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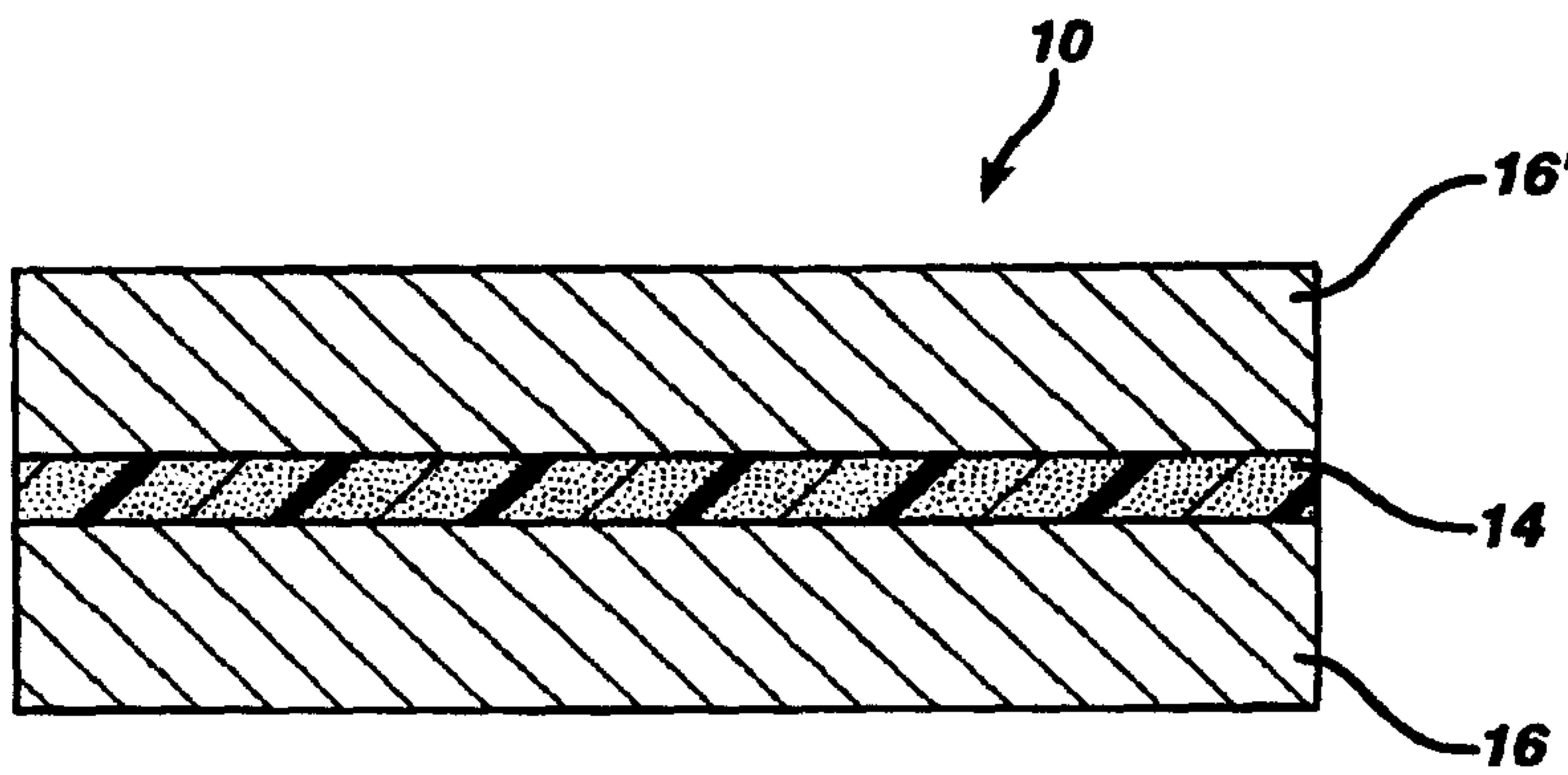
(54) **DETECTEUR DE VAPEUR DE SOLVANT ORGANIQUE**
(54) **ORGANIC SOLVENT VAPOR DETECTOR**




(57) L'invention concerne un détecteur de liquide et/ou de vapeur organique, utile dans les accumulateurs aux ions de lithium et dans d'autres dispositifs renfermant des liquides et/ou des vapeurs organiques, qui comportent un matériau polymère gonflant supporté ou non supporté sensible aux liquides et/ou aux vapeurs organiques. Ce matériau est un polymère, un copolymère ou un mélange physique des deux et, éventuellement, il peut être rempli de particules électriques conductrices. L'invention concerne également un procédé relatif à l'élaboration du détecteur et des dispositifs qui en sont équipés.

(57) The present invention is directed to an organic liquid and/or vapor detector which is useful in Lithium Ion batteries and other devices containing organic liquids and/or vapors comprising a supported or unsupported swellable polymeric material which is sensitive to organic liquids and/or vapors. The swellable polymeric material is a polymer, copolymer or physical mixture thereof that may, optionally, be filled with electrically conductive particles. A process of preparing the detector and devices containing the same are also disclosed.

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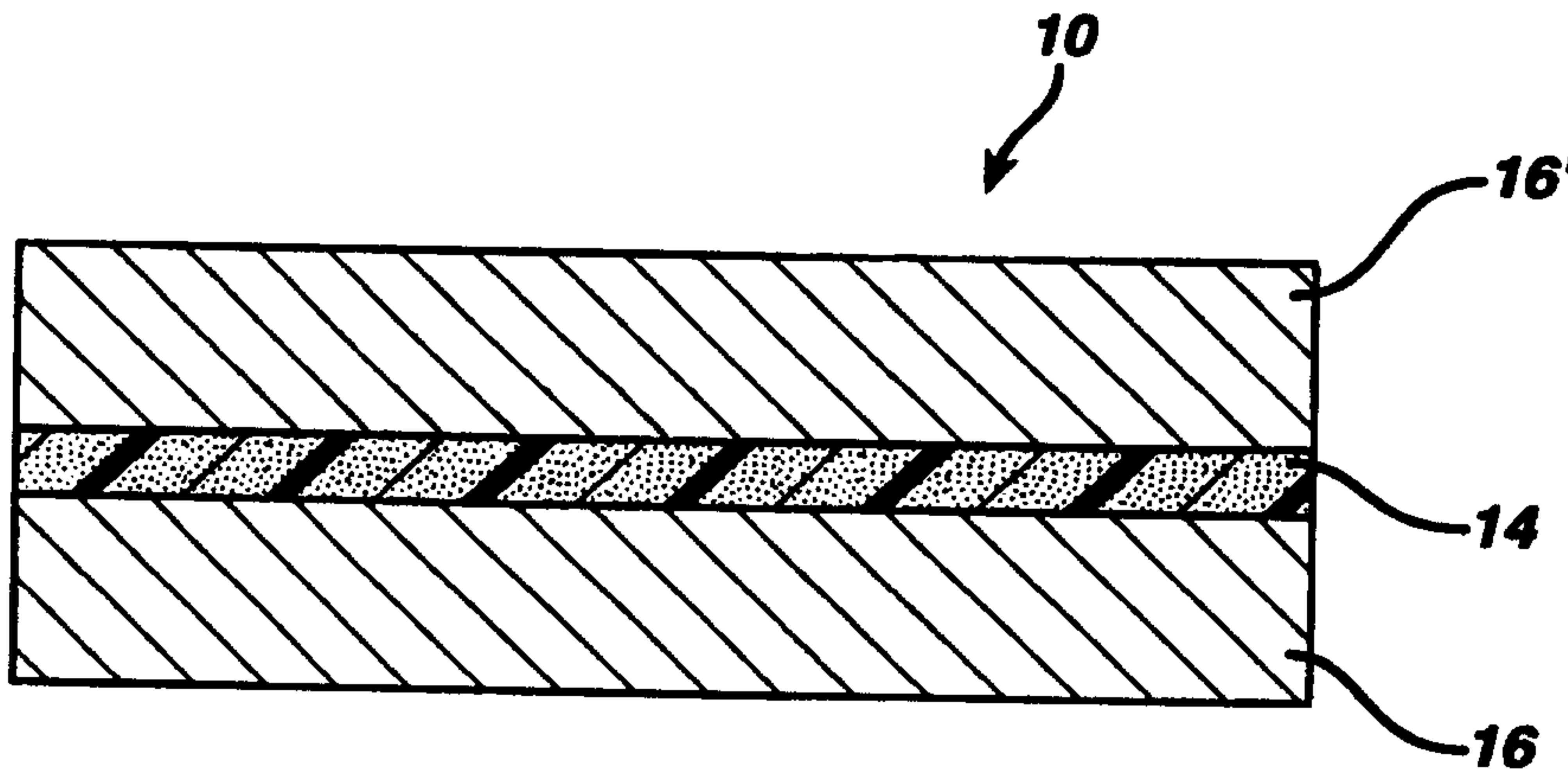
(54) Title: ORGANIC SOLVENT VAPOR DETECTOR

(57) Abstract

The present invention is directed to an organic liquid and/or vapor detector which is useful in Lithium Ion batteries and other devices containing organic liquids and/or vapors comprising a supported or unsupported swellable polymeric material which is sensitive to organic liquids and/or vapors. The swellable polymeric material is a polymer, copolymer or physical mixture thereof that may, optionally, be filled with electrically conductive particles. A process of preparing the detector and devices containing the same are also disclosed.



# ORGANIC SOLVENT VAPOR DETECTOR

The present invention relates generally to the art of an organic liquid and/or vapor detector and more specifically to a battery pack detector which can be used in conjunction with a battery operated device or an intelligent on-board battery controller. The detector of the present invention comprises an organic liquid swellable polymeric material which, optionally, may contain electrically conductive particles dispersed therein. The detector of the present invention, which may be supported or unsupported, is highly sensitive in detecting organic liquids and/or vapors typically found in rechargeable or primary batteries as well as the level of such organic liquids in a container.

The advent of intelligent portable electronic devices such as notebook computers, video cameras, cellular phones and the like has enabled the development of rechargeable and primary batteries that maintain safety and in some instances, can communicate with the intelligent device to provide accurate information on the battery's present state of charge, and how best to recharge the battery to maintain maximum battery life, thus enabling the highest number of charge-discharge states. A user of such intelligent portable electronic devices, using such batteries, will not only know how much charge is left in the battery, but battery run time at various rates of power consumption. This enables the user to select a mode of operation that will enable maximum service life on the remaining state of charge and, how long the device will operate.

Although rechargeable and primary batteries are reliable and an economical energy source, under some circumstances such as during various charge-discharge cycles, leaks in the battery may develop which could adversely affect the operation of the electronics and safety devices. The leaks are typically caused by either defects in the construction of the battery itself or by generation of electrolytic gases during battery cycling or elevated temperature storage that may rupture the battery cell or cause a seal failure. Even though leaks are not a common occurrence in rechargeable and primary batteries, they can be detrimental to the electronic safety circuitry of the portable device since the battery is typically in close proximity to the device's electronic circuitry. There is thus a need for a battery pack containing a leak detector which is highly responsive to organic liquids and/or vapors that are present in the battery's cell. The electronics, upon sensing the leak, would have sufficient time to render the pack benign. By maintaining safety, the pack could be returned for repair, replacement or etc. The user could also be signaled that the pack had suffered fatal damage and should be replaced or repaired.

Accordingly, one object of the present invention is to provide a detector that can be used in a battery pack or in conjunction with an intelligent portable electronic device.

Another object of the present invention is to provide a detector which is highly sensitive to polar and/or non-polar organic liquids and/or vapors and thus provides a rapid response if such organic liquids and/or vapors are emitted by a nearby battery cell or other source containing such organic liquids and/or vapors.

A further object of the present invention is to provide a detector which can be used to detect leaks in various devices and/or the fluid level of an organic liquid in a container.

Another object of the invention is to provide a reversible response. That is, the detector is capable of signaling the removal of organic liquid and/or vapor from a container.

These as well as other objects are achieved by the present invention by providing a detector which comprises a supported or unsupported organic liquid swellable polymeric material which, optionally, may contain electrically conductive particles dispersed therein. That is, the detector of the present invention comprises a swellable polymeric material which is capable of exhibiting volume changes when exposed to an organic liquid and/or vapor.

Any change in the volume of the polymeric material as a result of liquid swelling, can subsequently produce an electrical signal response such as a change in resistivity, capacitance or transducer acoustical inductance. The nature of the polymeric material is dependent upon the solubility parameters such as polarity and hydrogen bonding index of the target liquid. Generally, the solubility parameters of the polymeric material is similar to the target liquid. Thus, when detection of polar liquids and/or vapors is sought, the polymeric material is composed of a polar swellable polymeric material. Likewise, a non-polar swellable polymeric material is used for detecting non-polar organic liquids and/or vapors.

When operating in the preferred resistance mode, the polymeric material is filled with electrically conductive particles and electrically bonded between electrically conductive terminals. The polymeric material can be coated onto at least one side of a mechanically supporting carrier, or it can be unsupported. Organic liquid swelling of the polymeric material increases the distance between the dispersed electrically conductive particles resulting in a corresponding electrical resistance increase.

The preferred geometry of the polymeric material operating in the resistive mode is a supported or unsupported thin film. The rate of change of the electrical signal response is proportional to the rate of swelling of the polymeric material. In order to maximize the response time, the mass ratio of the polymeric material to target organic liquid or vapor must be minimized and this can be achieved with thin film geometry.

In another embodiment of the present invention, the polymeric material can be operated in the capacitive mode and is achieved by sandwiching the polymeric material, preferably as a thin film, between two electrically conductive porous or nonporous plates. Exposure to an organic liquid and/or vapor induces swelling of the polymeric material and produces a corresponding change in the distance between the conductive plates resulting in a capacitive signal.

In yet another embodiment of the present invention, the polymeric material can be operated in an acoustical conductive mode by mechanically attaching the polymeric material between two mechanical transducers (a transmitter and receiver), such as is present in a surface acoustical wave (SAW) device. Exposure to an organic liquid and/or vapor produces a change in the acoustical conduction properties of the swollen polymeric material resulting in a corresponding modulation of the transducer signal.

Another aspect of the present invention relates to processes of fabricating the aforementioned detector. In accordance with this aspect of the present invention, the detector is fabricated by either printing the swellable polymeric material using printing techniques well known to those skilled in the art directly across two electrically conductive circuit traces on a printed circuit board, or as a separate supported film component which is subsequently electrically connected to a circuit. An example of the latter method is as follows:

providing the above mentioned polymeric material coated support film;

diecutting said polymeric coated support film to provide a material having a resistance of from about 100 to about 1 Megohms/sq.; and

attaching electrically conductive wires to said diecut film or directly bonding the diecut film to a circuit board.

A further aspect of the present invention relates to various devices such as smoke detectors, fire alarms and battery packs for camcorders and the like which contain the detector of the present invention. In the case of battery packs, there is provided a terminal means for connecting the battery pack to a battery powered device, a battery including at least one rechargeable or primary battery cell connected to said terminal means, and the detector of the present invention connected to the battery. This set-up allows for the detection of leaks by the nearby battery cell.

In yet another aspect of the present invention, the detector is utilized as a continuous level indicator to monitor the amount of fluid in a container. This aspect of the present invention is predicated on the ability of the polymeric material to return to substantially the same form as prior to liquid contact.

Figure 1 is a cross-sectional view of a detector of the present invention comprising an unfilled organic liquid and/or vapor swellable polymeric material which is sandwiched between two electrically conductive plates.

Figure 2 is a cross-sectional view of a detector of the present invention comprising an electrically conductive filled organic liquid and/or vapor swellable polymeric material supported on a polymer base.

Figure 3 is an electronic diagram showing the detector of the present invention in use in a Duracell Battery Operating System (hereinafter 'DBOS').

As stated above, the detector of the present invention comprises an organic liquid and/or vapor swellable polymeric material that, optionally, may be filled with electrically conductive particles. By "swellable polymeric material" it is meant any polymer, copolymer or physical mixture thereof which upon contact with an organic liquid and/or vapor exhibits volume expansion. It is noted that after the organic liquid and/or vapor is removed, the polymeric material returns to its original volume.

The detector of the present invention may be in any geometric form or shape such as cubic, spherical or thin film. A preferred geometric form of the detector of the present invention is a thin film. As stated above, the detector of the present invention may be supported on a carrier material or it may be unsupported depending upon its mode of operation.

Reference is now made to the accompanying drawings which show the various detectors of the present invention. It is emphasized that like elements in the drawings are referred to by like reference numerals. Specifically, in Fig. 1, there is shown a capacitive detector 10 which comprises an organic liquid and/or vapor swellable polymeric material 14 that is sandwiched between conductive plates 16 and 16'. Conductive plates 16 and 16' employed in the present invention are composed of conventional conductive materials such as Cu, Ag, brass, Sn, Ni, Au and the like. In this embodiment, polymeric material 14 is not filled with an electrically conductive material. If plates 16 and 16' are replaced with a transmitting and receiving mechanical transducer, the device operates as an acoustical transducer type organic liquid detector.

In another embodiment of the present invention, as shown in Fig. 2, detector 10 is a solid material comprising a support film 12 which is coated with an organic liquid and/or vapor swellable polymeric material 14 that is filled with electrically conductive particles. Alternatively, support film 12 may be a printed circuit board or card wherein the filled organic liquid and/or vapor swellable polymeric material is coated or printed oh the surface thereof.

Support film 12 that is employed in the present invention as a carrier material may be any non-electrically conductive material that is not dissolved or the integrity of which is not adversely affected by the matrix coating solvent. Preferred materials are polymer films, sheets or laminates such as polyesters (including poly(ethylene terephthalate), poly(butylene terephthalate), poly (naphthelene terephthalate), aromatic heterocyclic polyimides (such as Kapton® supplied by Dupont), polypropylene, polyethylene, polyethylene ionomers (such as Surlyn® supplied by Dupont), polybutylene, polyvinyl fluoride, polyvinylidene chloride, polyvinyl chloride, polyamides (such as Nylon® supplied by Dupont), ethylene vinylacetate, cellulose acetate, polyurethane and the like. As stated above, support film 12 may be a printed circuit board or card.

The thickness of the support film is not a critical limitation to the instant invention, but typically, the support film has a thickness which ranges from about 0.5 to about 50 mils.

Polymeric material 14 employed in the present invention is any polar or non-polar elastomeric polymer or copolymer that is preferably crosslinked and which swells upon contact with an organic liquid and/or vapor. Physical mixtures of said polymers and/or copolymers are also contemplated by the instant invention. The term "physical mixtures" is used herein to denote an admixture of polymers and/or copolymers wherein no chemical bonding between said polymers and/or copolymers is formed. Additionally it is preferred, but not necessary, that the swellable polymeric material has a glass transition temperature below about 30°C in order to have the polymer chains mobile enough to expand upon contact with an organic liquid and/or vapor.

Suitable polymers that may be used in forming polymeric material 14 include, but are not limited to: fluoroelastomers, urethanes, neoprenes, polyacrylates, polysulfides, silicones, butyl and the like. Examples of suitable copolymers that may be employed include, but ar not limited to: acrylonitrile-butadiene, acrylonitrile-styrene-butadiene, acrylonitrile-styrene-isoprene, styrene-butadiene, styrene-butadiene-isoprene and the like. A highly preferred polymer employed in the present invention is a flouroelastomer such as is commercially available from Pelomer Labs under the tradename PLV 2069.

It is emphasized that the above mentioned polymers and copolymers are highly sensitive to detecting polar or non-polar organic liquids and/or vapors depending on matching the respective polarity of the swellable polymer to the target organic liquid and/or vapor.

When organic liquid and/or vapor swellable polymeric material 14 is filled, it is typically filled with a population of electrically conductive particles. The electrically conductive particles employed in the present invention are conventional conductors well known to those skilled in the art. Examples of electrically conductive particles that may be employed in the present invention include, but are not limited to: carbon black, graphite, silver, tin, gold, palladium, nickel and the like. Mixtures of these electrically conductive particles such as silver and graphite are also contemplated herein. Highly preferred electrically conductive particles that are employed in the present invention are a mixture of carbon black and graphite.

The electrically conductive particles may be any shape. It is however preferred that the electrically conductive particles are flat shaped flakes or spherical-shaped powders. Typically, the size of the electrically conductive particles range from about 10 nm to about 100 microns. More preferably, the particle size of the electrically conductive particles is from about 0.01 to about 50 microns.

It should be emphasized that the unfilled swellable polymeric material or the electrically conductive filled swellable polymeric material employed in the present invention may be fabricated using conventional means well known to those skilled in the art or they can be commercially obtained. An example of a commercially available electrically conductive filled swellable polymeric material is Electrodag 501® supplied by Acheson Colloids Inc. which is a combination of carbon black and graphite particles in a fluoroelastomer resin system.

Typically, the organic liquid and/or vapor swellable polymeric material contains from about 1 to about 90%, by weight, of electrically conductive particles dispersed in the matrix of the polymeric material. More preferably, the swellable polymeric material contains from about 30 to about 70%, by weight, of electrically conductive particles.

When supported on a base material, the organic liquid and/or vapor swellable polymeric material is in the form of a thin coating which is prepared by predispersing the conductive particles in a solvent capable of dissolving the swellable polymeric material, followed by dissolving the swellable polymeric material. Depending on the type of swellable polymeric material employed, suitable coating solvents include, but are not limited to: methyl ethyl ketone, acetone, toluene, tetrahydrofuran and the like. Alternatively, the matrix coating solution can be prepared by mixing commercially available conductive coating solutions with suitable swellable polymeric materials.

Following application to the support film, the electrically conductive filled swellable polymeric material has a resistance of from about 20 ohm/sq. to about 1 Megohm/sq. More preferably, the resistance of the electrically conductive filled swellable polymeric material, prior to application, is from about 1 Kohm/sq to about 100 Kohm/sq and can be adjusted by varying the ratio of conductive particle mass to swellable polymeric mass.

The filled swellable polymeric solution is cast upon, i.e. applied to at least one surface of support film 12, using conventional coating techniques well known to those skilled in the art. For example, coating of the support film with the filled swellable polymeric material may be conducted by brushing, dipping, knife coating, gravure, wire bar coating, spraying and the like. A preferred means of applying the filled swellable polymeric coating solution to the support film is by wire bar coating.

It is again emphasized that when the support material is a circuit board or card, the swellable polymeric material containing electrically conductive particles is either printed directly on to the circuit elements of the circuit board or card using printing techniques well known to those skilled in the art or, alternatively, it is first supported on a support film and then bonded to the circuitry found on the circuit board or card using a silver epoxy adhesive.

In accordance with the present invention, a uniform coating of the filled swellable polymeric solution is applied to the surface of the support film. By "uniform", it is meant that the wet coating has a thickness of from about 1 to about 30 mils. It is emphasized that the above range represents the thickness of the wet coating prior to drying.

Next, the coated support film is dried using conditions and techniques well known to those skilled in the art. One way of drying the coated film is by air drying, which, depending upon the size of the coated film and the coating solvent chosen, may take from about 0.1 to about 1.0 hrs. Another way of drying the coated film is by heating in an oven. Typically, when oven drying is employed, the temperature of the oven is from about 60° to about 150°C and the drying time is from about 1 to about 30 minutes. No matter which of the above drying techniques is employed, the final thickness of the coating is from about 0.1 to about 1.5 mils.

After drying, the coated support film is diecut to a shape which provides a resistance of from about 20 ohms/sq to about 1 Megohm/sq. Moreover, since the polymeric swelling rate is proportional to the rate of increase in the organic liquid/polymeric mass ratio, the ideal shape of the device would be a thin film.

All of the above mentioned properties can be achieved by diecutting the coated film into a shape that maximizes the electrical path length while minimizing the overall outer dimensions, such as a "u" or "w" shaped thin film.

The next step of the present invention is to attach electrical conductive wires 20, e.g. Ag or Cu wires, to the diecut coated film. The wires can be attached at any edge of the thin film but it is preferred they be attached at the most distant ends of the coated surface of the thin film. The wires are attached using conventional electrical bonding means well known to those skilled in the art. A preferred means of electrically bonding wires 20 to the diecut film is by using a silver epoxy filled thermoplastic or thermoset adhesive 18 such as a silver epoxy.

When the organic liquid and/or vapor swellable polymeric material is not supported on a support film, the swellable polymeric material is either positioned between two conductive plates or two transducers which are electrically connected to a circuit. In these cases, the swellable polymeric material is in the form of an unsupport thin film and is diecut as mentioned above and placed between the plates or transducers.

The above description describes the basic form of the detector of the present invention as well as the process which is employed for fabricating the same. The detector of the present invention is useful in detecting organic liquids, e.g., polar and/or non-polar liquids, emitted or leaked by a nearby source containing said organic liquids. Alternatively, the detector of the present invention can be used to continuously monitor the level of an organic liquid in a container.

The following description illustrates the use of the detector of the present invention as a leak detector in a battery pack which comprises at least one rechargeable or primary battery cell which contains a polar organic liquid as the electrolyte. Suitable polar organic liquids which may be present in such battery cells and thus detected by the present invention are ethylene carbonate, dimethyl carbonate, and the like. Mixtures of these polar organic liquids may also be present in the battery cell.

The term "rechargeable battery cell" is used herein to denote rechargeable Lithium Ion (LiIon), Nickel Metal Hydride (NiMH) or Nickel Cadmium (NiCad) batteries. A preferred rechargeable battery employed in the present invention is a LiIon battery.

In accordance with the present invention, a battery pack for detecting polar organic liquids and/or vapors is provided which comprises terminal means for connecting the pack to a battery powered device, a battery including at least one of the aforementioned rechargeable battery cells connected to said terminal means, and a detector of the present invention electrically connected to said battery. The rechargeable battery cell may be replaced by a primary battery cell which is described for example in Kirk-Othmer, Encyclopedia of Chemical Technology, Third Edition, Vol. 13, 1978, pp. 503-545.

When a leak in the battery cell is detected by the above arrangement, an electronic signal is emitted by the leak detector to a computer, fuse or other device which will alarm the user of such a leak. A preferred device for alarming the user of a leak is a smart battery device, such as a Duracell Battery Operating System (DBOS) which includes ASIC (Application Specific Integrated Circuit) hardware, CPU, Analog to Digital Convertor, Current Measurement Means, Temperature Measurement Means, Pack-Voltage Measurement Means, Cell Voltage Measurement Means, ROM, RAM, RAM Data Back-Up Circuit, 12C/SMBUS Interface, Clock generator circuit, Wake-up comparator circuit, LED Drivers, Interface Circuits, Hardware Modes of operation, Run Mode: Entry/Exit, Sample Mode: Entry/Exit and Sleep Mode: Entry/Exit. A complete discussion of DBOS can be found in commonly owned applications U.S. Serial Nos. 08/336,945, filed November 10, 1994, now U.S. Patent No. 5,633,573; and 08/318,004 filed October 4, 1994, now U.S. Patent No. 5,606,242; as well as copending and commonly owned U.S. provisional application Serial No. 60/034,320, filed December 20, 1996, (Attorney docket P-10445) the contents of which are incorporated herein by reference.

Reference is made to Fig. 3 which shows the use of a detector of the present invention comprising a supported swellable polymeric material which is filled with electrically conductive particles in a typical DBOS module. In this figure, C1, C2 and C3 denote LiIon cells which are connected in series with each other; Q1 and Q2 are transistors which are connected to the LiIon cells through resistor R5; F1 is a fuse;

R1 and V1 are the resistance and the voltage between the positive and negative terminal ends, respectively. The detector of the present invention is also positioned between the positive and negative terminal ends of the DBOS module. The module has two major functional blocks, namely overvoltage protection and fuel gauging whose functions are described in more detail in the aforementioned copending applications. It also contains an electronic switch circuit and data communication ports, I2C and port, respectively, which are typically connected to a computer.

In accordance with the present invention, when the detector of the present invention is exposed to a polar organic liquid and/or vapor, its electrical resistance rises increasing the voltage V1. The electronic switch circuit shown in Fig. 3 is designed to trip in response to increasing voltage such that it provides a low resistance path and blows fuse F1.

In addition to being employed for detecting leaks in batteries, the detector or the present invention may be employed in other areas wherein organic liquids (polar and/or non-polar) and/or vapors are emitted into the atmosphere. Examples of other uses for the detector of the present invention include, but are not limited to: solvent storage areas, naval bilge compartments, chemical vapor hoods, fire alarms, smoke stacks, car engine compartments, solvent coating manufacturing operations and the like.

For example, when used in a boat bilge, if gasoline (a non-polar liquid) were to leak from an adjacent fuel tank, the gasoline or its vapors would cause the non-polar polymeric material of the detector to swell, change resistance, etc. (depending on what type of detector was used) and correspondingly trip an alarm.

The following examples are given to illustrate the scope of the invention. Because these examples are given for illustrative purposes only, the invention embodied therein should not be limited thereto.

EXAMPLE 1

A 4 mil Kapton® film (a polyimide support film supplied by Dupont) was bar coated with 12 mils of Electrodag® 502 (carbon filled fluoroelastomer dissolved in methyl ethyl ketone supplied by Acheson Colloids Inc.) and allowed to air dry. The final coating of Electrodag® 502 had a thickness of about 0.4 mil and a specific resistivity of 1 Kohm/sq. The coated film was then cut into 1 inch squares and fine copper (Cu) wires were bonded to the edges of the cut film using a silver epoxy resin as the adhesive (Epotek® E3114 supplied by Epoxy Technology Inc.). When exposed to 1M $LiPF_6$ EC (ethylene carbonate): DMC (dimethyl carbonate) lithium ion cell electrolyte vapor (100% saturated in vapor phase), the resistivity increases by a factor of over two times within sixty seconds. This example demonstrates that a support film coated with an electrically conductive filled swellable polymeric material can be successfully used as a leak detector in lithium ion batteries.

EXAMPLE 2

A 4 mil polyester film was bar coated with 14 mils of a 50:50 mixture of Electrodag® 501 (Acheson Colloids Inc.): PLV 2069 Viton® (Pelomer Labs) solution and was dried at 60°C for 30 minutes. The dry film thickness of the coating was about 0.7 mils. Next, a 0.62 x 0.20 inch rectangular section of the coated polyester film was cut out and was electrically bonded at the longest distance edges with wires using an Ag epoxy (Epotek® E3114 supplied by Epoxy Technology Inc.). The normal resistance of the device was 40-50 Kohms. When exposed to 1M $LiPF_6$ EC:DMC 1:1 LiIon electrolyte vapor, the resistance increased to 130 Kohms in one minute and greater than 1 mega-ohm in less than two minutes.

EXAMPLE 3

A 7 mil wet drawdown of the following polymer solution was cast onto a 4 mil Mylar® support film (a polyester film supplied by DuPont.):

| MATERIAL | SUPPLIER | PARTS BY WEIGHT |
|---|---|---|
| Cabot XC72 Carbon Black | Cabot Corp. | 10 |
| K5 44 Graphite | Lonza Corp. | 50 |
| 3781 Urethane solution | KJ Quinn Corp. | 10 |
| Tamol 165 dispersant | Rohm and Haas | 0.6 |
| Methyl ethyl ketone | ——— | 100 |
| Butanol | ——— | 10 |

The carbon black, graphite and Tamol 165 were predispersed in the solvent with a ball mill followed by the addition of the urethane polymer solution. After the cast film was dried, 0.62 x 0.20 inch rectangular sections were cut and electrical leads were Ag epoxied to the longest edges using Epotek® E3114 (Epoxy Technology Inc.) and heat cured at 130°C for about 30 minutes. The resistance of the device, as measured by a standard ohm meter, was 27 Kohm. When exposed to 1M $LiPF_6$ ethylene carbonate: dimethyl carbonate 1:1 vapor, the resistance rose to 70 Kohm in about 1 minute.

EXAMPLE 4

An acrylic matrix film was prepared by mixing the following acrylic polymer solution:

| Component | Parts by Weight |
|---|---|
| Electrodag 114* | 50 |
| Gelva 2480* | 50 |

* A carbon/acrylic mixture supplied by Acheson Colloids Inc.

** An acrylic polymer solution supplied by Monsanto Chemical

A 14 mil wet drawdown was cast onto a 4 mil polyester support film and dried, resulting in a 3 mil dry acrylic/carbon coating. Gelva 2480 crosslinks after it is dried rendering it insoluble but swellable in solvents. Rectangular sections (0.62 X 0.20 inch) were cut and electrical leads were silver/epoxied to the longest edges using Epotek® E3114 (Epoxy Technology Inc.) and heat cured at 130°C for about 30 minutes. The film was attached to a multiohmeter and the resistance was recorded. The resistance of the device was 10 Kohm. When exposed to 1M $LiPF_6$ ethylene carbonate:dimethyl carbonate 1:1 vapor, the resistance of the device rose to 28 Kohms in 2 minutes and 380 Kohm in 15 minutes.

The above embodiments and examples are given to illustrate the score and spirit of the present invention. These embodiments and examples will make apparent, to those skilled in the art, other embodiments and examples. These other embodiments and examples are within the contemplation of the present invention; therefore, the instant invention should be limited only by the appended claims.

# CLAIMS

1. A detector comprising a swellable polymeric material, wherein said swellable polymeric material is a swellable polymer, copolymer or physical mixture thereof capable of volume changes when exposed to an organic liquid and/or vapor.

2. The detector of claim 1, wherein said swellable polymeric material is filled with electrically conductive particles.

3. The detector of claim 1 or 2, wherein the swellable polymeric material is supported on a support film, circuit board or card.

4. The detector of claim 3, wherein the support material is a support film.

5. The detector of claim 2, wherein said electrically conductive particles are selected from the group consisting of carbon black, graphite, silver, tin, gold, palladium, nickel and mixtures thereof.

6. The detector of claim 5, wherein said electrically conductive particles are a mixture of carbon black and graphite particles.

7. The detector of claim 1, wherein said swellable polymeric material has a glass transitition temperature below about 30°C.

8. The detector of claim 1, wherein said swellable polymeric material is a crosslinked polymer or copolymer capable of undergoing organic liquid and/or vapor absorption and corresponding volumetric expansion.

9. The detector of claim 1, wherein said polymeric material is composed of a polar or non-polar polymer or copolymer.

10. The detector of claim 9, wherein said swellable polymeric material is a polymer selected from the group consisting of fluoroelastomers, urethanes, neoprenes, polyacrylates, polysulfides, butyl, silicones, and or physical mixtures thereof.

11. The detector of claim 9, wherein said copolymer is selected from the group consisting of acrylonitrile-styrene-butadiene, acrylonitrile-butadiene and styrene-isoprene, styrene-butadiene and styrene-butadiene-isoprene, butyl rubber, isoprene rubber and physical mixtures thereof.

12. The detector of claim 10, wherein said swellable polymeric material is a fluoroelastomer.

13. The detector of claim 2, wherein said electrically conductive particles are flat shaped flakes or spherical-shaped powders.

14. The detector of claim 2, wherein said electrically conductive particles have a particle size ranging from about 10 nm to 100 microns.

15. The detector of claim 14, wherein said electrically conductive particles have a particle size of from about 0.01 to about 50 microns.

16. The detector of claim 4, wherein said support film has a thickness of from about 0.5 to about 50 mils.

17. The detector of claim 2, wherein said swellable polymeric material contains from about 1 to about 90%, by weight, of said electrically conductive particles.

18. The detector of claim 1, wherein said swellable polymeric material is applied to a support material as a uniform wet thin film having a thickness of from about 1 to about 30 mils.

19. The detector of claim 18, wherein said swellable polymeric material, after drying, has a thickness of from about 0.1 to about 1.5 mils.

20. The detector of claim 1, wherein said swellable polymeric material is unsupported and is positioned between two porous or non-porous electrically conductive plates.

21. The detector of claim 1, wherein said swellable polymeric material is unsupported and is positioned between a transmitting and receiving mechanical transducer.

22. A detector useful in battery packs comprising:

a swellable polymeric material which swells when contacted with a polar organic liquid and/or vapor.

23. The detector of claim 22, wherein said swellable polymeric material is a polar polymer copolymer, or physical mixture thereof.

24. The detector of claim 22, wherein said swellable polymeric material is filled with electrically conductive particles.

25. A process of fabricating an organic liquid and/or vapor detector useful in battery packs comprising:

providing a support film having an organic liquid and/or vapor swellable polymeric material coated on at least one surface of said base material; and

diecutting said coated support film to provide a material having an electrical resistance of from about 20 ohms to about 1 Megohm/sq.

26. The process of claim 25, wherein said swellable polymeric material is a polymer, copolymer or physical mixture thereof capable of exhibiting a volume change when exposed to an organic liquid and/or vapor.

27. The process of claim 26, wherein said polymeric material is filled with electrically conductive particles.

28. The process of claim 25, further comprising attaching electrically conductive wires to said diecut film.

29. The process of claim 25, further comprising directly bonding the diecut film to a circuit board or card.

30. The process of claim 25, wherein said coating is applied by brushing, dipping, knife coating, grauve, wire bar coating or spraying.

31. The process of claim 30, wherein said coating is applied by wire bar coating.

32. The process of claim 28, wherein said electrically conductive wire is a Cu or Ag wire.

33. The process of claim 32, wherein said wire is attached using a Ag epoxy adhesive.

34. The process of claim 25, wherein said diecut film is bonded to a circuit board or card using a Ag epoxy adhesive.

35. A process of providing a detector to a circuit board or card comprising providing a circuit board or card having circuit elements thereon; and printing a swellable polymeric material on said circuit elements.

36. The process of claim 35, wherein said swellable polymeric material is a polymer, copolymer or physical mixture thereof capable of exhibiting a volume change when exposed to an organic liquid and/or vapor.

37. The process of claim 36, wherein said swellable polymeric material is filled with electrically conductive particles.

38. A battery pack comprising: terminal means for connecting a battery pack to a battery powered device; a battery including at least one rechargeable or primary battery cell connected to said terminal means, and a detector according to claim 1 or 22 connected to said battery.

39. The battery pack of claim 38, wherein said rechargeable battery cell is a lithium ion battery cell.

40. The battery pack of claim 38, wherein said battery powered device is a notebook computer, a video camera or a cellular phone.

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FIG. 1

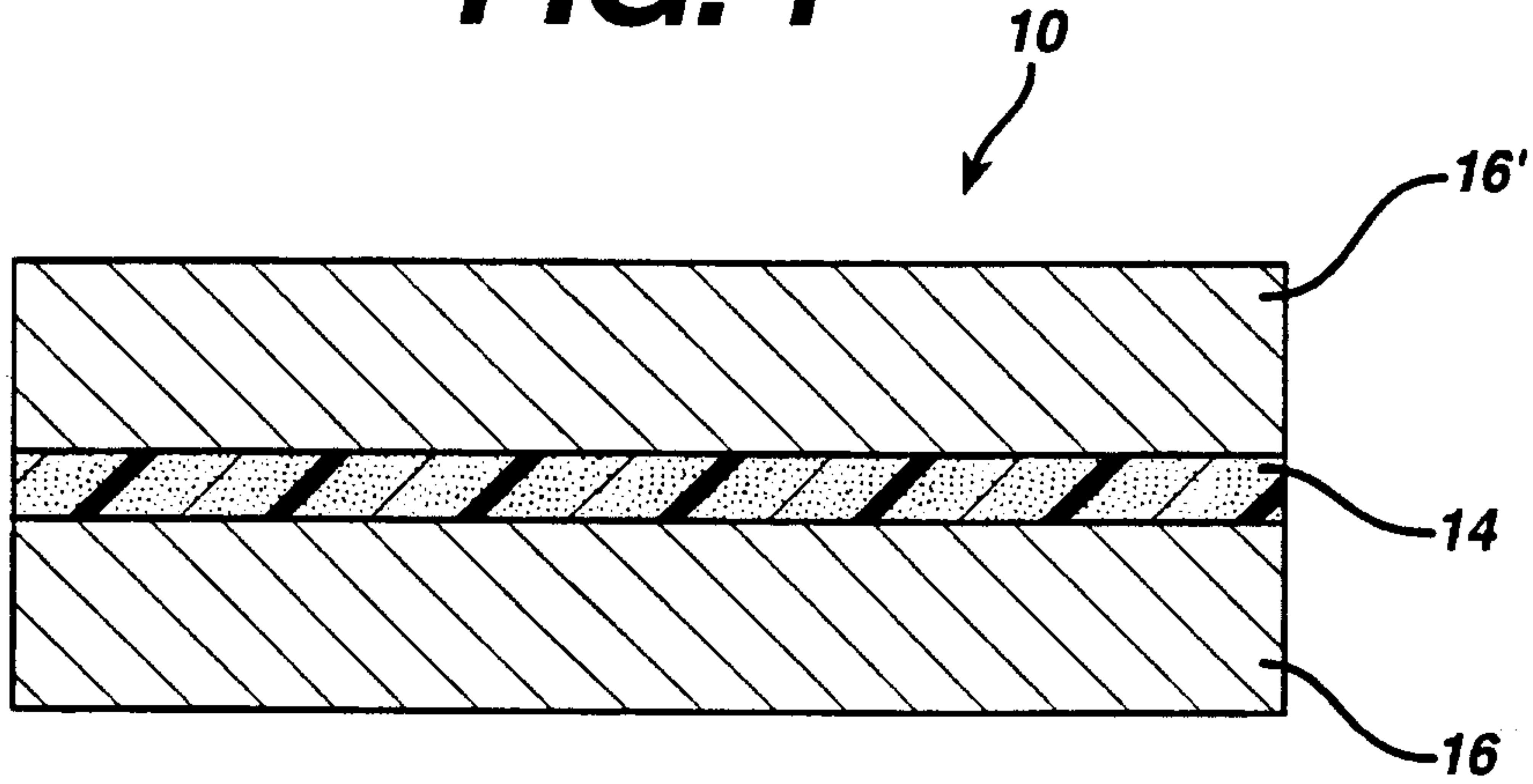


FIG. 2

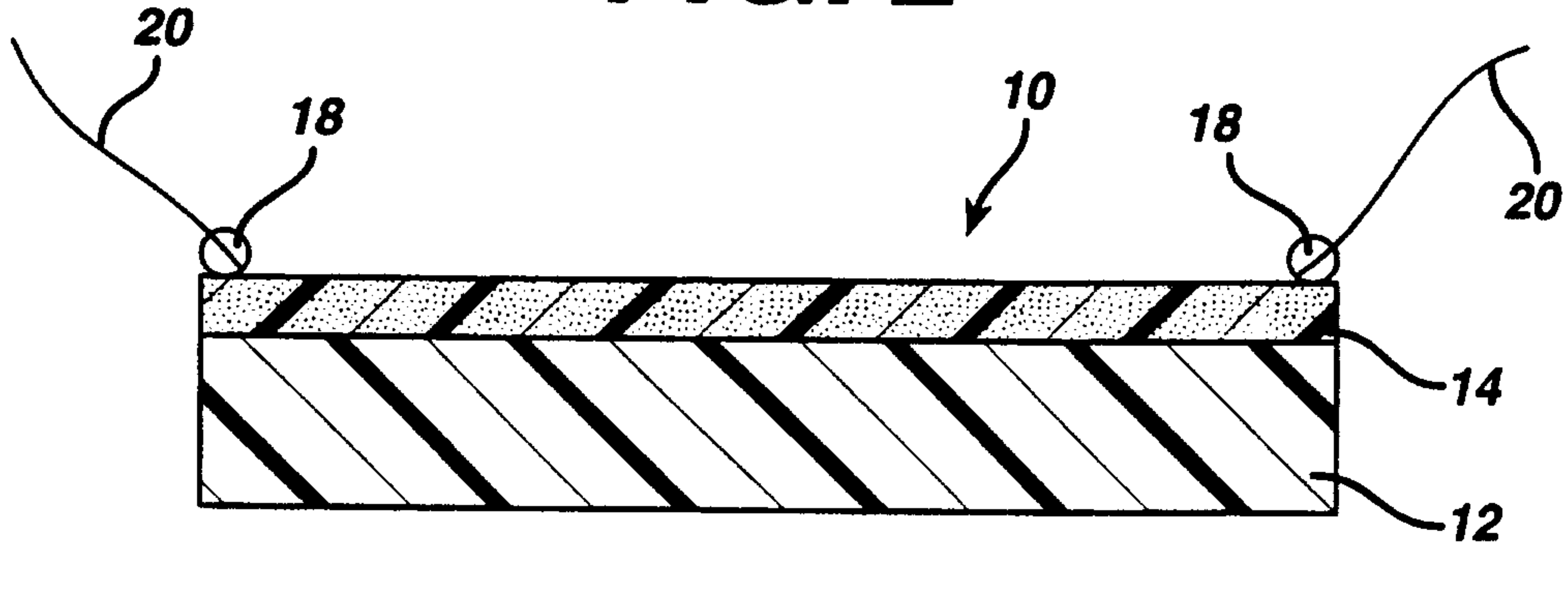

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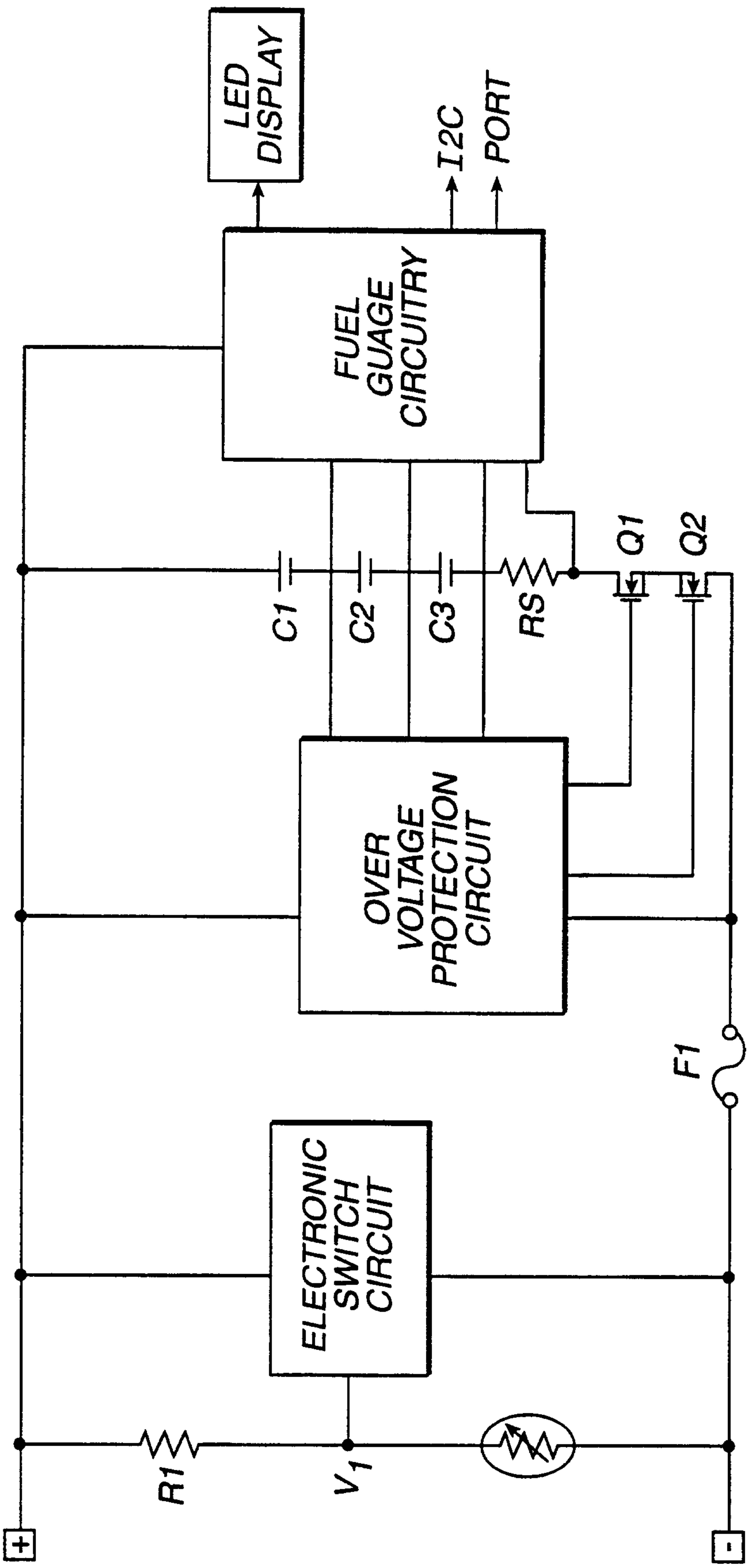
FIG. 3


LED DISPLAY
FUEL GUAGE CIRCUITRY
I2C
PORT
C1
C2
C3
RS
Q1
Q2
OVER VOLTAGE PROTECTION CIRCUIT
F1
ELECTRONIC SWITCH CIRCUIT
R1
$V_1$
+
-