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(54) **MULTIPLE NON-CONDUCTIVE POLYMER SUBSTRATES AND CONDUCTIVE COATINGS AND METHODS FOR DETECTING VOC**

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(57) **ABSTRACT**

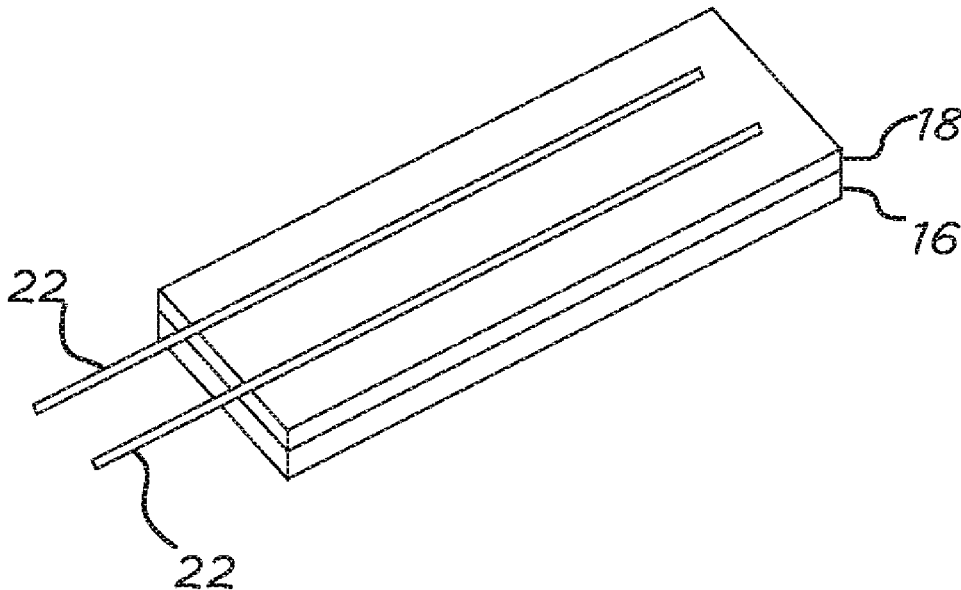
A product for sensing may include a non-conductive layer of a polymer that may be selected for its responsiveness to a stimulus from one of a selected analyte, or a selected group of analytes. The non-conductive layer may be non-conductive of an electrical current. A conductive layer may be in contact with the non-conductive layer and may be conductive of the electrical current. A lead for may provide an electric current to the conductive layer. A device may be provided to detect at least one property of the conductive layer in response to the stimulus.

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**Related U.S. Application Data**

(60) Provisional application No. 62/186,568, filed on Jun. 30, 2015.



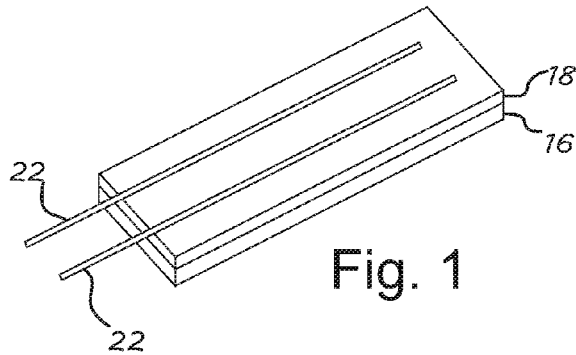


Fig. 1

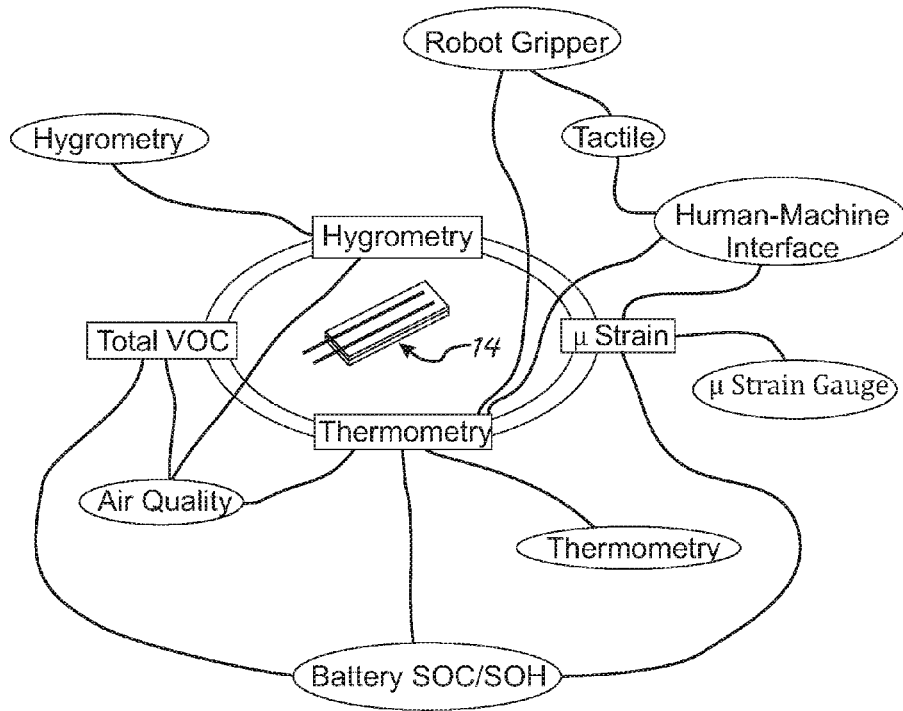


Fig. 2

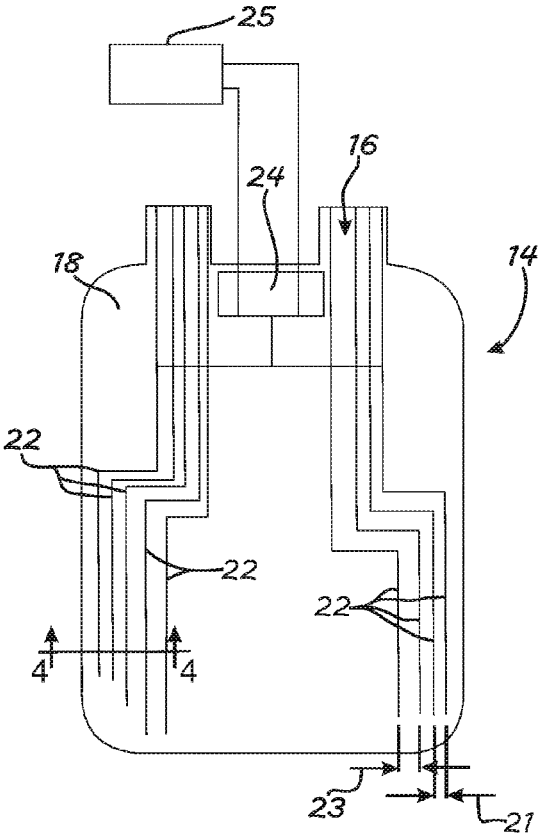


Fig. 3

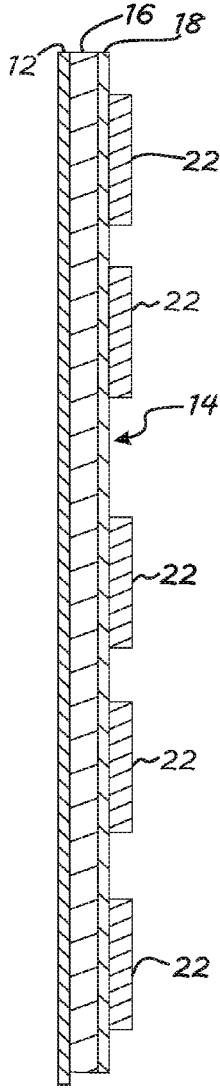


Fig. 4

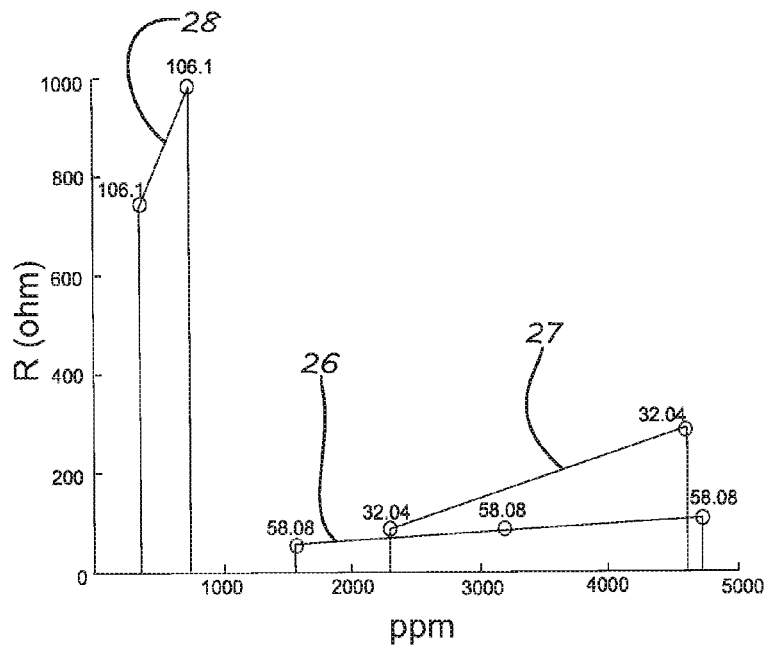


Fig. 5

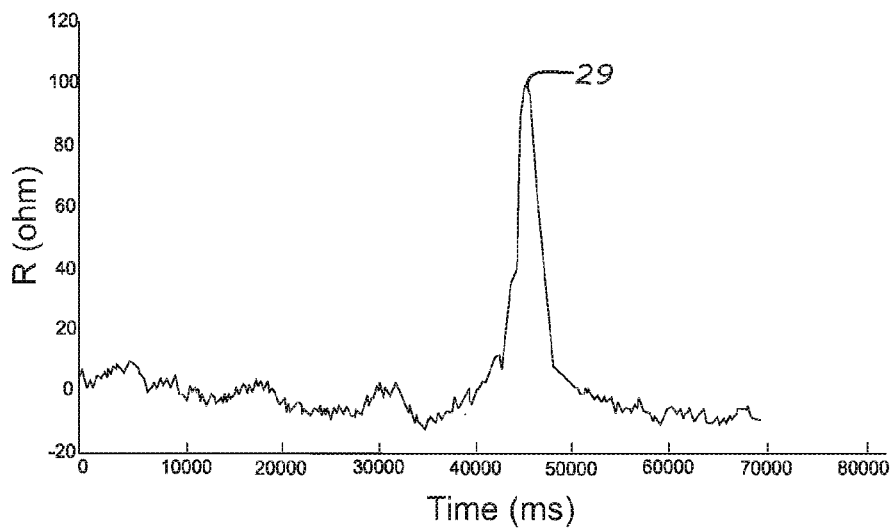


Fig. 6

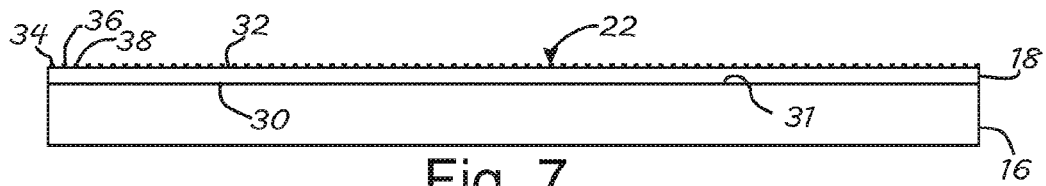


Fig. 7

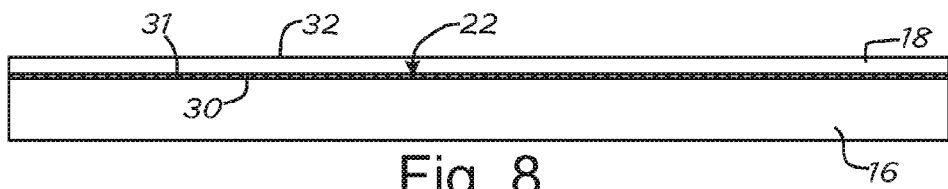


Fig. 8

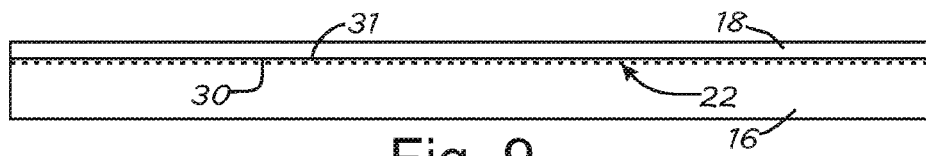


Fig. 9

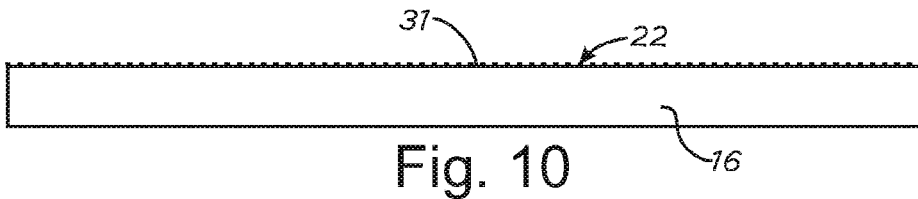


Fig. 10

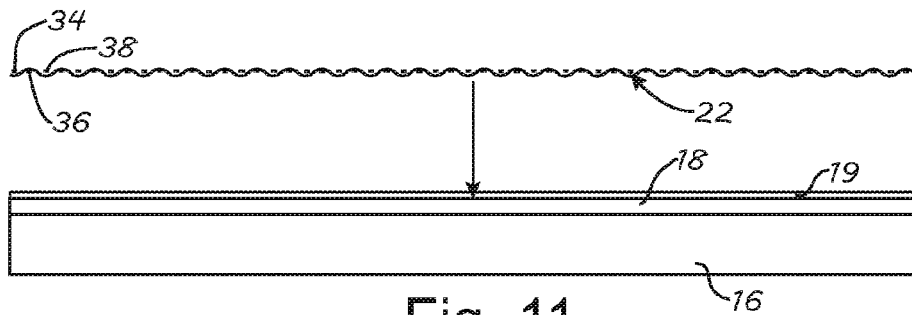


Fig. 11

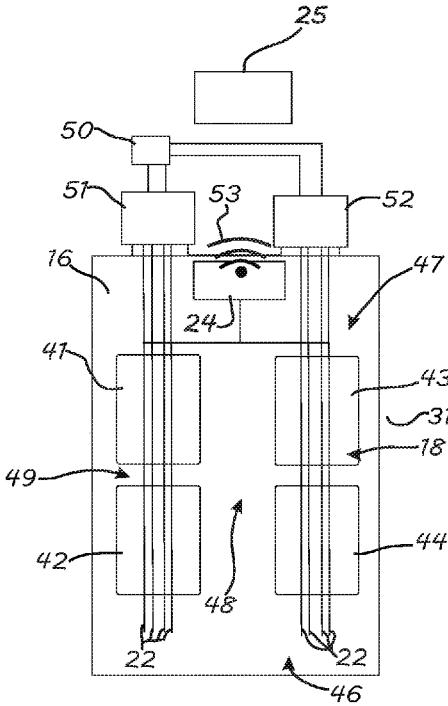


Fig. 12

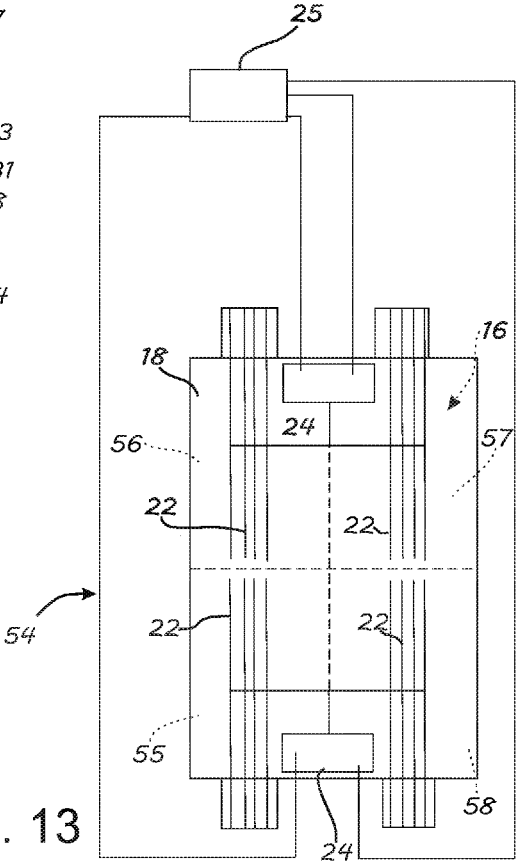


Fig. 13

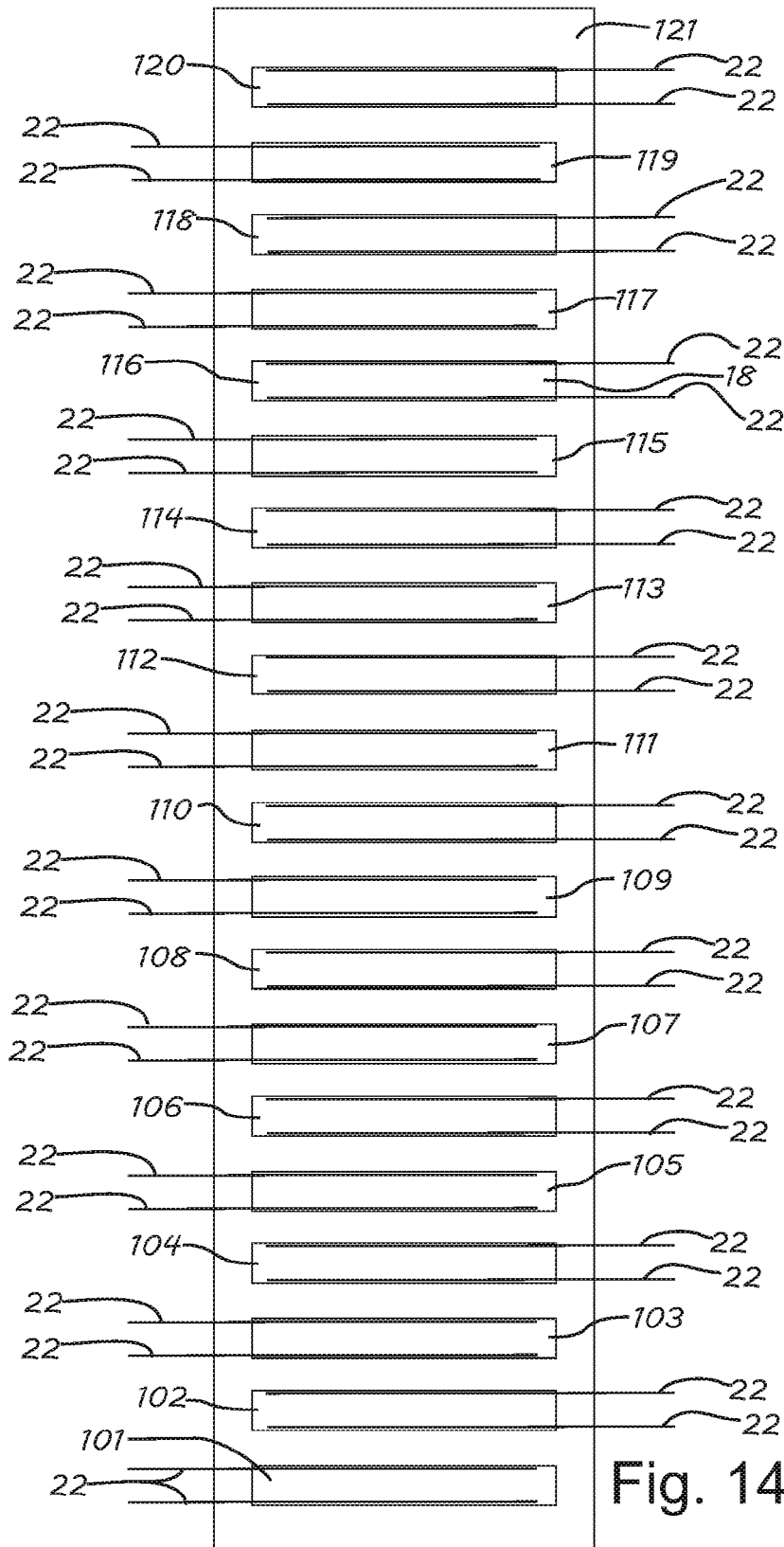


Fig. 14

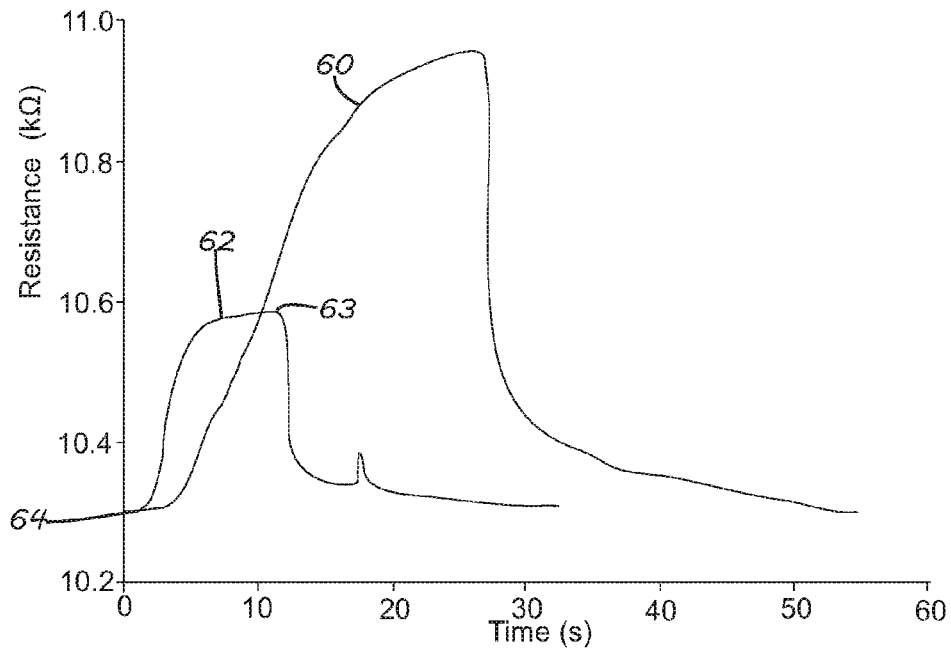


Fig. 15

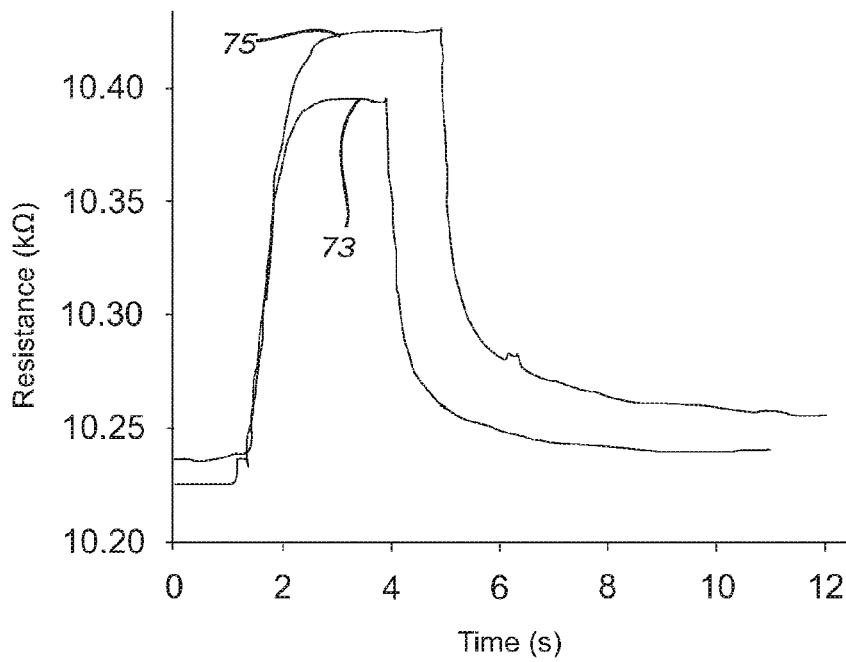


Fig. 16



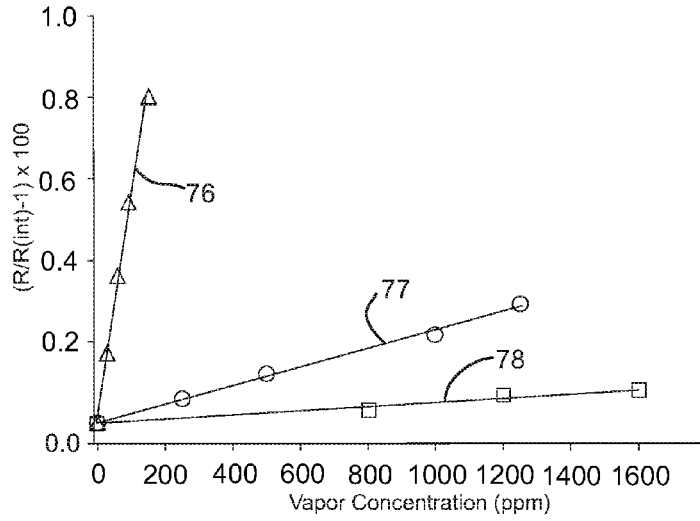


Fig. 17

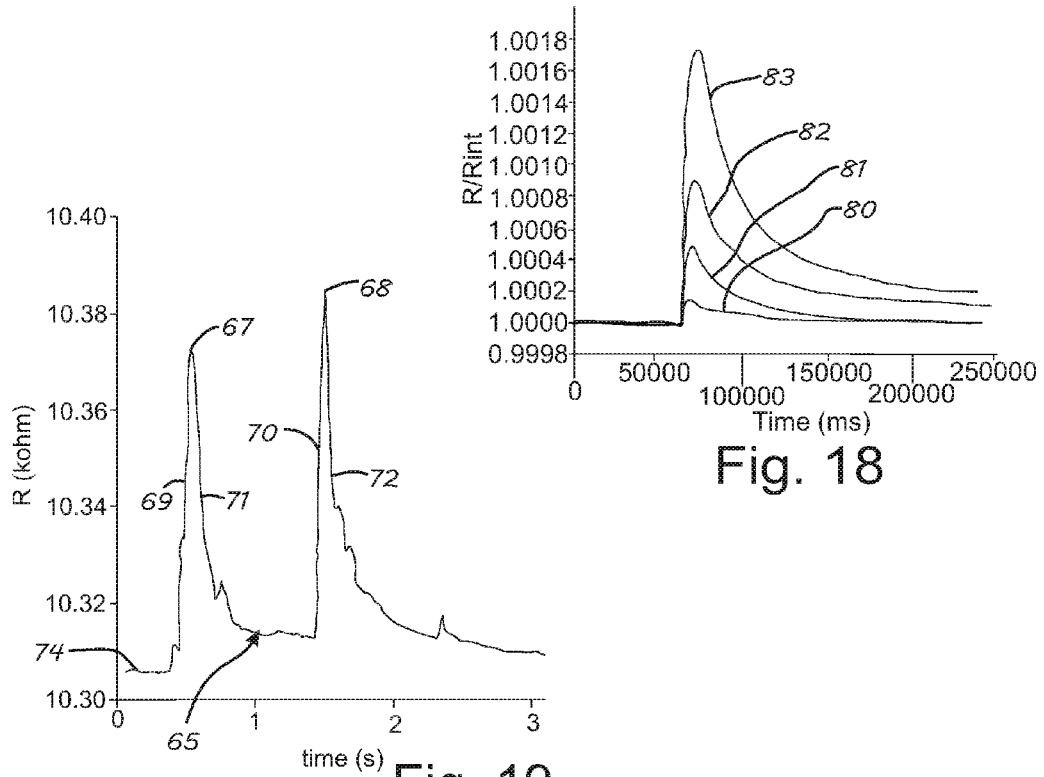


Fig. 19

Fig. 18

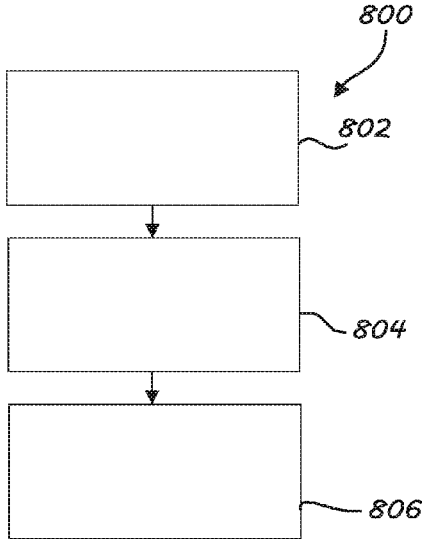


Fig. 20

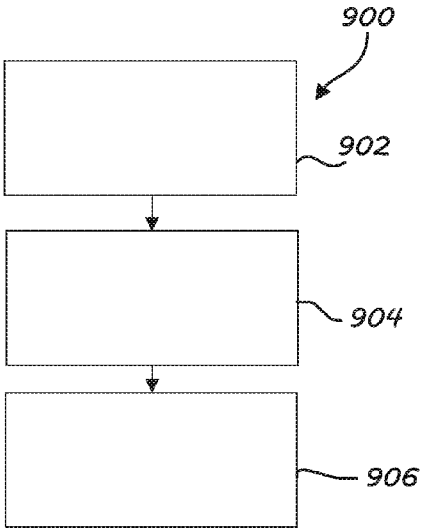


Fig. 21

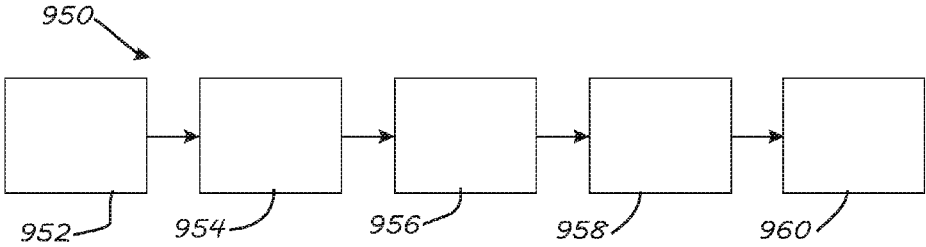


Fig. 22

**MULTIPLE NON-CONDUCTIVE POLYMER  
SUBSTRATES AND CONDUCTIVE  
COATINGS AND METHODS FOR  
DETECTING VOC**

CROSS REFERENCE TO RELATED  
APPLICATIONS

[0001] This application claims benefit of U.S. Provisional Application No. 62/186,568 filed Jun. 30, 2015.

TECHNICAL FIELD

[0002] The field to which the disclosure generally relates to includes sensor devices and methods of detecting compositions, in particular, volatile organic compounds.

BACKGROUND

[0003] In a number of variations, sensor devices may be used to measure environmental conditions or variables pertaining to components.

SUMMARY OF ILLUSTRATIVE VARIATIONS

[0004] A number of illustrative variations may involve a product for sensing that may include a non-conductive layer of a polymer that may be selected for its responsiveness to a stimulus from one of a selected analyte, or a selected group of analytes. The non-conductive layer may be non-conductive of an electrical current. A conductive layer may be in contact with the non-conductive layer and may be conductive of the electrical current. A lead may provide an electric current to the conductive layer. A device may be provided to detect at least one property of the conductive layer in response to the stimulus.

[0005] Additional illustrative variations may involve a method of monitoring for an exposure to an analyte. A sensing device may be provided with a non-conductive layer. A lead structure may be provided to apply a current to a zone of the sensing device that exhibits an opposition to the current. The opposition may vary in response to the exposure of the non-conducting layer to the analyte.

[0006] Other illustrative variations within the scope of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing variations within the scope of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Select examples of variations within the scope of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0008] FIG. 1 illustrates a product according to a number of variations.

[0009] FIG. 2 illustrates examples of applications of a product according to a number of variations.

[0010] FIG. 3 illustrates a product according to a number of variations.

[0011] FIG. 4 illustrates a fragmentary cross section of the product of FIG. 3 taken along the portion indicated by the line 4-4, according to a number of variations.

[0012] FIG. 5 illustrates a graph of measured resistance in relation to concentrations of volatile organic compounds for a product according to a number of variations.

[0013] FIG. 6 illustrates a graph of a product's response to volatile organic compounds showing measured resistance versus time product according to a number of variations.

[0014] FIG. 7 illustrates a product according to a number of variations.

[0015] FIG. 8 illustrates a product according to a number of variations.

[0016] FIG. 9 illustrates a product according to a number of variations.

[0017] FIG. 10 illustrates a product according to a number of variations.

[0018] FIG. 11 illustrates a product according to a number of variations.

[0019] FIG. 12 illustrates a product according to a number of variations.

[0020] FIG. 13 illustrates a product according to a number of variations.

[0021] FIG. 14 illustrates an array of sensing devices according to a number of variations.

[0022] FIG. 15 illustrates a graph of response to volatile organic compounds in relation to measured resistance versus time of a product according to a number of variations.

[0023] FIG. 16 illustrates a graph of response to volatile organic compounds in relation to measured resistance versus time of a product demonstrating a fast and reversible response according to a number of variations.

[0024] FIG. 17 illustrates a graph of a resistance percentage versus vapor concentration in parts per million for three analytes as measured by a product according to a number of variations.

[0025] FIG. 18 illustrates a graph of a resistance ratio versus time in milliseconds for four volumes of an injected analyte as measured by a product according to a number of variations.

[0026] FIG. 19 illustrates a graph of resistance versus time in seconds for two successive injections of an analyte as measured by a product according to a number of variations.

[0027] FIG. 20 illustrates methods according to a number of variations.

[0028] FIG. 21 illustrates methods according to a number of variations.

[0029] FIG. 22 illustrates methods according to a number of variations.

DETAILED DESCRIPTION OF ILLUSTRATIVE  
VARIATIONS

[0030] The following description of the variations is merely illustrative in nature and is in no way intended to limit the scope of the invention, its application, or uses.

[0031] FIG. 1 shows a product according to a number of variations. In a number of variations, the product may include a sensor device 14. The sensor device 14 may include a non-conductive layer 16. The sensor device 14 may include a conductive layer 18. The conductive layer 18 may overlie the non-conductive layer 16, or may otherwise be in physical contact with the non-conductive layer 16. The sensor device 14 may be mounted in any location where sensing is desired. In a number of variations the sensor device 14 may overlie or may otherwise be in physical contact with a substrate 12, which in the case of FIGS. 3 and 4 may be a battery pouch. The sensor device 14 may be

constructed and arranged to measure or monitor at least one variable. The variable may involve a physical property such as temperature, pressure, deformation, or another property, or may involve detection, identification, classification, tracking, or other characteristics of a property. The variable may involve concentration, rate, time or another characteristic of a compound, such as volatile organic compound vapor pressure. It has been found that a correlation exists between the time needed to reach full saturation and the vapor pressure of the analyte. This enables a level of discrimination between analytes. FIG. 2 depicts a graphic representation of some applications for the sensor device 14.

**[0032]** The variable may involve a status of a device or environment such as state of charge, or state of health, depletion status, diagnosis properties, or other variables indicative of status. In a number of variations, a plurality of sensor devices 14 may be used to monitor the surface or space where sensing is desired, as further described below. The sensor device 14 may include at least one lead 22, which may be in contact with the conductive layer 18 to monitor at least one variable such as resistance or impedance. Resistance and impedance may be generally referred to an opposition to the passage of an applied current from a DC or AC source, respectively, through an area of interest. In a number of variations, the sensor device 14 may include a data acquisition module (DAQ) 24. With additional reference to FIGS. 3 and 4, the sensor device 14 or DAQ 24 may be electrically coupled to an electronic control module (ECM) 25, which may be a controller for processing information. As used herein, the term “electrically coupled” may mean possessing the ability to transfer electrons or electric signals between the at least two components. As used herein, the term “electrically coupled” relationship may include a conducting wire or may include wireless connection. In a number of variations, at least one variable may be measured via inputs of at least one of deformation of the non-conductive layer 16 or the substrate 12, 15 to which it may be mounted, or change in opposition to current of the area of interest, which may involve at least one calculation. In monitoring changes in the opposition to current such as between leads 22, impedance changes may be evaluated in the aggregate or its components may be evaluated separately. Where impedance  $Z=R+jX$ , where R is resistance, j is an imaginary number called the j operator, and X denotes reactance. It has been found that the imaginary component impedance may experience greater changes than the resistance part when exposed to certain vapors, for example, vapors of biological origin. Accordingly, depending on the application, monitoring for, and evaluating, changes in the imaginary component of impedance may be useful in identifying the presence of certain vapors being monitored.

**[0033]** In a number of variations, the non-conductive layer 16 may include a polymeric material. The non-conductive layer 16 may comprise a polymer including, but not limited to, Acrylonitrile butadiene styrene (ABS), Polymethyl Methacrylate (PMMA), Celluloid, Cellulose acetate, Cycloolef in Copolymer (COC), Ethylene-Vinyl Acetate (EVA), Ethylene vinyl alcohol (EVOH), Fluoroplastics (including PTFE, FEP, PFA, CTFE, ECTFE, ETFE)lonomers, Kydex™, a trademarked acrylic/PVC alloy, Liquid Crystal Polymer (LCP), Polyacetal (POM or Acetal), Polyacrylates (Acrylic), Polyacrylonitrile (PAN or Acrylonitrile), Polyamide (PA or Nylon), Polyamide-imide (PAI), Polyaryletherketone (PAEK or Ketone), Polybutadiene (PBD), Poly-

butylene (PB), Polybutylene terephthalate (PBT), Polycaprolactone (PCL), Polychlorotrifluoroethylene (PCTFE), Polyethylene terephthalate (PET), Polycyclohexylene dimethylene terephthalate (PCT), Polycarbonate (PC), Polyhydroxyalkanoates (PHAs), Polyketone (PK), Polyester, Polyetheretherketone (PEEK), Polyetherketoneketone (PEKK), Polyetherimide (PEI), Polyethersulfone (PES), Polysulfone, Polyethylenechlorinates (PEC), Polyimide (PI), Polylactic acid (PLA), Polymethylpentene (PMP), Polyphenylene oxide (PPO), Polyphenylene sulfide (PPS), Polyphthalamide (PPA), Polystyrene (PS), Polysulfone (PSU), Polytrimethylene terephthalate (PTT), Polyurethane (PU), Polyvinyl acetate (PVA), Polyvinyl chloride (PVC), Polyvinylidene chloride (PVDC), Styrene-acrylonitrile (SAN), polycarbonate+acrylonitrile butadiene styrene mix (ABS+PC), Polypropylene (PP) (including, but not limited to, impact, random, and homo), Polyethylene (PE) (including, but not limited to, linear low density, linear high density), combinations or blends in any amount thereof, or may be another type. In a number of variations, the non-conductive layer 16 may be a combination of the above polymers in any amount or concentration. In a number of variations, the non-conductive layer 16 may include a composite layer comprising several layers of the materials listed. In a number of variations, the non-conductive layer 16 may be formed via a method including, but not limited to, injection moulding, extrusion moulding, structural foam, vacuum forming, extrusion blow moulding, a hand lay-up operation, a spray lay-up operation, a pultrusion operation, a chopped strand mat, vacuum bag moulding, pressure bag moulding, autoclave moulding, resin transfer moulding, vacuum assisted resin transfer moulding, bladder moulding, compression moulding, mandrel wrapping, wet layup, chopper gun, filament winding, melting, staple fiber, continuous filament, or may be formed another way.

**[0034]** In a number of variations, the conductive layer 18 may include a metallic or semimetallic material. In a number of variations, the conductive layer 18 may include a metal including, but not limited to, plastic steel, stainless steel, copper, nickel, tin, gold, silver, molybdenum, palladium, tungsten, graphite or another form of carbon, zinc, iron, bronze, aluminum, titanium, platinum, silicide, or may be another type), metallic alloys, combinations thereof, or may be another type. In a number of variations the conductive layer may include a non-metal material that conducts electric current sufficiently to measure changes in impedance or resistance. In a number of variations, the conductive layer 18 may be a combination of the materials in any amount or concentration. In a number of variations, the conductive layer 18 may include a composite layer comprising several layers of the materials. In a number of variations, the conductive layer 18 may be formed on or overlying the non-conductive layer 16 via a method including, but not limited to, inkjet/laser printing, 3-D printing, casting, extrusion, forging, plating (electroless, electro), plasma spraying, aerosol spraying, thermal spraying, dip coating, roll-to-roll coating, spin coating, spray coating, chemical solution deposition, thermal evaporation, pulsed laser deposition, cathodic arc deposition, or known etching techniques (i.e. sputter, Chemical Vapor Deposition, Physical Vapor Deposition, Atomic Vapor Disposition, ALD, or combination of deposition and thermal growth), conversion coating, ion beam mixing, thin film printing, or may be formed another way. The process for applying the conductive layer 18 may be

selected to enhance permeability of a monitored compound to the non-conductive layer **16**, such with a vapor deposition process. In a number of variations, the at least one lead **22** may include a conductor such as a metal material, and may be used to measure resistance or impedance in an area of interest. In a number of variations, the at least one lead **22** may include a metal including, but not limited to, plastic steel, stainless steel, copper, nickel, tin, gold, silver, molybdenum, palladium, tungsten, graphite or another form of carbon, zinc, iron, bronze, aluminum, titanium, platinum, silicide, or may be another type), metallic alloys, combinations thereof, or may be another type. In a number of variations, the at least one lead **22** may be a combination of materials in any amount or concentration. In a number of variations, the at least one lead **22** may include a composite layer comprising several layers of materials. In a number of variations, the at least one lead **22** may be formed on or overlying the conductive layer **18**, or otherwise in contact therewith (such as being formed on the non-conductive layer **16**), via a method including, but not limited to, inkjet/laser printing, 3-D printing, casting, extrusion, forging, plating (electroless, electro), plasma spraying, thermal spraying, dip coating, roll-to-roll coating, spin coating, spray coating, chemical solution deposition, thermal evaporation, pulsed laser deposition, cathodic arc deposition, or known etching techniques (i.e. sputter, Chemical Vapor Deposition, Physical Vapor Deposition, Atomic Vapor Deposition, ALD, or combination of deposition and thermal growth), conversion coating, ion beam mixing, thin film printing, or may be formed another way. In a number of variations, the at least one lead **22** may be attached to the conductive layer **18**, (or the non-conductive layer **16** with electric coupling to the conductive layer **18** so as to have minimal resistance there between), through an adhesive comprising at least one of, silver paste, acrylonitrile, cyanoacrylate, acrylic, resorcinol glue, epoxy resin, epoxy putty, ethylene-vinyl acetate, phenol formaldehyde resin, polyamide, polyester, polyethylene, polypropylene, polysulfides, polyurethane, polyvinyl acetate, polyvinyl alcohol, polyvinyl chloride, polyvinyl chloride emulsion, polyvinylpyrrolidone, rubber cement, silicone, combinations thereof, or may be another type. In the case of attachment of the lead(s) **22** to the conductive layer **18**, the adhesive may be selected to be electrically conductive to make good ohmic contact. In a number of variations as shown in FIGS. **1** and **3**, the leads may be provided individually, or in pairs with the same or different spacing. For example a first pair may have a spacing that represents a distance **21** between the leads **22** and a second pair may have a second spacing of a distance **23** that may have a greater distance between the leads **22**. The distances **21**, **23** may span areas of interest for monitoring changes in opposition to current as a strain gauge. Spacing of the leads **22** may be modulated to decouple thermal and mechanical responses in providing spatial resolution. For example, for a substrate **12** of a known material the coefficient of thermal expansion (CTE), will be known. Deformation due to temperature changes may be factored into the evaluation through a calibration approach. If when monitoring the resistance/reactance change at **4** set of leads **22** of varying spacing and the changes all fall on the same calibration curve for CTE, then it may be concluded that a temperature rise in the substrate **12** has occurred. If however, one set of leads **22** shows a resistance/reactance change that departs from the predefined calibration curve for CTE, then an

inference may be drawn that a deformation event associated with a change in state of charge or state of health, such as where the substrate is a battery pouch in the pouch. The spatial resolution may be used in diagnostics, such as to identify a defective portion of a cell through evaluating differences in sensed deformation.

**[0035]** In a number of variations, the sensor device **14**, non-conductive layer **16**, and/or conductive layer **18** may operate as a strain gauge. In a number of variations, the sensor device **14**, non-conductive layer **16**, and/or conductive layer **18** may be used to operate as a strain gauge to measure a variable by measuring deformation of the substrate to which the sensor device **14** may be mounted, and/or of the non-conductive layer **16**, or change in resistance of the conductive layer **18** through at least one calculation. In a number of variations, the use of multiple leads **22** may be used to pinpoint a location of deformation, wherein different changes may be detected through different leads at known locations. In a number of variations, the sensor device **14**, non-conductive layer **16**, and/or conductive layer **18** may be used to operate as a strain gauge to measure compounds such as volatile organic compounds (VOC's) in vapor state by measuring deformation of the substrate to which the sensor device may be mounted and/or non-conductive layer **16**, or change in resistance/reactance of the conductive layer **18**. In a number of variations, the VOC's may include, but are not limited to, aromatic and aliphatic hydrocarbons, ketones, imides, amides, mercaptans or aldehydes, or maybe another compound. The sensor device **14** provides the ability to detect VOCs in low concentrations through deformation induced by VOC ab(d)sorption in an electrically insulating polymer —non-conducting layer **16**. The deformation may be detected by measuring changes in resistance or impedance of the conductive coating and/or of the non-conducting layer **16**. Direct current may be used, and alternating current is an alternative. The polymer non-conducting layer **16** may absorb/adsorb the organic gas phase compounds causing micro swelling and elastic deformation. The resulting strain may modify the conduction paths of the conductive layer **18** resulting in a measurable resistance or impedance change.

**[0036]** An ability to discriminate to analytes of choice, in the sensor device **14** with a rapid response, reversibility and high sensitivity may be provided, along with an ability to operate in environments with humidity/water. The non-conductive layer **16** may advantageously desorb water that has been absorbed, reversibly. In a number of variations fluorinated polymers that may be highly hydrophobic may be used for the non-conductive layer **16**, or portions thereof, as a way of differentiating between high humidity and high VOC levels. Use of a fluorinated polymer may inhibit absorption of water. For example, the non-conductive layer **16** may be composed of PVDF, PTFE, PCTFE, FEP, ETFE, ECTFE, or another polymer with hydrophobic properties. This is advantageous since it increases the already existing ability of sensors device **14** to perform without a need to be shielded from water. In a monitoring application, multiple sensor devices **14** may be used, one of which may include a fluorinated polymer as the non-conductive layer **16**. If the nonfluorinated sensor devices **14** are triggered it may be due to VOC or humidity. If the fluorinated sensor device **14** is not triggered while the nonfluorinated ones are, the cause may be concluded to be a rise in humidity. If both the fluorinated and nonfluorinated sensor devices **14** are triggered the cause can be concluded to be a rise in VOC

concentration. In a number of other variations, the materials for the non-conductive layer **16** of the sensor devices **14** may be selected so that their VOC response is comparable but their response to humidity is measurably different.

**[0037]** FIG. 5 illustrates a relation of VOC concentration to resistance measured in the conductive layer **18** according to a number of variations wherein the non-conductive layer **16** comprises PMMA and the conductive layer **18** comprises a graphite spray coating. The resistance change in Ohms of the sensor device **14** is shown on the vertical axis as a function of analyte vapor concentrations presented in parts per million on the horizontal axis. Proportional responses are demonstrated for acetone at curve **26**, methanol at curve **27** and xylene at curve **28**. The demonstrated response for xylene is relatively very high, and by extrapolation, the detection limit for this particular compound can be in the single PPM to 100's of PPB range. The other compounds have a lower effect on the sensor device **14** and may reflect either a weaker affinity of the VOC for the polymer or the smaller molecules may cause a smaller amount of swelling even for the same moles of gas absorbed into the sensor. In this example, data collected from the sensor device **14** may be used to discern the presence of xylene, acetone and/or methanol in the same environment, or to tailor the sensor device **14** to discern xylene at very low concentrations. Other polymers may be selected for other VOCs for example, PMMA may exhibit greater sensitivity to polar compounds while PE/PP may exhibit greater sensitivity to nonpolar species. The affinity of the analyte for the polymer can be understood by the partition coefficient relationship between the gas and solid phase (absorbed into sensor), which can be expressed as:  $K=C_sC_g=RT\rho_1M_1\gamma_2P_2$  Where  $K$  is the partition coefficient,  $C_s$  and  $C_g$  is analyte concentration in the polymer ( $C_s$ ) and gas ( $C_g$ ) phase, respectively,  $\rho_1$  and  $M_1$  are the density and molecular mass of the polymer and  $\gamma_2$  and  $P_2$  are the activity coefficient and saturation vapor pressure of the analyte, respectively. Where the fractional resistance increase ( $\Delta R$ ), is linear with fractional mass uptake in the sensor such that  $\Delta R=kiC_s$  where  $ki$  is a constant. then we can combine this with the equation for the partition coefficient to obtain:  $\log 1/C_g=\log 1/P_2+\log ki/\gamma_2+\log RT\rho_1/M_1\Delta R$  and therefore, the slope of the log of the inverse analyte gas phase concentration and the log of the inverse of its saturation partial pressure yield the values for  $ki/\gamma_2$ . This response enables determining for example, that xylene is present in the environment around the sensor device **14**.

**[0038]** FIG. 6 illustrates a response of the sensor device **14** for a stimulus from a VOC with resistance in ohms on the vertical axis as a relative response.  $R_{baseline}+R_{measurement}$  and time in milliseconds on the horizontal axis. In a number of variations, spikes in the measured resistance, as illustrated as spike **29** in FIG. 6 for example, may indicate a change or increase in presence of VOC's while rate of change in the resistance may indicate a change in the source generating the VOC. For example, the sensor device **14** may be exposed to acetone introduced to the sensing device **14** in the presence of air flow. A measured resistance of greater than the baseline of approximately 10 ohms may indicate the presence of acetone in the environment, while the rapid change from the baseline to the peak **29** may indicate an underlying change in the operation being monitored, where the changes results in the generation or release of additional acetone from a norm. As demonstrated, the sensor device **14**

responds to the introduction of analytes quickly and returns to the baseline resistance after the exposure demonstrating a rapid and reversible response. As can be seen the signal to noise of the response is very good and the response nearly instantaneous. Return to the baseline within seconds demonstrates that very small and quick changes in environmental quality can be detected readily.

**[0039]** In a number of variations as illustrated in cross section in FIG. 7, the product may include the non-conductive layer **16** and the conductive layer **18**. The conductive layer **18** may have a surface **30** in contact with the non-conductive layer **16** at its surface **31**. The lead(s) **22** may be provided on the surface **32** of the conductive layer **18**, opposite the surface **30**. The leads **22** may be provided in a series of conductive micro-structure elements (e.g. **34**, **36**, **38**, etc.), that may be applied to the surface **32**. The micro-structure elements **34**, **36**, **38**, may be made of any of the materials listed above for the leads **22**, or any material sufficient to conduct current for sensing purposes. The micro-structure elements **34**, **36**, **38** may be selected as leads **22** to increase sensitivity of the sensor device **14**, and/or to pinpoint deformation changes. In a number of variations, the leads **22** may be placed at the surfaces **30**, **31** between the nonconductive layer **16** and the conductive layer **32**, as shown in FIG. 8. In a number of variations the leads **22** may be embedded in the non-conductive layer **16**, but still in electrical communication with conductive layer **18** as shown in FIG. 9. In this case the leads **22** may be adjacent the surface **32** and may preferably be in contact with the conductive layer **18**, or may otherwise be electrically coupled therewith. In a number of variations as shown in FIG. 10, the leads may be applied to the surface **31**, of the non-conductive layer **16**, or may be embedded therein as shown in FIG. 9, and the conductive layer may be omitted. In such a case, the presence of the micro-structures **34**, **36**, **38**, on or in the non-conductive layer **16** may support monitoring by measuring changes in capacitance over gaps between the leads **22**. The micro-thread approach may support exclusion of the conductive layer **18**, although embedding in the non-conductive layer **16** may result in less sensitivity. The micro-structures **34**, **36**, **38**, may be provided as linear threads, non-linear threads, tubes, or other structures applied to the surface of, or embedded in the non-conductive layer **16** or the conductive layer **18**. In any of the variations of FIGS. 7-11, the leads **22** may be conductors such as shown in FIGS. 1 and 3. In a number of variations, the micro-structures **34**, **36**, **38** may be formed in woven mesh creating a matrix as shown in FIG. 11, (shown before application for clarity), or may otherwise be distributed on, or interspersed in, the conductive layer **18**. In a number of variations the micro-structures **34**, **36**, **38** may be aligned in a designed fashion with specified spacing, or may be randomly arranged in forming the matrix. It should be understood that the physical layout and dimensions of the sensor device **14** may be provided in any shape suitable to the application where monitoring is desired. For example, the sensor device **14** may be matched to the shape of a mating substrate, may be cylindrical, may be a wire-like shape, may be round, may be spherical, may be irregularly shaped, or may be otherwise shaped.

**[0040]** With reference again to FIG. 3, in a number of variations, the DAQ **24** or ECM **25** may receive and process input from at least one sensor device **14** in light of stored instructions and/or data, determine a variable through at

least one calculation, and transmit output signals to various receptors. The data acquisition module (DAQ) 24 or electronic control module (ECM) 25 may include, for example, an electrical circuit, an electronic circuit or chip, and/or a computer. In an illustrative computer variation, the data acquisition module (DAQ) 24 or electronic control module (ECM) 25 generally may include one or more processors, or memory storage units that may be coupled to the processor(s), and one or more interfaces electrically coupling the processor(s) to one or more other devices, including at least one of the other of the data acquisition module (DAQ) 24 or electronic control module (ECM) 25, or to the at least one sensor device 14, or to a different component of a vehicle. The processor(s) and other powered system devices (including at least one of the other of the data acquisition module (DAQ) 24, electronic control module (ECM) 25, or to the at least one sensor device 14) may be supplied with electricity by a power supply, for example, a generated and distributed power source, a battery, other fuel cells, a vehicle engine, other vehicle power component, or other source. The processor(s) may execute instructions or calculations that provide at least some of the functionality for the sensor device 14 and methods 800, 900 (FIGS. 20 & 21). As used herein, the term instructions may include, for example, control logic, computer software and/or firmware, programmable instructions, or other suitable instructions. The processor may include, for example, one or more microprocessors, microcontrollers, application specific integrated circuits, programmable logic devices, field programmable gate arrays, and/or any other suitable type of electronic processing device(s).

[0041] Also, in a number of variations, the data acquisition module (DAQ) 24, or electronic control module (ECM) 25, may be configured to provide storage for data received by or loaded to the at least one of the other of the data acquisition module (DAQ) 24 or electronic control module (ECM) 25, or to the at least one sensor device 14, or to a different component of a vehicle, or the like, for processor-executable instructions or calculations. The data, calculations, and/or instructions may be stored, for example, as look-up tables, formulas, algorithms, maps, models, and/or any other suitable format. The memory may include, for example, RAM, ROM, EPROM, and/or any other suitable type of storage article and/or device.

[0042] In a number of variations, the interfaces may include, for example, analog/digital or digital/analog converters, signal conditioners, amplifiers, filters, other electronic devices or software modules, and/or any other suitable interfaces. The interfaces may conform to, for example, RS-232, parallel, small computer system interface, universal serial bus, CAN, MOST, LIN, FlexRay, and/or any other suitable protocol(s). The interfaces may include circuits, software, firmware, or any other device to assist or enable the data acquisition module (DAQ) 24 or electronic control module (ECM) 25, in communicating with other devices.

[0043] In a number of variations as illustrated in FIG. 12, the conductive layer 18 may be applied to less than the entire surface 31 of the non-conductive layer 16. The conductive layer 18 may be applied in strips, geometric shapes, patterns, random places, or in other shapes to leave exposed areas of the surface 31. For example, as shown in FIG. 12, the conductive layer 18 may be applied in patches, such as patches 41-44 so that areas such as gaps or areas 46-49 on the surface 31 may be exposed. Exposure of the surface 31

may increase the response of the non-conductive layer to an exposure to a monitored compound. The leads 22 may be applied on the patches 41-44 and may pass along the surface 31 in the areas 46-49. The leads may be connected with a power source 50 through connectors 51, 52. The DAQ 24 may control and monitor the sensor device, may collect information from the leads 22, may record the information as data, and may communicate with the ECM 25. Communication may be effected through a wired connection or a wireless interface 53.

[0044] In a number of variations a semi-permeable layer 19 such as PVC or low density PE (shown in FIG. 11), may be applied to the sensor device 14 and/or the conductive layer may be formed of a semi-permeable material such as carbon, or graphite, in each case where the material may be chosen to allow the passage of selected compounds and/or to inhibit the passage of select compounds. For example, pore diameters in the membrane selected for the conductive layer 18 may be larger than the largest molecular diameter that is the target to be monitored, and may be on the same size as the mean free path of the gas molecules. This may allow for the separation of species that reach the non-conductive layer 16 by molecular weight such that the rate of diffusion through the conductive layer 18 is inversely proportional to the square root of the molecular weight. If the pore diameter is smaller than the mean free path of the diffusing gas molecules and the density of the gas is low, the gas molecules collide with the pore walls more frequently than with each other. This Knudsen flow or Knudsen diffusion process and may be selected when the monitored compound has a relatively large molecule to pass through a 100 to 300 angstrom pore size conductive layer 18. For medium sized molecules, a pore size in the range of 40 to 100 angstroms may be selected for the conductive layer 18 wherein the monitored compound may condense into these pores and diffuse through Kelvin condensation to reach the non-conductive layer 16. The material for the conductive layer 18 or coating may be selected for molecular sieve permeation, which may be used with a pore size distribution such that a monitored compound with smaller molecules can diffuse into the pores to reach the non-conductive layer 16 at the exclusion of larger molecules. By selecting a material for the semi-permeable coating or for the conductive layer 18, the non-conductive layer may be tailored to respond to a monitored compound by molecular size.

[0045] In a number of variations an array of sensors may be used. For example, the array may include a sensor device 54 with selected different nonconductive polymers provided in the quadrants of the nonconductive layer 16. For example, as shown in FIG. 13, the quadrants 55-58 may be comprised of any of the polymeric materials listed above for use in the non-conductive layer 16. Each of the quadrants 55-58 may be comprised of a different one of those polymeric materials. Each of the chosen polymeric materials may be selected for their response to a selected compound of interest for monitoring purposes. The quadrants 55-58 may have separate leads 22 for collecting information. The non-conductive layer 16 may be coated with the conductive layer 18. In a number of variations quadrants 55-58 may be provided as separate sensor devices that are not attached together so that they may be dispersed to different monitoring points. Providing multiple sensor quadrants or devices with different polymers as the non-conductive layer 16, enhances the ability to monitor for different compounds and/or to dis-

criminate between compounds, due to the ability to select different polymers that respond differently. In VOC monitoring, the sensor devices **14** in the array may be free of an underlying substrate so as to increase surface area for absorbance of the analyte(s) and/or to maximize sensitivity to the monitored compounds. In other variations an array of sensor devices **14** may be configured as shown in FIG. **14**. The sensor array **57** may include a plurality of such devices to improve discrimination between monitored compounds. For example, the sensing devices **101-120** may be arranged on a supporting substrate **121** to provide an index of air quality. The index for example, may be categorized in any number of ways depending on the purpose of monitoring. The categories may be defined based on the type and quantity of VOC present. By choosing the particular polymer for each of the non-conducting layers **16** of the sensor devices **101-121**, sensors with affinities to different monitored compounds may be included. By selecting the polymers for the non-conductive layers **16** based on their affinity to certain compounds, the type of compound providing a stimulus to the array may be discerned. Each of the sensing devices **101-120** may have an independent pair of leads **22** on the conductive layer **18** for monitoring each non-conductive layer **16** individually. An analysis of the array may involve N resistance readings resulting in resistance changes for the sensor devices **101-120**, where the relative resistance changes of the sensor devices **101-120** may be a diagnostic indicative of a stimulus such as VOC presence, deformation, strain, etc. Complex mixtures of analytes may be further distinguished using vapor pressure data for the monitored compounds as related to reaching a full resistance change in a sensor device at saturation.

**[0046]** FIG. **15** illustrates responses of the sensor device **14** as a function of time for 0.5 microliters of xylene injected into a 100 ml vessel at curve **60**, and for 5 microliters of acetone into the same volume at curve **62**. Analyte concentrations for the two VOCs are identical and the varied response is due to differing affinities between the non-conducting layer **16** and the analyte. Resistance in kilohms is plotted on the vertical axis and time in seconds is plotted on the horizontal axis. The traces are plotted together to demonstrate the difference in the magnitude and temporal response of the sensor device **14** to the two analytes. In each case the analyte was introduced at point **64**. As demonstrated, acetone has a much lower response in terms of resistance magnitude, despite the introduction of a tenfold larger sample volume relative to xylene. The rise time, defined as the time required to reach one-half the saturation resistance response is much shorter for acetone as compared to xylene. A factor influencing rise may be the rate of diffusion of the analyte into the polymer non-conductive layer **16**. Other factors may include vapor pressure and diffusion coefficient of the analyte, which may impact transport rate to the sensor device **14**. Since diffusion into the polymer influences rise time, monitoring, measuring and processing rise time can be used to distinguish between VOC analytes. For the rapidly rising portion of the curve **62**, response can be represented by:  $M(t)/M(\infty)=2(Dt/\pi L^2)^{0.5}$  where  $M(t)$  and  $M(\infty)$  are the mass uptake by the non-conductive layer **16** at time  $t$  and an equilibrium mass uptake, respectively.  $L$  is the thickness of the non-conductive layer and  $D$  is the diffusion coefficient. For analytes of different molecular weights, response rise time for analyte diffusion into the non-conductive layer **16** may be monitored

and determined. This may include determining the rise time between a baseline at **64** and a peak **63**, and may include determining the magnitude of the peak **63** to determine the type of VOC sensed based its molecular weight. FIG. **15** demonstrates a correlation between the time needed to reach full saturation at the peaks and the vapor pressure of the analyte, with curve **62** for acetone with a vapor pressure of 30 kPa and curve **60** for xylene with vapor pressure of 2.0 kPa.

**[0047]** With reference to FIG. **16**, illustrated is a response of the sensor device **14** as demonstrated by curves **73** and **75** to two different injection volumes of tetrahydrofuran (THF). Resistance in kilohms is plotted on the vertical axis and time in seconds is plotted on the horizontal axis. The injected volume was greater for curve **75** resulting in an approximate vapor concentration of 2900 PPM from a 1.0 microliter injection than for curve **73** resulting in an approximate vapor concentration of 1160 PPM from an injection of 0.4 microliter. The response is demonstrated as correlative or proportional to the amount of analyte injected. As a result the data collected from the sensor device **14** may be correlated to the concentration of VOC analyte in the environment around the sensor device **14**. FIG. **17** demonstrates a correlative/proportional response of three analytes. Resistance is graphed on the vertical axis as a percentage determined by (measured resistance  $R$  over initial resistance  $R-1$ ) times 100. Vapor concentration in parts per million is graphed on the horizontal axis. Curve **76** plots the response of the sensor device **14** to increasing concentrations of xylene and demonstrates an increasing resistance change correlating to an increase in concentration. Curve **77** plots the response of the sensor device **14** to increasing concentrations of acetone and demonstrates an increasing resistance change correlating to an increase in concentration, but with a lower slope than xylene. Curve **78** plots the response of the sensor device **14** to increasing concentrations of pentane and demonstrates an increasing resistance change correlating to an increase in concentration, with yet a lower slope than acetone.

**[0048]** With reference to FIG. **18**, resistance is graphed on the vertical axis as a proportion of  $R_{measured}$  over  $R_{initial}$  and time in milliseconds is graphed on the horizontal axis. Different volumes of acetone were injected into an argon environment containing the sensing device **14**, with the environment experiencing a flow of 1150 cc/minute. Curve **79** demonstrates the response of the sensor device **14** after the injection of 0.2 microliters of acetone. Curve **80** demonstrates the response of the sensor device **14** after the injection of 1.0 microliters of acetone. Curve **81** demonstrates the response of the sensor device **14** after the injection of 2.0 microliters of acetone. Curve **82** demonstrates the response of the sensor device **14** after the injection of 5.0 microliters of acetone. Each of the curves **79-82** demonstrates the rapid response of the sensor device **14** following the injection point **83**. Each of the curves **79-82** also demonstrates the recovery of the sensor device **14** as the compounds are desorbed from the non-conductive layer **16**. In FIG. **19**, the curve **65** also demonstrates the rapid response **69**, **70** of the sensor device **14** to the introduction of an analyte, and the rapid recovery **71**, **72** of the sensor device **14** to near baseline **74**. As a result, the sensor device **14** may be used to detect an increased concentration of a VOC and the ECM **25** may be programmed to respond to different concentrations in different manners. Once the VOC



concentration diminishes, the sensor device's response reverses for ongoing monitoring.

**[0049]** In a number of variations, the methods or parts thereof may be implemented in a computer program product including instructions or calculations carried on a computer readable medium for use by one or more processors to implement one or more of the method steps or instructions. The computer program product may include one or more software programs comprised of program instructions in source code, object code, executable code or other formats; one or more firmware programs; or hardware description language (HDL) files; and any program related data. The data may include data structures, look-up tables, or data in any other suitable format. The program instructions may include program modules, routines, programs, objects, components, and/or the like. The computer program may be executed on one processor or on multiple processors in communication with one another.

**[0050]** In a number of variations, the program(s) can be embodied on computer readable media, which can include one or more storage devices, articles of manufacture, or the like. Illustrative computer readable media include computer system memory, e.g. RAM (random access memory), ROM (read only memory); semiconductor memory, e.g. EPROM (erasable, programmable ROM), EEPROM (electrically erasable, programmable ROM), flash memory; magnetic or optical disks or tapes; and/or the like. The computer readable medium also may include computer to computer connections, for example, when data may be transferred or provided over a network or another communications connection (either wired, wireless, or a combination thereof). Any combination(s) of the above examples is also included within the scope of the computer-readable media. It is therefore to be understood that the method may be at least partially performed by any electronic articles and/or devices capable of executing instructions corresponding to one or more steps of the disclosed methods.

**[0051]** In a number of variations, as shown in FIG. 20, a method 800 is shown. In a number of variations, the method 800 may include a step 802 of providing a substrate. The method 800 further includes step 804 of providing a non-conductive layer 16 and overlying the substrate with the non-conductive layer 16, or mounting the non-conductive layer on the substrate. The method 800 may further include step 806 of providing a conductive layer 18 and overlying the non-conductive layer 16 with the conductive layer 18 to form a sensor device 14 constructed and arranged to measure or monitor at least one variable of the substrate, or the environment around the non-conductive layer 16. In a number of variations, as shown in FIG. 21, a method 900 is shown. The method 900 may include a step 902 of providing a substrate. The method 900 may further include step 904 of providing a sensor device 14 electronically coupled to the substrate comprising a non-conductive layer 16 and a conductive layer 18 overlying the non-conductive layer 16 constructed and arranged to measure or monitor at least one variable comprising at least one of temperature, pressure, volatile organic compound concentration, state of charge, or state of health of a substrate. The method 900 further includes step 906 of determining at least one of deformation of the non-conductive layer 16 or the substrate, or change in resistance of the conductive layer 18 to provide measurement or monitoring of the at least one variable based on at least one calculation.

**[0052]** In a number of variations as illustrated with the assistance of FIG. 22, a method 950 may include the step 952 of providing a non-conductive layer 16. In a number of variations the non-conductive layer 16 may be provided in step 952 as one contiguous structure comprised of one non-conductive polymer. In a number of variations the non-conductive layer 16 may be provided in step 952 as one contiguous structure comprised of multiple different non-conductive polymers, such as in quadrants 55-58. In a number of variations the non-conductive layer 16 may be provided in step 952 as an array of separate structures, each comprised of one non-conductive polymer, or each comprised of one or more different non-conducting polymers. In a number of variations in step 952, a polymer with hydrophobic properties may be used for the non-conductive layer 16 as a way of differentiating between humidity and VOC presence. The method 950 may include the step 954 of providing a conductive layer 18 that may overlie, or may otherwise be in contact with, the non-conductive layer 16. In step 954 the conductive layer 18 may be constructed and arranged to measure or monitor at least one variable in the non-conducting layer 16. In a number of variations in step 954, the conductive layer 18 may cover the surface 31 of the non-conductive layer 16, substantially completely, or may completely cover the surface 31. In a number of variations the conductive layer 18 may be provided in step 954 over only a part of the surface 31. For example, the conductive layer 18 may be applied so that areas 46-49 may be uncovered spaces on the surface 31 between areas of the conductive layer 18, such as by applying the patches 41-44. The method 950 may include the step 956 of providing a number of lead(s) 22 to support monitoring at least one variable of the sensor device 14. In a number of variations the lead(s) may be connected in step 956 to a power source 50. In a number of variations in step 956, the lead(s) 22 may be formed on or overlying the conductive layer 18. In a number of variations the lead(s) may be provided in step 956 in differently spaced pairs. In a number of variations the leads 22 may be located between the conductive layer 18 and the non-conducting layer 16 in step 956. In a number of variations the lead(s) 22 may be formed on or overlying the non-conductive layer 16 in step 956. In a number of variations in step 956, the lead(s) 22 may be embedded in the non-conductive layer 16, or the conductive layer 18. In a number of variations in step 956, the lead(s) 22 embedded in the non-conductive layer 16 may be in contact with the conducting layer 18. In a number of variations in step 956, the lead(s) 22 may be formed as spaced aligned individual leads. In a number of variations the leads 22 may be formed as a mesh in step 956. In a number of variations in step 956, the lead(s) 22 may be formed as a distributed structure according to a pattern or randomly. The method 950 may include the step 958 of providing a mechanism to monitor the response of the non-conductive layer 16, which may include providing the DAQ 24. In a number of variations in step 958, the DAQ 24 may be connected with the lead(s) 22 to collect information. In a number of variations in step 958, the lead(s) 22 may be connected directly to the ECM 25 to collect information. In a number of variations in step 958, the DAQ may be in communication with the ECM 25 through a wireless connection. In a number of variations in step 958, the DAQ 24 may monitor for resistance or impedance changes between a pair of leads 22. The method 950 may further include the step 960 of determining a deforma-

tion of the non-conductive layer **16** by monitoring for a change in resistance between the lead(s) **22** to provide measurement or monitoring of a VOC in the environment surrounding the sensing device **14**. In a number of variations the step **960** may include determining the type of VOC sensed, such as by comparing the magnitude and/or the rate of the resistance change to known resistance changes for different types of VOCs, such as through a lookup table reference. In a number of variations the step **960** may include determining the concentration of VOC sensed, such as by comparing the magnitude of the resistance change to known resistance changes for different types of VOCs, such as through a lookup table reference. In a number of variations the step **960** may include monitoring for a change in an operation or an environment, where the changes results in the generation or release of additional VOC. For example, the normal presence of a varying amount of analyte may be accompanied by a rate of change indicative of an abnormal event. In a number of variations step **960** may include determining the rise time between a baseline at **64** and a peak **63**, and may include determining the magnitude of the peak **63** to determine the type of VOC sensed based its molecular weight.

[0053] Referring again to FIG. 3, in a number of variations, the non-conductive layer **16** and/or conductive layer **18** of the sensor device **14** may be used to operate as a PTC thermocouple to measure temperature of a substrate to which the sensor device **14** may be mounted or the area in close proximity to the sensor device **14** through at least one calculation. In a number of variations, the sensor device **14** may cover the entirety of a substrate to which it may be mounted and may act as a grid-like system of interconnected sensor devices **14** to provide inputs to determine variables at a number of locations to provide local and overall variable (including, but not limited to, temperature, pressure, or volatile organic compound concentration) measurement and monitoring through at least one calculation. In a number of variations, placement of a plurality of sensor devices **14** onto various locations on or in close proximity to a substrate may decouple the deformation measurements of the substrate and/or non-conductive layer **16** to provide more accurate measurement and monitoring on deformation related to SOC or SOH versus deformation related to the presence of VOC's. In a number of variations, this may allow the sensor device **14** or plurality of sensor devices **14** to measure the presence of VOC's in relation to the substrate independent of the state of charge or state of health measurements of the substrate. In a number of variations, placement of a plurality of sensor devices **14** onto various locations on or in close proximity to a substrate may decouple the deformation measurements of the substrate and/or non-conductive layer **16** to provide more accurate measurement and monitoring on deformation related to SOC or SOH versus deformation related to the temperature or pressure. In a number of variations, temperature or pressure may be indicated through deformation measurements of the substrate and/or non-conductive layer **16** via a calculation and may be measured independent of SOC or SOH measurement through the use of the PTC thermocouple.

[0054] As detailed above, the sensor device **14** may have multiple advantages including superior long term stability of the sensor element since the polymer's chemical reactivity to the ambient environment is decoupled from the transduction mechanism through inclusion of the conductive layer

**18**, a faster response, and a higher degree of reversibility since the transduced signal does not rely on a chemical interaction between the polymer and analyte. Use of the non-conducting layer **16** supports performance without a need to be shielded the sensor device **14** from water and oxygen since the polymer will not degrade over time with exposure to them. The sensor device **14** may be used for analyte detection, identification, classification, and/or tracking through a polymer non-conducting layer **16** with conductive layer **18** that may be provided as a coating on the non-conducting layer **16**. Electrical resistance or impedance changes may be used for analyte detection and classification. Signal processing for the detection, identification, classification and/or tracking of a narrow band of likely analyte. Tuning sensitivity for a specific analyte may be accomplished by altering the composition of the non-conductive layer **16**. For example, PMMA may be used due to its sensitivity to polar compounds while PE or PP may be used due to their sensitivity to nonpolar species. An array of sensors with unique response to individual analyte may be used for classifications. Examples of uses of the products and methods described herein may include food quality inspection, pharmaceutical processing, chemical synthesis, beverage processing, monitoring for health purposes, cosmetic production, manufacturing plant monitoring, vehicle interior air quality, residential air evaluation, vehicle shed testing, or any application where the monitoring, detection, identification, classification, and/or tracking of analytes is desired. Specific uses may involve employing an array of multiple detectors with differing polymer composition as the non-conductive layer to discriminate between emissions from adhesives or polymer components in a vehicle or a fuel or oil source during a vehicle sealed housing evaporative determination (SHED), test. Another use may involve diagnosis of welding tips by evaluating the gases resulting from a welding process where a depleted weld tip releases different VOCs than a non-depleted weld tip.

[0055] The following description of variants is only illustrative of components, elements, acts, product and methods considered to be within the scope of the invention and are not in any way intended to limit such scope by what is specifically disclosed or not expressly set forth. The components, elements, acts, product and methods as described herein may be combined and rearranged other than as expressly described herein and still are considered to be within the scope of the invention.

[0056] Variation 1 may involve a product for sensing that may include a non-conductive layer of a polymer that may be selected for its responsiveness to a stimulus from one of a selected analyte or a selected group of analytes. The non-conductive layer may be non-conductive of an electrical current. A conductive layer may be in contact with the non-conductive layer and may be conductive of the electrical current. A lead may provide an electric current to the conductive layer. A device may be provided to detect at least one property of the conductive layer in response to the stimulus.

[0057] Variation 2 may include the product according to variation 1 wherein the conductive layer may be in contact with a surface of the non-conductive layer and may cover only a portion of the surface so that an area of the surface may be exposed directly to the stimulus.

**[0058]** Variation 3 may include the product according to variation 1 wherein the non-conductive layer may be comprised of areas of different polymers having different responses to the stimulus.

**[0059]** Variation 4 may include the product according to variation 3 wherein the areas may be part of one contiguous structure.

**[0060]** Variation 5 may include the product according to variation 1 wherein the lead may include at least a first pair of leads and a second pair of leads. The first pair of leads may be spaced from each other at a first distance. The second pair of leads may be spaced from each other at a second distance that may be greater than the first so that the first and second pairs of leads communicate a different response to the stimulus.

**[0061]** Variation 6 may include the product according to variation 1 wherein the device may include a data acquisition module that may be in communication with the lead to collect information on responses to the stimulus.

**[0062]** Variation 7 may include the product according to variation 1 wherein the lead may be applied to the conductive layer.

**[0063]** Variation 8 may include the product according to variation 1 wherein the lead may be disposed between the conductive layer and the non-conductive layer.

**[0064]** Variation 9 may include the product according to variation 1 wherein the lead may be a number of spaced apart leads.

**[0065]** Variation 10 may include the product according to variation 1 and may include a semi-permeable layer overlying one of the non-conductive layer or the conductive layer. The semi-permeable layer may have a pore size selected to pass the selected analyte or the selected group of analytes.

**[0066]** Variation 11 may involve a method of monitoring for an exposure to an analyte. A sensing device may be provided with a non-conductive layer. A lead structure may be provided to apply a current to a zone of the sensing device that exhibits an opposition to the current. The opposition may vary in response to the exposure of the non-conducting layer to the analyte.

**[0067]** Variation 12 may include the method according to variation 11 and may include providing a device to monitor changes in the opposition to electrical current. The changes may be processed. A rate of change of the opposition may be determined. A magnitude of change in the opposition may be determined. The rate of change and the magnitude of change may be compared to classify the analyte.

**[0068]** Variation 13 may include the method according to variation 11 and may include providing the non-conductive layer as a polymer that does not conduct the current. A conductive layer may be applied to the non-conductive layer, the conductive layer may conduct the current.

**[0069]** Variation 14 may include the method according to variation 13 and may include providing the lead structure electrically coupled with the conductive layer. The zone may be provided in the conductive layer. The response of the non-conductive layer to the exposure to the analyte may be measured by evaluating changes in the opposition.

**[0070]** Variation 15 may include the method according to variation 14 and may include allowing the non-conductive layer to expand in response to the exposure to the analyte so that the opposition changes in the zone as a result of the expansion.

**[0071]** Variation 16 may include the method according to variation 11 and may include providing the non-conductive layer as an array of different polymers selected to have different responses to the exposure to the analyte.

**[0072]** Variation 17 may include the method according to variation 11 and may include providing a conductive layer overlying a surface of the non-conductive layer with areas of the surface exposed and not covered by the conductive later to tune the sensitivity of the sensing device to the analyte.

**[0073]** Variation 18 may include the method according to variation 11 and may include discerning between the analyte and water vapor by providing the non-conductive layer as a fluorinated polymer.

**[0074]** Variation 19 may include the method according to variation 11 and may include classifying the analyte by comparing a magnitude and a rate of the opposition change to known opposition changes for different types of analytes.

**[0075]** Variation 20 may include the method according to variation 11 and may include quantifying a concentration of the analyte by determining a magnitude of change in the opposition and comparing the magnitude to known magnitudes of change for different concentrations of the analyte.

**[0076]** The above description of select variations within the scope of the invention is merely illustrative in nature and, thus, variations or variants thereof are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A product for sensing comprising a non-conductive layer comprising a polymer selected for its responsiveness to a stimulus from one of a selected analyte or a selected group of analytes, the non-conductive layer being non-conductive of an electrical current, a conductive layer in contact with the non-conductive layer and being conductive of the electrical current, a lead for providing an electric current to the conductive layer, and a device detecting at least one property of the conductive layer in response to the stimulus.

2. The product according to claim 1 wherein the conductive layer is in contact with a surface of the non-conductive layer and covers only a portion of the surface so that an area of the surface is exposed directly to the stimulus.

3. The product according to claim 1 wherein the non-conductive layer is comprised of areas of different polymers having different responses to the stimulus.

4. The product according to claim 3 wherein the areas are part of one contiguous structure.

5. The product according to claim 1 wherein the lead comprises a first pair of leads and a second pair of leads, wherein the first pair of leads are spaced from each other at a first distance, and the second pair of leads are spaced from each other at a second distance that is greater than the first so that the first and second pairs of leads communicate a different response to the stimulus.

6. The product according to claim 1 wherein the device comprises a data acquisition module in communication with the lead to collect information on responses to the stimulus.

7. The product according to claim 1 wherein the lead is applied to the conductive layer.

8. The product according to claim 1 wherein the lead is disposed between the conductive layer and the non-conductive layer.

9. The product according to claim 1 wherein the lead comprises a number of spaced apart leads.

**10.** The product according to claim **1** comprising a semi-permeable layer overlying one of the non-conductive layer or the conductive layer, the semi-permeable layer having a pore size selected to pass the selected analyte or the selected group of analytes.

**11.** A method of monitoring for an exposure to an analyte comprising: providing a sensing device with a non-conductive layer; providing a lead structure to apply a current to a zone of the sensing device that exhibits an opposition to the current, wherein the opposition varies in response to the exposure of the non-conducting layer to the analyte.

**12.** A method according to claim **11** comprising a device to monitor changes in the opposition, processing the changes; determining a rate of change of the opposition, determining a magnitude of change in the opposition, and comparing the rate of change and the magnitude of change to classify the analyte.

**13.** A method according to claim **11** comprising providing the non-conductive layer as a polymer that does not conduct the current, applying a conductive layer to the non-conductive layer, the conductive layer conducting the current.

**14.** The method according to claim **13** comprising providing the lead structure electrically coupled with the conductive layer, providing the zone in the conductive layer, and measuring the response of the non-conductive layer to the exposure to the analyte by evaluating changes in the opposition.

**15.** The method according to claim **14** comprising allowing the non-conductive layer to expand in response to the exposure to the analyte as a result of the opposition changes in the zone through the expansion.

**16.** The method according to claim **11** comprising providing the non-conductive layer as an array of different polymers selected to have different responses to the exposure to the analyte.

**17.** The method according to claim **11** comprising providing a conductive layer overlying a surface of the non-conductive layer with areas of the surface exposed and not covered by the conductive later to tune the sensitivity of the sensing device to the analyte.

**18.** The method according to claim **11** comprising discerning between the analyte and water vapor by providing the non-conductive layer as a fluorinated polymer.

**19.** The method according to claim **11** comprising classifying the analyte by comparing a magnitude and a rate of the opposition change to known opposition changes for different types of analytes.

**20.** The method according to claim **11** comprising quantifying a concentration of the analyte by determining a magnitude of change in the opposition and comparing the magnitude to known magnitudes of change for different concentrations of the analyte.

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