applied to a sensor that is responsive to the external forces being applied thereto.

Figure 2

An alternative environment is illustrated in Figure 2 in which a press 201 applies force against a workpiece 202 so as to press the workpiece into a desired shape. The press operates with a plurality of control mechanisms 203 and as such it is necessary for the degree of pressure to be determined. Thus, again, detectors 204 are included that are configured to experience resistance

changes in response to the external pressure being applied.

Figure 3

A layered structure of an embodiment is shown in Figure 3. The detector has three layers. The first layer 301 is of a conductive material and has a connection to a single electrode 304. The first layer may be fabricated from a metallic material, including copper, or may be a fabric. The second intermediate layer 302 is of a material having a resistance sensitive to an external interaction. The second intermediate layer 302 is not connected to an electrode. The second intermediate layer is preferably fabricated from a quantum tunnelling composite. The second intermediate layer may be printed directly onto the first layer 301 or the third layer 303. The third layer may be fabricated from a metallic material, including copper. The third layer 303 consists of a first set of fingers interdigitated with a second set of fingers (not shown). Both the first set of fingers and the second set of fingers each have a second electrode 305 and a third electrode 306 respectively attached thereto. As shown in Figure 3, there are therefore three connections 304, 305 and 306 to electrodes.

The first electrode 304 is connected to one of said second electrode 305 or said third electrode 306 to make a parallel connection. Resistance is measured between said parallel connection and the remaining third or second electrode.

Figure 4

A generalised representation of an embodiment of the detector is shown in Figure 4. The detector 401 with an interdigitated electrode structure 402 on one side and a single electrode structure 403 on the other side is shown.

The interdigitated electrode structure 402 consists of a first set of fingers 404 interdigitated with a second set of fingers 405. The interdigitated

electrode structure 402 may be constructed from a metallic material, including copper. The interdigitated electrode structure 402 or the single electrode structure 403 is coated in a pressure sensitive material (not shown). This pressure sensitive material is preferably a quantum tunnelling composite.

Figure 5

A representation of the electronic circuit of an embodiment is shown in Figure 5. The sensor 501 with an interdigitated electrode structure 502 on one side and a single electrode structure 503 on the other side is shown. The interdigitated electrode structure 502 consists of a first set of fingers 504 interdigitated with a second set of fingers 505. The first set of fingers 504 and the second set of fingers 505 have a second electrode 506 and a third electrode 507 respectively attached thereto. The single electrode structure 503 has a connection to a single electrode 508. As shown in Figure 5, the single electrode 508 may be connected to either of the second electrode 506 or the third electrode 507. The first electrode 508 is therefore connected to one of said second electrode 506 or said third electrode 507 to make a parallel connection. Resistance is detected because the second layer (not shown) is fabricated from a material having a resistance sensitive to external interactions. The second layer is preferably made from a quantum tunnelling composite. The resistance is measured between said parallel connection and the remaining third electrode 507 or second electrode 506.

Figure 6

A graphical representation of the force-resistance (F-R) profiles for different readings of an embodiment of a detector is shown in Figure 6. The vertical axis measures resistance (R) whilst the horizontal axis measures application of force (F). In the embodiment shown in Figure 6, the detector has a first layer of a conductive material, preferably copper, having a first electrode connected giving a single electrode structure and a third layer having an

interdigitated finger electrode structure. A second intermediate later fabricated from a quantum tunnelling composite is printed onto the single electrode structure.

The top dotted line 601 represents a measurement across the interdigitated finger electrode, which gives poor first touch sensitivity but continues to change upto high loads. The current path goes up one set of interdigitated fingers and through the intermediate layer, fabricated from a quantum tunnelling composite giving a pressure sensitive variation. The current path then moves through the single electrode, back through the intermediate layer, fabricated from a quantum tunnelling composite to the second set of interdigitated fingers, giving a second pressure sensitive result. Such a measurement is useful for the detection of high force applications.

The lowermost solid line 603 represents a measurement through the sensor, from the layer having the interdigitated electrode structure to the layer with the single electrode structure. This represents a typical measurement through a detector having top and bottom solid electrodes. A very sensitive detector responding to low forces but which flattens off when high forces are applied, is seen.

The middle dashed line 602 represents a measurement in a detector according to an embodiment of the invention, wherein the first electrode (connected to the first layer of conductive material) is connected to one of said second electrode or said third electrode (connected to the first and second set of interdigitated fingers respectively) to make a parallel connection. The resistance is measured between said parallel connection and the remaining third or second connection. Such a parallel measurement gives a good first touch sensitivity and continues to change up to the application of relatively high forces.

A sensor configured according to an embodiment of the invention benefits from a much extended force resistance curve, still being sensitive to low forces but continuing to show a response up to high force loads.

Figure 7

Figure 7 shows a representation of the detector profiles described in Figure 6 on a logarithmic scale, wherein the intermediate layer of the detector which is sensitive to external interaction and is preferably fabricated from a quantum tunnelling composition is printed onto the single electrode structure.

The dotted line 701 represents a measurement across the interdigitated finger electrode, which shows a good resistance changing response up to high loads but has a poor response at low loads.

The solid line 703 represents a measurement through the detector, from the layer having the interdigitated electrode structure to the layer with the single electrode structure. This represents a typical measurement through a detector having top and bottom solid electrodes. A detector which shows good resistance changes at low loads but which reduces at high loads is seen.

The dashed line 702 represents a measurement in a detector according to an embodiment, wherein the first electrode (connected to the first layer of conductive material) is connected to one of said second electrode or said third electrode (connected to the first and second set of interdigitated fingers respectively) to make a parallel connection. The resistance is measured between said parallel connection and the remaining third or second connection. Such a parallel measurement gives a good balanced changing resistance through the force range.

Figure 8

A graphical representation of the F-R profiles for different readings of an embodiment of the sensor is shown in Figure 8. The vertical axis measures resistance (R) whilst the horizontal axis measures application of force (F). In the embodiment of the detector used for the F-R profile shown in Figure 8, the detector has a first layer of a conductive material, preferably copper, having a first electrode connected thereto and a third layer having an

interdigitated finger electrode structure. A second intermediate later, fabricated from a quantum tunnelling composite is printed onto the interdigitated finger electrode structure. This embodiment therefore differs from the embodiment described in the paragraph detailing the profiles shown in Figure 6 in that the intermediate layer is printed onto the interdigitated finger electrode structure rather than onto the single electrode structure.

The top dotted line 801 represents a measurement across the interdigitated finger electrode, which gives a start resistance of the quantum tunnelling composite sheet resistance but little change in resistance through the force range.

The lowermost solid line 803 represents a measurement through the detector, from the layer having the interdigitated electrode structure to the layer with the single electrode structure. This represents a typical measurement through a detector having top and bottom solid electrodes. This measurement gives good first touch sensitivity but flattens out at high loads.

The middle dashed line 802 represents a measurement in a detector according to the present invention, wherein the first electrode (connected to the first layer of conductive material) is connected to one of said second electrode or said third electrode (connected to the first and second set of interdigitated fingers respectively) to make a parallel connection. The resistance is measured between said parallel connection and the remaining third or second connection. Such a parallel measurement has the start resistance of the quantum tunnelling composite sheet resistance and shows an improved range through the force range.

A detector configured according to an embodiment of the invention benefits from a much extended force resistance curve, still being sensitive to low forces but continuing to show a response up to high force loads.

Figure 9

Figure 9 shows a representation of the detector profiles described

in Figure 8 on a logarithmic scale, wherein the intermediate layer of the detector which is sensitive to external interaction and is preferably fabricated from a quantum tunnelling composite, is printed onto the interdigitated electrode structure.

The dotted line 901 represents a measurement across the interdigitated finger electrode, which shows a good resistance changing response upto high loads but nothing at low loads.

The solid line 903 represents a measurement through the detector, from the layer having the interdigitated electrode structure to the layer with the single electrode structure. This represents a typical measurement through a detector having top and bottom solid electrodes. A detector which shows good resistance changes at low loads but which reduces at high loads is seen.

The dashed line 902 represents a measurement in a detector according to an embodiment of the invention, wherein the first electrode (connected to the first layer of conductive material) is connected to one of said second electrode or said third electrode (connected to the first and second set of interdigitated fingers respectively) to make a parallel connection. The resistance is measured between said parallel connection and the remaining third or second connection. Such a parallel measurement gives a balanced change of resistance through the force range.

Embodiments described above show a detector configured to experience resistance changes in response to an external interaction taking the form of applied force or applied pressure. It should also be appreciated that sensors of this type may be deployed to identify other physical interactions. For example, the resistivity of the intermediate glare may change in response to changes in temperature or in response to changes in an applied radiation. The applied radiation may take the form of heat or may take the form of an ionising radiation.

Claims

1. A detector configured to experience resistance changes in response to an external interaction, comprising:

a first layer of a conductive material having a first electrode connected thereto;

a second intermediate layer of a material having a resistance sensitive to said external interaction; and

a third layer consisting of a first set of fingers interdigitated with a second set of fingers, wherein:

said first set of fingers has a second electrode attached thereto and said second set of fingers has a third electrode attached thereto;

said first electrode is connected to one of said second electrode or said third electrode to make a parallel connection; and

resistance is measured between said parallel connection and the remaining third or second electrode.

2. The detector of claim 1, wherein said second intermediate layer is fabricated from a quantum tunnelling composite.

3. The detector of claim 2, wherein said quantum tunnelling composite is printed directly onto the first layer of a conductive material having a first electrode connected thereto.

4. The detector of claim 2, wherein said quantum tunnelling compound is printed directly onto said third layer consisting of a first set of fingers interdigitated with a second set of fingers.

5. The detector of claim 1, wherein said first layer of conductive material is fabricated from a metallic material.

6. The detector of claim 5, wherein said metallic material includes

copper.

7. The detector of claim 1, wherein said first layer of conductive material is a fabric.

8. The detector of claim 1, wherein said third layer is constructed from a metallic material.

9. The detector of claim 8, wherein said metallic material includes copper.

10. The detector of claim 1, wherein said external interaction takes the form of a mechanical interaction.

11. The detector of claim 10, wherein said mechanical interaction includes the application of pressure.

12. The detector of claim 1, wherein said external interaction includes the application of radiation.

13. A method of constructing a detector for detectoring an external interaction by effecting a change in resistance, comprising the steps of:

defining a first layer of a conductive material; defining a first layer of a conductive material;

attaching a first electrode to said first layer of a conductive material; defining a second intermediate layer of a material having a resistance sensitive to external interactions;

defining a third layer consisting of a first set of fingers interdigitated with a second set of fingers;

attaching a second electrode to said first set of fingers and attaching a third electrode to said second set of fingers;

connecting said first electrode to one of said second electrode or said third electrode to make a parallel connection; and measuring resistance between said parallel connection and the remaining third or second electrode.

14. The method of claim 1, wherein said second intermediate layer is fabricated from quantum tunnelling compound.

15. The method of claim 11 wherein said external interaction takes the form of a mechanical interaction, such as the application of pressure.

Application No:	GB1016329.3	**Examiner:**	Eamonn Quirk
Claims searched:	all	**Date of search:**	11 March 2011

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
A	-	JP2007178256 A (Canon KK) See figures
A	-	US4301337 A (Eventoff, Franklin Neal)
A	-	US6505521 B1 (Daimler Chrysler)
A	-	US4315238 A (Eventoff, Franklin Neal)
X	1,6-9,13	US6049080 A (Murata) see description of figures 3 and 4.

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

G01J; G01L; G01T; G06F; H01C; H01H

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

Online: WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
G01L	0001/20	01/01/2006
G01L	0001/18	01/01/2006
G06F	0003/041	01/01/2006
G06F	0003/045	01/01/2006