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(54) **FLUIDIC PIEZORESISTIVE STRAIN GAUGE**

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See application file for complete search history.

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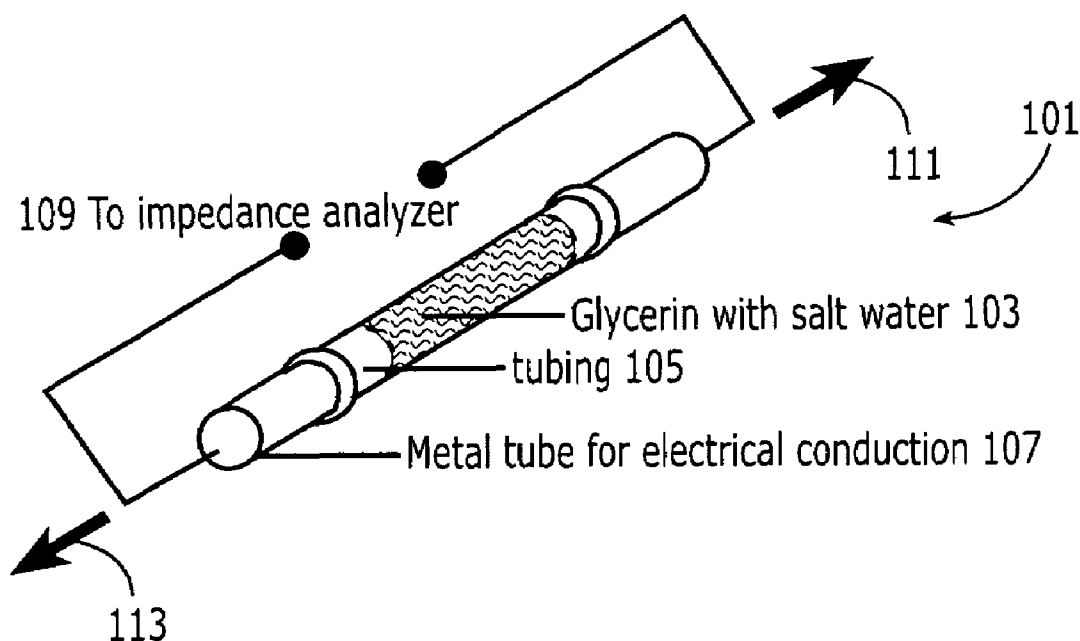
Primary Examiner—Max Noori

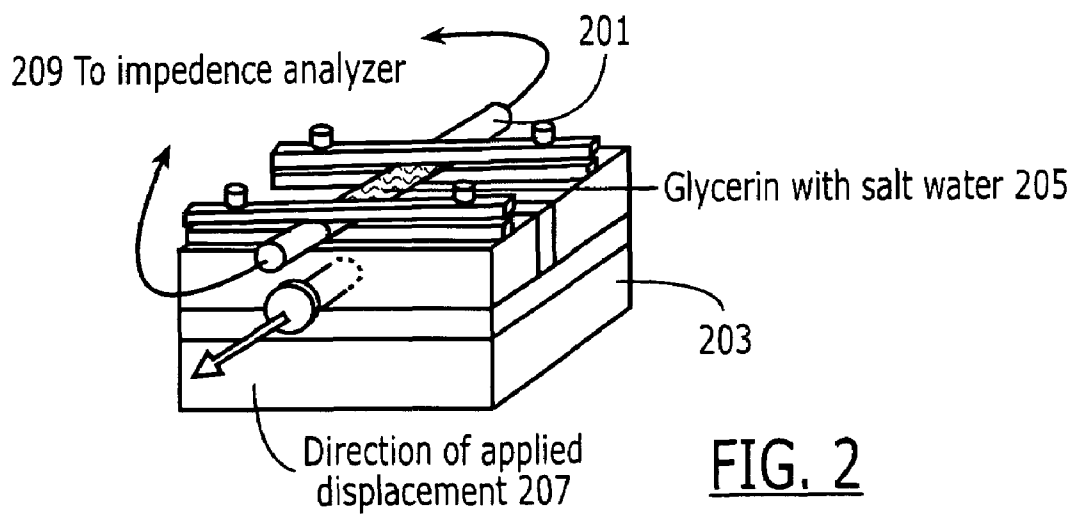
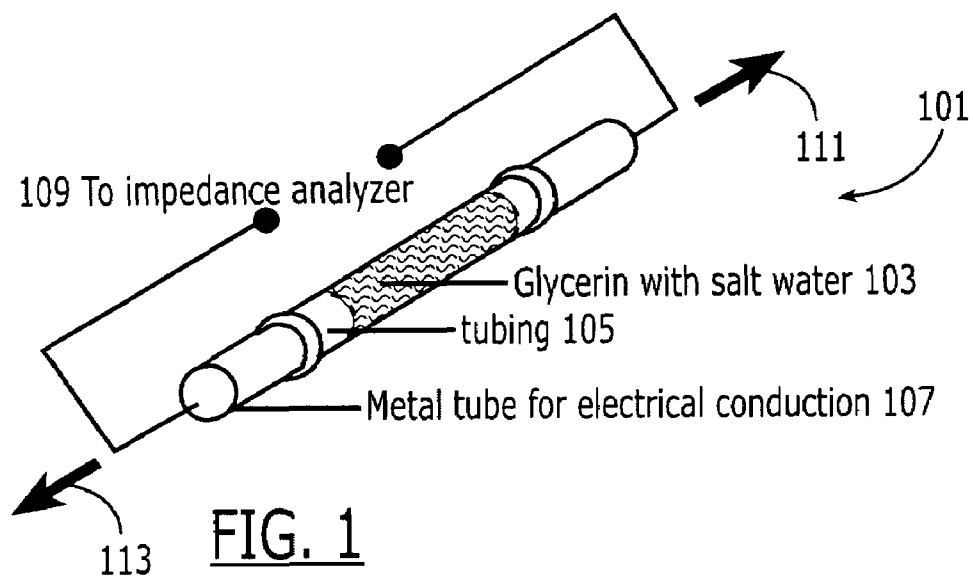
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(57) **ABSTRACT**

The present invention relates to a strain gauge having a con-
ductive fluid made of a glycerin/aqueous salt mixture, and
methods of making the strain gauge. The strain gauge is
capable of measuring large displacement of around 30% true
strain.

6 Claims, 3 Drawing Sheets





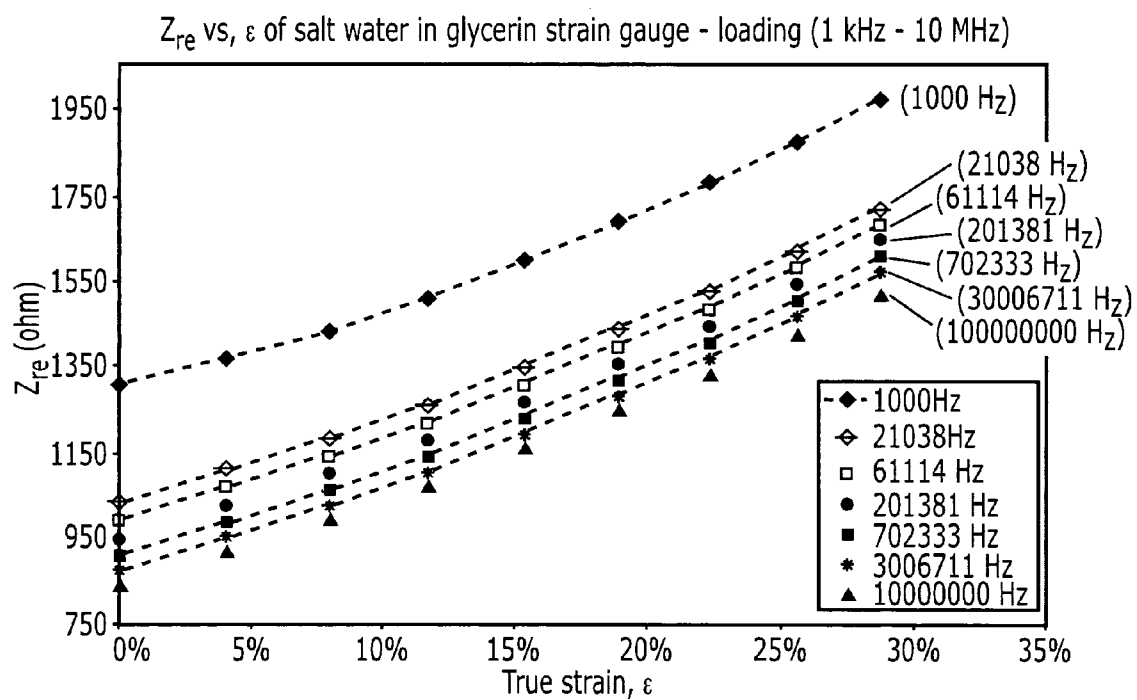


FIG. 3

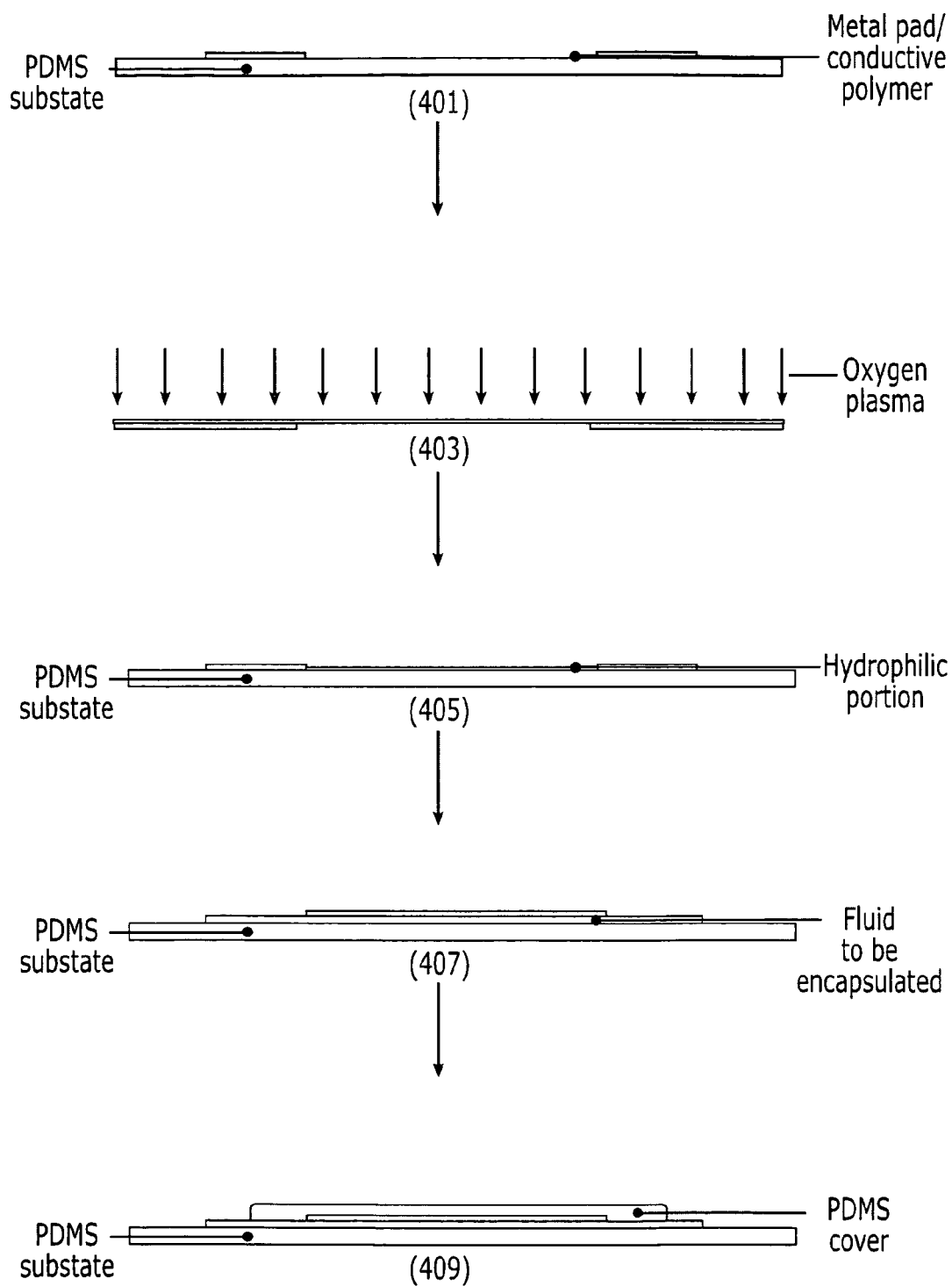


FIG. 4

FLUIDIC PIEZORESISTIVE STRAIN GAUGE

BACKGROUND

A strain gauge is a device for measuring dimensional change in a specimen. Electrical-type strain gauges are widely in use today and are based upon the measurement of a resistance change that is proportional to the strain. The principle of a resistance-type strain gauge can be illustrated with a conduction in rod shape. As the rod is elongated in response to tensile stress, the length of the rod increases when the basic resistivity of the material remains reasonably constant. The displacement is translated via a movement to a rotatable pointer that moves opposite a dial of calibrated pressure valves. Gauges displaying values in digital form often include an electronic pressure transducer, such as a piezo-type sensor, that generates an electrical signal in response to the pressure to which the transducer is exposed. The electrical signal is then converted to a symbol that is presented on the display. Traditional strain gauges are made of alloys such as copper-nickel alloy, nickel-chrome alloy, and platinum-8% tungsten, etc.

It is an object of the present invention to provide a fluidic strain gauge capable of high displacement measurement not recorded in the prior art.

DESCRIPTION

The present invention relates to a strain gauge having a conductive fluid made of a glycerin/aqueous salt mixture, and methods of making the strain gauge. The present gauge is useful in biomedical applications, for example in the measurement of large tissue deformation.

These and other features, aspects, and advantages of the invention and methods of making such will become better understood from the following description, appended claims, and accompanying drawings where:

FIG. 1 shows an embodiment of a fluidic strain gauge of the present invention;

FIG. 2 shows the fluidic strain gauge embodiment on a displacement apparatus;

FIG. 3 shows the results of the present fluidic strain gauge impedance measurements at applied strains under a frequency range of 1 KHz-10 MHz;

FIG. 4 shows a method of making the present fluidic strain gauge embodiment.

The following description of certain exemplary embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

Now, to FIGS. 1-4,

FIG. 1 is an embodiment of a strain gauge **101** of the present invention, including a glycerin/aqueous salt mixture **103** serving as the fluid inside a polymer casing **105** to which it is attached, on either end of the casing **105**, metal tubes **107**. Leads **109** are connected to the metal tube **107** ends for feeding to an impedance analyzer for alternating current measurements.

The gauge length (length between two electrodes) of the casing **105** used in gauge **101** can range from 15 mm to 30 mm in length. The casing **105** can be circular, with a diameter of from about 1 mm to about 5 mm or any other suitable shape. The casing **105** can be made of a polymer material, such as an elastic or rubber-like polymer. The casing **105** is sealed at both ends to contain the glycerin mixture **103**, and attached to metal tubes **107** on both ends.

The metal tubes **107** are attached to leads **109** and to a measuring instrument.

In use, tensile stress/displacement **111/113** is applied to both ends of the strain gauge **101**. The gauge **101** is elongated, which results in a resistance increase. The resistance increase results in a electrical impedance change, exhibited by an attached impedance analyzer.

The glycerin/aqueous salt mixture **103** includes salt, water and glycerin. Salt may be used in an amount of from 0.5 to 1.5 parts, water in an amount of from 7 to 10 parts, and glycerin in an amount of from 2 to 4 parts. The salt can be sodium chloride or common salt; suitable water can be distilled water, deionized water, double distilled water, and the like.

FIG. 2 is an embodiment of a strain gauge **201** of the present invention, positioned on a displacement apparatus **203**.

As shown, the gauge **201** is attached to the displacement apparatus **203** at the two ends. The tubing contains the glycerin/aqueous salt mixture **205**. Through leads, a measuring device **209** is connected to the gauge **201** via metal terminals. Tensile stress/displacement **207** is applied to the gauge **201**, and the electrical impedance change measured.

FIG. 3 shows the variation between the real part of the impedance measured (Z_{re}) against true stain (ϵ) applied at different frequencies (1 KHz-10 MHz) for an embodiment of the present strain gauge. A linear relationship between Z_{re} and ϵ is obtained which shows linear strain sensitivity. As shown, the gauge is capable of measurements up to and beyond a 30% change in displacement.

FIG. 4 is an embodiment of a method of making the present strain gauge.

Firstly, a metal pad, such as gold, or a conductive polymer pad is deposited on a polymer, for example for polydimethylsiloxane substrate **401**. Oxygen plasma is then applied to the substrate for approximately 1 to 3 minutes **403**, creating a hydrophilic layer with pattern **405**. The conductive fluid of the gauge, containing a glycerin/aqueous salt mixture, is poured onto the substrate at the hydrophilic layer **407**. The fluid is then encapsulated with a polymer cover **409**.

Having described embodiments of the present system with reference to the accompanying drawings, it is to be understood that the present system is not limited to the precise embodiments, and that various changes and modifications may be effected therein by one having ordinary skill in the art without departing from the scope or spirit as defined in the appended claims.

In interpreting the appended claims, it should be understood that:

- a) the word "comprising" does not exclude the presence of other elements or acts than those listed in the given claim;
- b) the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements;
- c) any reference signs in the claims do not limit their scope;
- d) any of the disclosed devices or portions thereof may be combined together or separated into further portions unless specifically stated otherwise; and
- e) no specific sequence of acts or steps is intended to be required unless specifically indicated.

The invention claimed is:

1. A strain gauge, comprising
 - a polymer casing;
 - a fluidic piezoresistive material made of a glycerin/aqueous salt mixture;
 - metal tubes, metal conducting pads, or conductive polymer pads positioned on both ends of said polymer casing;
 - and

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wherein the length between electrodes of said fluidic piezoresistive material is contained within said polymer casing.

2. The strain gauge of claim 1, wherein said glycerin/aqueous salt mixture comprises 0.5 to 1.5 parts salt, 7 to 10 parts water, and 2 to 4 parts glycerin.

3. The strain gauge of claim 2, wherein said salt is sodium chloride.

4. The strain gauge of claim 1, wherein water is distilled water, deionized water, or double distilled water.

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5. The strain gauge of claim 1, wherein the gauge length of said polymer casing is between 15 mm to 30 mm in length.

6. The strain gauge of claim 1, wherein said polymer casing is made of an elastomer selected from the group consisting of an acylate, butyls, fluorocarbons, fluorosilicones, sulfides, urethanes, neopenes, isoprenes, nitrites, silicones, and butadienes.

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