(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 January 2017 (26.01.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/014764 A1

(51) International Patent Classification: *G01N 27/404* (2006.01)

(21) International Application Number: PCT/US2015/041449

(22) International Filing Date: 22 July 2015 (22.07.2015)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: HONEYWELL INTERNATIONAL INC. [US/US]; Patent Services M/S AB/2B, 101 Columbia Road, P. O. Box 2245, Morristown, New Jersey 07962-2245 (US).

(72) Inventors: HANSEN, Neils; Honeywell International Inc., Patent Services M/S AB/2B, 101 Columbia Road, P. O. Box 2245, Morristown, New Jersey 07962-2245 (US). HARRIS, Stuart; Honeywell International Inc., Patent Services M/S AB/2B, 101 Columbia Road, P. O. Box 2245, Morristown, New Jersey 07962-2245 (US).

(74) Agents: BEATUS, Carrie et al.; Honeywell International Inc., Patent Services M/S AB/2B, 101 Columbia Road, P. O. Box 2245, Morristown, New Jersey 07962-2245 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

[Continued on next page]

(54) Title: INERT CORROSION BARRIERS FOR CURRENT COLLECTOR PROTECTION

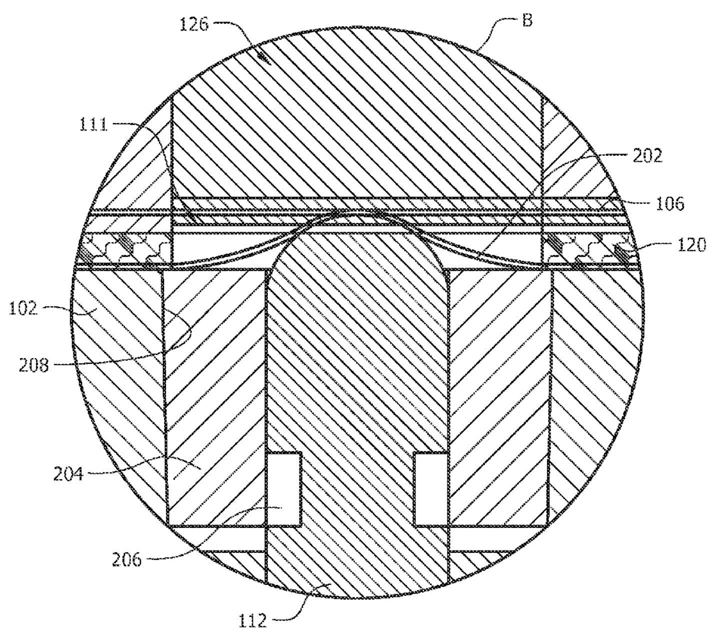

FIG. 2

(57) Abstract: A gas sensor comprises a cap, a housing coupled to the cap, a plurality of electrodes disposed within the interior space, a plurality of connector pins, and a metal foil sealing engaging the opening in the housing. An interior space is formed between the cap and the housing, and at least one electrode is disposed adjacent to an opening in the housing. At least one connector pin of the plurality of connector pins is electrically coupled to the metal foil, and the metal foil is electrically coupled to the at least one electrode. The metal foil can comprise a platinum foil.

WO 2017/014764 A1

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

INERT CORROSION BARRIERS FOR CURRENT COLLECTOR PROTECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

REFERENCE TO A MICROFICHE APPENDIX

[0003] Not applicable.

BACKGROUND

[0004] Electrochemical gas sensors generally comprise electrodes in contact with an electrolyte for detecting a gas concentration. The electrodes are electrically coupled to an external circuit though lead wires that are coupled to connector pins. During use, the electrolyte, which can be extremely corrosive, can migrate along the lead wires to contact the connector pins, which can contain corrodible material such as brass. When the electrolyte contacts the connector pins, the sensor can fail due to the undesirable electrochemical behavior associated with the corrosion disturbing the desired electrochemistry.

[0005] Some sensors have employed potting materials or coatings to help prevent the leakage of the electrolyte. However, the potting materials suffer from manufacturing issues such as shrinkage that creates fluid conduction pathways as well as expensive design issues to accommodate the presence of the potting materials. For example, the use of potting materials requires additional features to direct, locate, and retain the potting materials during manufacturing and curing. The curing process also requires additional steps while the operating temperature range is reduced to avoid damaging cured mateirals. Coatings are generally insufficient to withstand the strong acids (e.g., greater than 14 M sulfuric acid) present in the electrolytes of some sensors. Thus, the use of lead wires may not be suitable for use in all types of electrochemical gas sensors.

SUMMARY

[0006] In an embodiment, a gas sensor comprises a cap, a housing coupled to the cap, a plurality of electrodes disposed within the interior space, a plurality of connector pins, and a metal foil sealing engaging the opening in the housing. An interior space is formed between the cap and the housing, and at least one electrode is disposed adjacent to an opening in the housing. At least one connector pin of the plurality of connector pins is electrically coupled to the metal foil, and the metal foil is electrically coupled to the at least one electrode. The metal foil can comprise a platinum foil. The metal foil can be spot welded to the at least one connector pin, and the metal foil can be heat sealed over the opening in the housing. The gas sensor can also include an electrolyte disposed within the interior space, the electrolyte can be in contact with at least a portion of the at least one electrode. The connector pin can be fluidly isolated from the electrolyte by the metal foil. The gas sensor can also include at least one seal disposed between the at least one connector pin and the housing. The gas sensor can also include a base coupled to the housing opposite the cap, the plurality of connector pins can extend through the base and at least a portion of the housing.

[0007] In an embodiment, a gas sensor comprises a cap, a housing coupled to the cap, a plurality of electrodes disposed within the interior space, a plurality of connector pins, and a conductive seal disposed within the opening in the housing. An interior space is formed between the cap and the housing, and at least one electrode is disposed adjacent to an opening in the housing. At least one connector pin of the plurality of connector pins is electrically coupled to the conductive seal, and the conductive seal is electrically coupled to the at least one electrode. The conductive seal can comprise a conductive insert formed from glassy carbon. The gas sensor can also include a

polymeric insert disposed about the conductive seal, and the polymeric insert can sealingly engage the seal insert and the opening in the housing. The gas sensor can also include an electrolyte disposed within the interior space. The electrolyte can be in contact with at least a portion of the at least one electrode, and the connector pin can be fluidly isolated from the electrolyte by the conductive seal. The conductive seal can comprise a protective sleeve disposed about an end of the at least one connector pin. The protective sleeve can comprises a platinum sleeve.

[0008] In an embodiment, a method of operating a gas sensor comprises passing a gas through an aperture in a gas sensor, contacting the gas with an electrolyte disposed within the gas sensor, forming an electrical potential difference between at least two electrodes in the gas sensor based on the contacting, detecting the electrical potential difference through the conduct seal and at least one connector pin, determining a concentration of the gas based on the electrical potential difference, and preventing contact between the at least one connector pin and the electrolyte using the conductive seal. At least one electrode of the at least two electrodes is in electrical contact with a conductive seal. The conductive seal can comprise a metal foil sealing engaging an opening in the gas sensor. The at least one connector pin can be electrically coupled to the metal foil, and the metal foil can be electrically coupled to the at least one electrode. The metal foil can comprise a platinum foil. The conductive seal can comprise a conductive insert disposed within an opening in the sensor. The at least one connector pin can be electrically coupled to the conductive insert, and the conductive insert can be electrically coupled to the at least one electrode. The conductive insert can comprise glassy carbon. The conductive seal can comprise a protective sleeve disposed over an end of the at least one connector pin, and the protective sleeve can sealingly engage an opening in the gas sensor. The protective sleeve can be formed from platinum.

[0009] These and other features will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a more complete understanding of the present disclosure, reference is now made to the following brief description, taken in connection with the accompanying drawings and detailed description, wherein like reference numerals represent like parts.

[0011] FIG. 1 illustrates a schematic cross section of an embodiment of an electrochemical gas sensor according to an embodiment.

[0012] FIG. 2 illustrates a cross-sectional view of a connector pin and electrode arrangement according to an embodiment.

[0013] FIG. 3 illustrates another cross-sectional view of a connector pin and electrode arrangement according to an embodiment.

[0014] FIG. 4 illustrates still another cross-sectional view of a connector pin and electrode arrangement according to an embodiment.

DETAILED DESCRIPTION

[0015] It should be understood at the outset that although illustrative implementations of one or more embodiments are illustrated below, the disclosed systems and methods may be implemented using any number of techniques, whether currently known or not yet in existence. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques illustrated below, but may be modified within the scope of the appended claims along with their full scope of equivalents.

[0016] The following brief definition of terms shall apply throughout the application:

[0017] The term "comprising" means including but not limited to, and should be interpreted in the manner it is typically used in the patent context;

[0018] The phrases "in one embodiment," "according to one embodiment," and the like generally mean that the particular feature, structure, or characteristic following the phrase may be included in at least one embodiment of the present invention, and may be included in more than one embodiment of the present invention (importantly, such phrases do not necessarily refer to the same embodiment);

[0019] If the specification describes something as "exemplary" or an "example," it should be understood that refers to a non-exclusive example;

[0020] The terms "about" or approximately" or the like, when used with a number, may mean that specific number, or alternatively, a range in proximity to the specific number, as understood by persons of skill in the art field; and

[0021] If the specification states a component or feature "may," "can," "could," "should," "would," "preferably," "possibly," "typically," "optionally," "for example," "often," or "might" (or other such language) be included or have a characteristic, that particular component or feature is not required to be included or to have the characteristic. Such component or feature may be optionally included in some embodiments, or it may be excluded.

[0022] Electrochemical gas sensors generally detect the presence of a gas in the atmosphere adjacent the sensor by allowing a controlled flow rate of the ambient gases to enter and react within the sensor. The composition of the electrodes and electrolyte within the sensor can be selected to react with different gases, thereby enabling a degree of selectivity in determining the ambient concentration of a targeted gas. The electrolyte can be corrosive to some of the materials used within the sensors. For example, connector pins can be used to provide an electrical connection between the electrodes within the sensor and external detection circuitry. The connector pins may be formed from various degradable materials such as tin, brass, copper, or the like. Any contact between the connector pins and the electrolyte may then result in the degradation of the connector pins, which can result in adverse electrochemical interactions and potential leakage of the electrolyte from the sensor. While seals can be used to limit the amount of leakage of the electrolyte, any seals between the connector pins and the housing of the sensor may not prevent direct access between the electrolyte and the connector pins.

[0023] In order to limit any contact between the connector pins and the electrolyte, a conductive seal can be placed over an opening in the housing of the sensor, and the connector pins can be placed in electrical contact with the conductive seal. As described herein, the conductive seal can provide a relatively inert barrier to the migration of any electrolyte out of the sensor while providing an electrically conductive pathway between the electrode and the external detection circuitry through a connector pin. In a first embodiment, the conductive seal can comprise a metal foil disposed over an opening in the housing. The metal foil may be inert to the electrolyte and can be sealed to the housing. This may prevent any leakage of the electrolyte while providing an inert seal with the housing itself. The metal foil can be placed into contact with the electrode and electrically coupled to the connector pin by direct contact with the connector pin. Thus, the metal foil can serve as a conductive seal with the housing to prevent the leakage of any electrolyte while also providing an electrically conductive pathway between the electrode and the connector pin.

[0024] In another embodiment, the metal foil can be formed into a protective sleeve that can be disposed about the end of the connector pin. The protective sleeve may protect the connector pin from direct contact with the electrolyte while allowing the connector pin with the protective sleeve to be placed into direct contact with the electrode. The protective sleeve can be sealed to the housing to prevent or reduce any leakage of the electrolyte or contact between the electrolyte and the connector pin.

[0025] In still another embodiment, the conductive seal can comprise a conductive insert within an opening of the housing of the sensor. For example, a relatively inert material can be disposed within an opening of the housing. A sealing element or polymeric insert can be used to provide a substantially fluid tight seal between the conductive insert and the opening in the housing. For example, a cylinder of conductive glassy carbon can be disposed within an opening in the housing and a seal can be formed around the conductive insert to form a seal. A first end of the conductive insert can be placed in contact with the electrode, and the second end opposite the first end can be placed in contact with the connector pin. Thus, the conductive insert can also serve as a conductive seal with the housing to prevent the leakage of any electrolyte while also providing an electrically conductive pathway between the electrode and the connector pin. Each of these embodiments are described in more detail herein.

[0026] FIG. 1 illustrates a cross-section of an electrochemical gas sensor 100. The electrochemical gas sensor 100 comprises a multi-part housing including at least a body 102 defining a hollow interior space 110 for receiving and retaining an electrolyte (e.g., forming an electrolyte reservoir), a base 104, and a cap 106. The base 104 and the cap 106 can sealingly engage the body 102 to form an integral unit.

[0027] The body 102 may have a generally rectangular or square shape, though other shapes such as cylindrical, oval, oblong, or the like are also possible. The body 102, the cap 106, and the base 104 can all be formed from materials that are inert to the selected electrolyte. For example, the body 102, the cap 106, and/or the base 104 can be formed from one or more plastic or polymeric materials. In an embodiment, the body 102, the cap 106, and/or the base 104 can be formed from a material including, but not limited to, acrylonitrile butadiene styrene (ABS), polyphenylene oxide (PPO), polystyrene (PS), polypropylene (PP), polyethylene (e.g., high density polyethylene (HDPE)), polyphenylene ether (PPE), or any combination or blend thereof.

[0028] Within the electrochemical gas sensor 100, a separator 120 may be disposed between the body 102 and the cap 106. The separator can comprise a porous member that acts as a wick for the retention and transport of the electrolyte between the reservoir and the electrodes. The separator can comprise a porous felt member, a porous polymer, or the like, and is generally chemically inert with respect to the electrolyte and the materials forming the electrodes. Since the separator 120 acts as a wick, the separator may form a continuous path between each of the electrodes within the sensor 100.

[0029] The electrolyte can comprise an aqueous solution of a salt, an acid, or a base depending on the target gas of interest. In an embodiment, the electrolyte can comprise sulfuric acid when oxygen is the target gas being detected. Other target gases may use the same or electrolyte compositions. In addition to aqueous based electrolytes, ion liquid electrolytes can also be used to detect certain gases.

[0030] The electrodes generally allow for various reactions to take place to allow a current or potential to develop in response to the presence of a target gas. The resulting signal may then allow for the concentration of the target gas to be measured by the sensor 100. In a two sensor configuration, the sensors may comprise a counter electrode 111 and a sensing electrode 113, and in a three sensor configuration, the sensors can include a counter electrode 111, a sensing electrode 113, and a reference electrode.

[0031] The electrodes can comprise a reactive material suitable for carrying out a desired reaction. For example, the electrodes can be formed of a mixture of electrically conductive catalyst particles in a binder such as polytetrafluoroethylene (PTFE). The catalyst composition can be selected based on the target gas of interest. For example, for an oxygen sensor, the electrode can comprise a mixture of carbon (e.g., graphite) and/or platinum. Other metals such as ruthenium and iridium can also be used in some embodiments. The electrode can also comprise a backing material or substrate such as a membrane to support the catalyst mixture. The backing material or substrate can comprise a porous material to provide gas access to the electrode through the substrate.

[0032] The electrodes might be deposited onto the substrate by for example screen printing, filtering in selected areas from a suspension placed onto the substrate, by spray coating, or any other method suitable for producing a patterned deposition of solid material. Deposition might be of a single material or of more than one material sequentially in layers, so as for example to vary the properties of the electrode material through its thickness or to add a second layer of increased electrical conductivity above or below the layer which is the main site of gas reaction.

[0033] A porous membrane 122 can also be disposed within the sensor 100, a portion of which can serve as a vent membrane to allow any gas forming within the sensor to pass through the membrane and out a hole in the cap 106 to the atmosphere. The vent membrane may be porous to a gas, but can generally form a barrier the passage of any liquids such as the electrolyte solution. A bulk flow membrane 124 can be disposed within the cap 106 to serve as a barrier the bulk flow of gases into the sensor 100. In an embodiment, the bulk flow membrane 124 can be impermeable to gases. A capillary opening through the cap 106 and/or the bulk flow membrane 124 may provide a path to allow the gases in the atmosphere to pass into the sensor 100 to react with the electrodes and electrolyte solution.

[0034] The two or more electrodes within the electrochemical gas sensor 100 can be electrically connected to an external circuit through one or more electrical connections. In an embodiment, the electrodes may have connector pins 112, 114 extending through the base 104 and/or the body 102 that can be electrically coupled, directly or indirectly, with the electrodes 111, 113. The external surfaces of the connector pins 112, 114 can be electrically coupled to the external circuit. While only two electrodes and connector pins are illustrated, each electrode may be associated with a connector pin when more than two electrodes are present. The connector pins 112, 114 may sealingly engage the base 104 and/or the body 102 so that the connector pins 112, 114 are substantially sealed from the interior space 110 of the electrochemical gas sensor 100.

[0035] The connector pins 112, 114 can be formed from an electrically conductive material, which may be plated or coated. In an embodiment, the connector pins 112, 114 can be formed from brass, nickel, copper, or the like. The connector pins 112, 114 can be coated to reduce degradation due to the contact with the electrolyte. For example, the connector pins 112, 114 can include a coating of precious metal such as gold, platinum, silver, or the like, or other base metals such as tin. In some embodiments, the conductive seal such as the metal foil may allow for the use of an uncoated connector pin, which may be less expensive to manufacture. For example, a connector pin 112, 114 can be formed from brass without any precious metal coating(s).

[0036] In order to protect the connector pins from the electrolyte, various types of conductive seals can be used to separate the connector pins from direct contact with the electrolyte or the electrode, which may comprise some amount of electrolyte that could otherwise contact the connector pin. An enlarged view of the connector pin 112 of FIG. 1 is shown in FIG. 2. Some elements and the scale of FIG. 2 are exaggerated in order to more clearly illustrate the features described herein. As illustrated in FIGS. 1 and 2, a metal foil 202 can be used to isolate the connector pin 112 from the interior of the sensor 100. A channel 208 defined through the body 102 may be configured to receive an insert 204 that can be used to align the connector pin 112 within the channel 208. The connector pin 112 can be disposed within a passage formed through the insert 204. The insert 204, along with one or more sealing elements 206, may serve to provide a seal between the connector pin 112 and the body 102 in the event that any liquid (e.g., the electrolyte) passes the metal foil 202. The insert 204 may be formed from a material that is substantially inert to the electrolyte solution while also providing a compliant seal between the connector pin 112 and the body 102. Various polymeric materials such as polytetrafluoroethylene can be used to form the insert 204 and/or one or more of the seals 206.

[0037] The metal foil 202 may generally have a shape matching that of the opening in the housing. In some embodiments, the metal foil 202 can be round in shape. The metal foil 202 can be disposed over the channel 208 and extend outwards a short distance to overlap with the body adjacent the channel 208. The metal foil can be sealed to the body in the overlap region. For example, the metal foil can be bonded (e.g., heat sealed and/or pressure sealed) to the body 102. For example, a heat seal can be formed using ultrasonic bonding, applied heat, or any other suitable method. In some embodiments, a sealant or any other type of sealing configuration can be used to form a seal between the metal foil and the body 102.

[0038] The metal foil 202 can comprise an electrically conductive material that is substantially inert to the electrolyte solution. The composition of the metal foil may be selected based on the non-reactivity with the electrolyte (e.g., being inert, corrosion resistant, etc.), the relative flexibility of the material to maintain a seal and allow the formation of a foil, the ability to be heat sealable, and/or a low electrical resistivity. In an embodiment, the metal foil can be formed from a noble metal such as platinum group metal (e.g., Pt, Pd, Ir, Rh, Ru, etc.) , gold, or the like. The metal foil can have thickness sufficient to provide the desired mechanical properties. in some embodiments, the metal foil has a thickness between about 5 microns and about 200 microns, between about 10 microns and about 100 microns, or between about 20 microns and about 50 microns. The diameter of the metal foil may be determined based on the geometry of the connector pin and/or the channel 208 through the body. In an embodiment, the metal foil may have a diameter between about 0.1 mm and about 10 mm, between about 1 mm and about 5 mm, or between about 1.5 mm and about 3 mm. In an embodiment, the metal foil may comprise a platinum foil disc having a thickness between about 20 microns and about 50 microns with a diameter of around 2 mm.

[0039] In order to provide a direct electrical connection between the connector pin 112 and the electrode 111, a hole or channel can be formed in the separator 120 above the connector pin 112. The metal foil 202 can then be placed into electrical contact with the electrode 111 and the connector pin 112. An overlying pressure pad 126 can provide a biasing force on the electrode 111 towards the metal foil 202 to compress the electrode 111 and maintain contact between the electrode 111 and the metal foil 202 and the connector pin 112.

[0040] In order to avoid the potential for the metal foil 202 and/or the connector pin 112 to lose contact with the electrode 111, the metal foil may be coupled to the connector pin 112. For example, the metal foil can be welded to the connector pin 112 to maintain the metal foil 202 in contact with the connector pin 112. In some embodiments, the metal foil 202 can be coupled to the connector pin using various types of couplings such as soldering, crimping, using a conductive adhesive, or the like.

[0041] The embodiment illustrated in FIG. 2 shows the metal foil 202 being formed over the end of the connector pin 112. While the metal foil can be at least partially deformed to conform to the shape of the connector pin 112 and/or be displaced towards the electrode 111, the metal foil 202 can also remain in a planar configuration. In this embodiment, the pressure pad 126 may be used to displace the electrode 111 into contact with the metal foil 202. Due to the relatively small thickness of the separator 120 and the electrodes, the actual deformation of either the metal foil and/or the electrode material may be minimal.

[0042] When the sensor is used, the electrolyte may be maintained in contact with the electrode 111 by passing through the separator 120. Since a hole or channel is created in the separator 120 over the connector pin 112, only a minimal amount of electrolyte solution may be contact with the metal foil 202. For example, some amount of electrolyte may pass through the material of the electrode 111 to contact the metal foil. If any electrolyte were able to pass between the metal foil 202 and the body 102, the insert 204 and the seals 206 may prevent any further migration of the electrolyte out of the sensor 100.

[0043] In addition to the use of a metal foil, the connector pin can also be separated from contact with the electrolyte through the use of an electrically conductive element disposed between the connector pin and the electrode. FIG. 3 illustrates another embodiment of a sensor 300 having a conductive insert 302 between the electrode 111 and the connector pin 112. While described in terms of the electrode 111 and the connector pin 112, this configuration can be used with any of the connector pins 112, 114 and/or electrode present in the sensor 100 of FIG. 1 or FIG. 2. Further, the configuration illustrated in FIG. 3 can be the same or similar to the configuration shown in FIG. 2, and like components are not discussed herein in the interest of clarity.

[0044] The embodiment of FIG. 3 is similar to the embodiment shown in FIG. 2 except that the metal foil has been replaced with a conductive insert 302. The conductive insert 302 may be disposed in the channel 208 within the insert 204 between the connector pin 112 and the electrode 111. A fluid seal can be formed between the conductive insert 302 and the elastomer insert 204 to prevent the migration of fluid such as the electrolyte into contact with the connector pin 112. One or more additional seals can be disposed between the connector pin 112 and the body 102 to provide a secondary seal to prevent any leakage of the electrolyte from the sensor 300.

[0045] The conductive insert 302 can contact the electrode 111 through the hole in the separator 120. The biasing force provided by the pressure pad 126 may maintain contact between the conductive insert 302 and the electrode 111. The biasing force may also maintain contact between the conductive insert 302 and the connector pin 112. In some embodiments, a coupling such as a conductive adhesive can be used between the connector pin 112 and the conductive insert 302.

[0046] The conductive insert 302 may comprise any type of material that is substantially inert to the electrolyte while also being electrically conductive. In an embodiment, the conductive insert 302 can comprise carbon (e.g., glassy carbon, graphite, etc.), a conductive polymer, or the like. In an embodiment, the conductive insert 302 may have a diameter that matches that of the connector pin 112, and the conductive insert 302 may have a length (e.g., in a direction aligned between the connector pin 112 and the electrode 111) of between about 0.1 mm and about 20 mm, between about 0.5 mm and about 15 mm, or between about 1 mm and about 10 mm.

[0047] Another embodiment of a sensor 400 comprising a conductive seal is illustrated in FIG. 4. The embodiment of FIG. 4 is similar to the embodiment shown in FIG. 2 except that the metal foil has been replaced with a protective sleeve 402 disposed over the connector pin 112. However, rather than being formed as a metal foil disc, the protective sleeve 402 may comprise a metal foil sleeve shaped to be disposed over the end of the connector pin 112. The protective sleeve 402 may comprise a formed platinum sleeve that is placed on the connector pin and coupled to the connector pin. Any of the coupling processes described with respect to the metal foil can also be used to couple the protective sleeve 402 to the connector pin. In an embodiment, the protective sleeve 402 can be welded to the connector pin.

[0048] In this embodiment, the protective sleeve 402 may be similar to the metal foil and can include any of the materials and thicknesses of the metal foil described herein. In an embodiment, the protective sleeve 402 may extend along the length of the connector pin between about 0.1 mm and about 20 mm, between about 0.5 mm and about 10 mm, or between about 1 mm and about 5 mm.

[0049] When the protective sleeve 402 is disposed on the connector pin 112, the connector pin 112 can be disposed in the channel 208 within the elastomer insert 204 and contact the electrode 111. The protective sleeve 402 can contact the electrode 111 through the hole in the separator 120. The biasing force provided by the pressure pad 126 may maintain contact between the protective sleeve 402 and the electrode 111. A fluid seal can be formed between the protective sleeve 402 and the elastomer insert 204 to prevent the migration of fluid such as the electrolyte into contact with the connector pin 112 at a point at which the protective sleeve 402 is not disposed over the connector pin 112. One or more additional seals can be disposed between the connector pin 112 and the body 102 to provide a secondary seal to prevent any leakage of the electrolyte from the sensor 300. This embodiment creates an elongated sealing surface and leakage path to reduce the migration of any electrolyte out of the sensor and into contact with the connector pin 112.

[0050] In use, the sensor can detect a gas in the environment adjacent to the sensor. Referring to FIG. 1, a gas present in the atmosphere adjacent the sensor 100 can enter the sensor 100 through a diffusion limiting structure such as one or more apertures, membranes, or the like in the cap 106. In some embodiments, the diffusion limiting structure can attenuate the flow of gas into the interior of the sensor and/or form a diffusion barrier for controlling the rate of gas inflow.

[0051] The gas can pass into the interior space 110 where the gas can contact the electrolyte and the electrodes 111, 113. A half-cell reaction can occur at each electrode depending on the specific gas present, the composition of the electrode (e.g., the catalyst composition), and the composition of the electrolyte solution. For example, electrode 113 acts as a sensing electrode for a target gas present in the atmosphere, and when the target gas is present, can act as a catalyst for reacting the gas with water in the electrolyte to produce ions in solution and electrons. At the counter electrode 111, oxygen in the electrolyte can react with the ions released by the sensing electrode 113 to complete an electrical circuit.

[0052] The resulting reactions can generate an electrical potential difference (e.g., a voltage) between at least two of the electrodes. When a reference electrode is present, the potential difference between the reference electrode and the counter electrode can be used to provide a relative potential difference between the sensing electrode and the counter electrode. For example, a reference electrode can act in conjunction with an external potentiostat circuit to bias the cell to a desired voltage level. Various sensor designs can use passive electrical potential differences to determine the electrical potential differences. Other designs may apply a constant potential between two or more of the electrodes to enable the detection of an electrical potential difference and/or an electrical current.

[0053] In the sensors described herein, at least one of the electrodes can be in electrical contact with a conductive seal. The conductive seal can include the metal foil 202, the conductive insert 302, and/or the protective sleeve 402 described with respect to FIG. 2,FIG. 3, and FIG. 4, respectively. The conductive seal can be in electrical contact with a connector pin, which can be electrically coupled to an external detection circuit. Based on the electrical potential and/or a generated electrical current, the external detection circuit can determine the concentration of the gas.

[0054] While the gas is contacting the electrolyte and/or the electrodes 111, 113, the conductive seal can serve to prevent contact between the associated connector pin and the electrolyte. This may prevent any leakage of the electrolyte and potential degradation of the connector pin. As described with respect to FIGS. 1 and 2, the conductive seal can comprise a metal foil disposed over an opening in the gas sensor (e.g., over an opening in the body 102). The metal foil (e.g., a noble metal foil such as a platinum foil) can sealingly engage the opening in the gas sensor by being, for example, heat sealed to the sensor around the opening. The connector pin can then be disposed in electrical contact with the metal foil to provide an electrical conduction pathway between the electrode and the connector pin. In some embodiments, the metal foil can be coupled to the connector pin, for example, by a weld (e.g., a spot weld). Within the sensor described herein, each electrode can be coupled to a connector pin using a metal foil sealingly engaged over an opening in the sensor.

[0055] In some embodiments, the conductive seal used to prevent contact between the electrolyte and the connector pin during the gas sensing process can include a conductive insert disposed within an opening in the sensor. The conductive insert (e.g., a conductive glassy carbon, etc.) can be in electrical contact with the electrode on one side and in electrical contact with the connector pin on a second side. The conductive insert can be surrounded by a sleeve that serves to form a seal between the conductive insert and the opening in the sensor in which the conductive insert is disposed. For example, the conductive insert can be surrounded by a relatively compliant polymeric material such as a PTFE sleeve to provide a seal between the conductive insert and the body of the sensor. The connector pin can then be placed into contact with the end of the conductive insert opposite that in contact with the electrode. A pressure pad disposed above the electrode can provide a biasing force to maintain electrical contact between the electrode, the conductive insert, and the connector pin.

[0056] In some embodiments, the conductive seal can comprise a protective sleeve disposed over the end of the connector pin. The protective sleeve (e.g., a platinum sleeve) can be in electrical contact with the electrode on one side and in electrical contact with the connector pin on a second side. The protective sleeve can be surrounded by an insert that serves to form a seal between the protective sleeve and the opening in the sensor in which the protective sleeve is disposed. For example, the protective sleeve can be surrounded by a relatively compliant polymeric material such as a PTFE sleeve to provide a seal between the protective sleeve and the body of the sensor. A pressure pad disposed above the electrode can provide a biasing force to maintain electrical contact between the electrode, the protective sleeve, and the connector pin.

[0057] Each embodiment of the conductive seal may serve to provide an inert seal between the interior of the sensor and the connector pin. This arrangement may prevent any corrosive materials such as the electrolyte from contacting the connector pin during use, thereby reducing the risk of failure of the sensor due to the degradation of one or more of the connector pins present in the sensor.

[0058] While various embodiments in accordance with the principles disclosed herein have been shown and described above, modifications thereof may be made by one skilled in the art without departing from the spirit and the teachings of the disclosure. The embodiments described herein are representative only and are not intended to be limiting. Many variations, combinations, and modifications are possible and are within the scope of the disclosure. Alternative embodiments that result from combining, integrating, and/or omitting features of the embodiment(s) are also within the scope of the disclosure. Accordingly, the scope of protection is not limited by the description set out above, but is defined by the claims which follow, that scope including all equivalents of the subject matter of the claims. Each and every claim is incorporated as further disclosure into the specification and the claims are embodiment(s) of the present invention(s).

Furthermore, any advantages and features described above may relate to specific embodiments, but shall not limit the application of such issued claims to processes and structures accomplishing any or all of the above advantages or having any or all of the above features.

[0059] Additionally, the section headings used herein are provided for consistency with the suggestions under 37 C.F.R. 1.77 or to otherwise provide organizational cues. These headings shall not limit or characterize the invention(s) set out in any claims that may issue from this disclosure. Specifically and by way of example, although the headings might refer to a "Field," the claims should not be limited by the language chosen under this heading to describe the so-called field. Further, a description of a technology in the "Background" is not to be construed as an admission that certain technology is prior art to any invention(s) in this disclosure. Neither is the "Summary" to be considered as a limiting characterization of the invention(s) set forth in issued claims. Furthermore, any reference in this disclosure to "invention" in the singular should not be used to argue that there is only a single point of novelty in this disclosure. Multiple inventions may be set forth according to the limitations of the multiple claims issuing from this disclosure, and such claims accordingly define the invention(s), and their equivalents, that are protected thereby. In all instances, the scope of the claims shall be considered on their own merits in light of this disclosure, but should not be constrained by the headings set forth herein.

[0060] Use of broader terms such as comprises, includes, and having should be understood to provide support for narrower terms such as consisting of, consisting essentially of, and comprised substantially of. Use of the term "optionally," "may," "might," "possibly," and the like with respect to any element of an embodiment means that the element is not required, or alternatively, the element is required, both alternatives being within the scope of the embodiment(s). Also, references to examples are merely provided for illustrative purposes, and are not intended to be exclusive.

[0061] While several embodiments have been provided in the present disclosure, it should be understood that the disclosed systems and methods may be embodied in many other specific forms without departing from the spirit or scope of the present disclosure. The present examples are to be considered as illustrative and not restrictive, and the intention is not to be limited to the details given herein. For example, the various elements or components may be combined or integrated in another system or certain features may be omitted or not implemented.

[0062] Also, techniques, systems, subsystems, and methods described and illustrated in the various embodiments as discrete or separate may be combined or integrated with other systems, modules, techniques, or methods without departing from the scope of the present disclosure. Other items shown or discussed as directly coupled or communicating with each other may be indirectly coupled or communicating through some interface, device, or intermediate component, whether electrically, mechanically, or otherwise. Other examples of changes, substitutions, and alterations are ascertainable by one skilled in the art and could be made without departing from the spirit and scope disclosed herein.

CLAIMS

What is claimed is:

1. A gas sensor comprising:

a cap (106);

a housing (102) coupled to the cap (106), wherein an interior space (110) is formed between the cap (106) and the housing (102);

a plurality of electrodes (111, 113) disposed within the interior space (110); wherein at least one electrode is disposed adjacent to an opening (208) in the housing (102);

a plurality of connector pins (112, 114); and

a conductive seal (202, 302, 402) disposed in the opening (208) in the housing (102), wherein at least one connector pin (112, 114) of the plurality of connector pins is electrically coupled to the conductive seal (202, 302, 402), and wherein the conductive seal (202, 302, 402), is electrically coupled to the at least one electrode (112, 114).

2. The gas sensor of claim 1, wherein the conductive seal comprises a conductive insert (302) formed from glassy carbon.

3. The gas sensor of claim 1, further comprising a polymeric insert (204) disposed about the conductive seal (202, 302, 402), wherein the polymeric insert (204) sealingly engages the opening (208) in the housing (102).

4. The gas sensor of claim 1, further comprising an electrolyte disposed within the interior space (110), wherein the electrolyte is in contact with at least a portion of the at least one electrode (111, 113), and wherein the connector pin (112, 114) is fluidly isolated from the electrolyte by the conductive seal (202, 302, 402).

5. The gas sensor of claim 1, wherein the conductive seal comprises a protective sleeve (402) disposed about an end of the at least one connector pin (112).

6. The gas sensor of claim 5, wherein the protective sleeve (402) comprises a platinum sleeve.

7. The gas sensor of claim 1, wherein the conductive seal (202, 302, 402) comprises a metal foil (202) sealingly engaged with the opening (208) in the housing, wherein the at least one connector pin (112) is electrically coupled to the metal foil (202), and wherein the metal foil (202) is electrically coupled to the at least one electrode (111).

8. The gas sensor of claim 7, wherein the metal foil (202) comprises a platinum foil.

9. The gas sensor of claim 7, wherein the metal foil (202) is spot welded to the at least one connector pin (112).

10. The gas sensor of claim 7, wherein the metal foil (202) is heat sealed over the opening (208) in the housing (102).

11. A method of operating a gas sensor, the method comprising:

passing a gas through an aperture in a gas sensor (100, 300. 400);

contacting the gas with an electrolyte disposed within the gas sensor (100, 300. 400);

forming an electrical potential difference between at least two electrodes (111, 113) in the gas sensor (100, 300. 400) based on the contacting, wherein at least one electrode of the at least two electrodes is in electrical contact with a conductive seal (202, 302, 402);

detecting the electrical potential difference through the conduct seal (202, 302, 402) and at least one connector pin (112);

determining a concentration of the gas based on the electrical potential difference; and

preventing contact between the at least one connector pin (112) and the electrolyte using the conductive seal (202, 302, 402).

12. The method of claim 11, wherein the conductive seal comprises a metal foil (202) sealing engaging an opening (208) in the gas sensor (100), wherein the at least one connector pin (112) is electrically coupled to the metal foil (202), and wherein the metal foil (202) is electrically coupled to the at least one electrode (111).

13. The method of claim 11, wherein the conductive seal comprises a conductive insert (302) disposed within an opening (208) in the gas sensor (300) , wherein the at least one connector pin (112) is electrically coupled to the conductive insert (302), and wherein the conductive insert (302) is electrically coupled to the at least one electrode (111).

14. The method of claim 13, wherein the conductive insert (302) comprises glassy carbon.

15. The method of claim 11, wherein the conductive seal comprises a protective sleeve (402) disposed over an end of the at least one connector pin (112), wherein the protective sleeve (402) sealingly engages an opening (208) in the gas sensor (400), and wherein the protective sleeve (402) is formed from platinum.

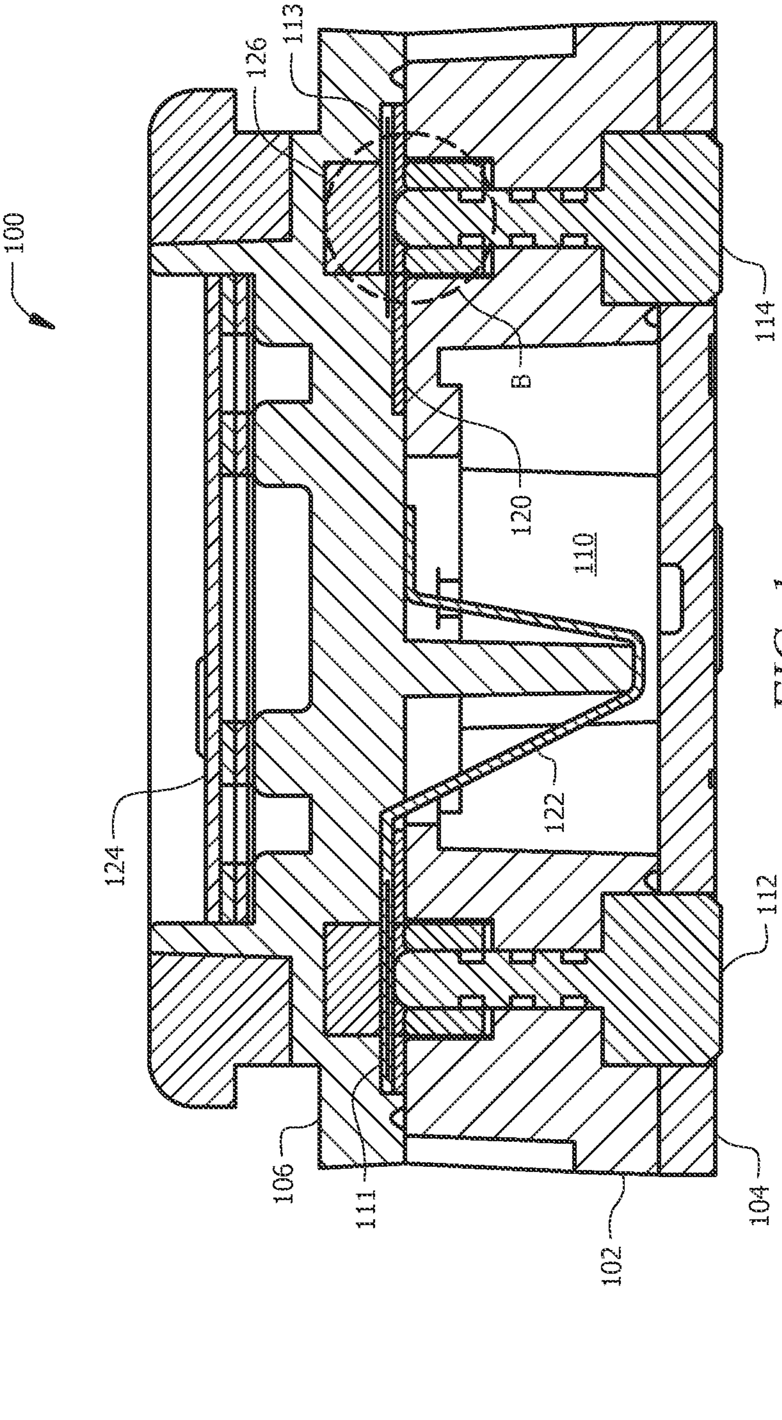

FIG. 1

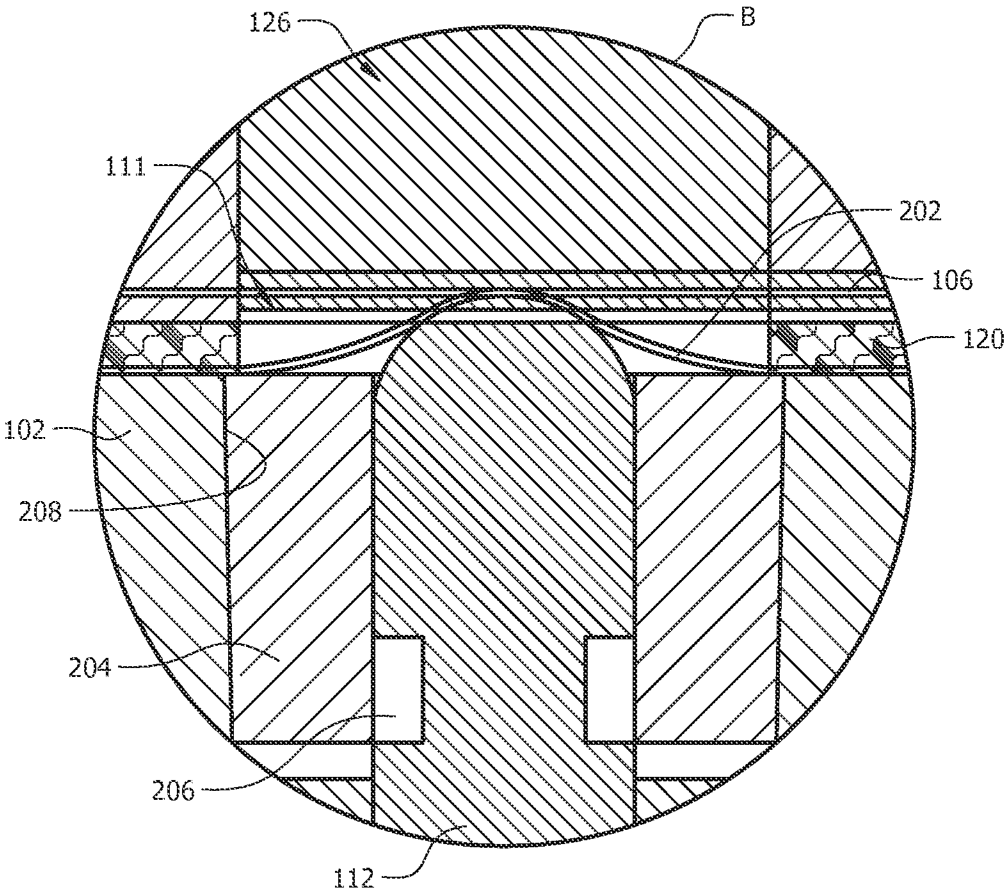

FIG. 2

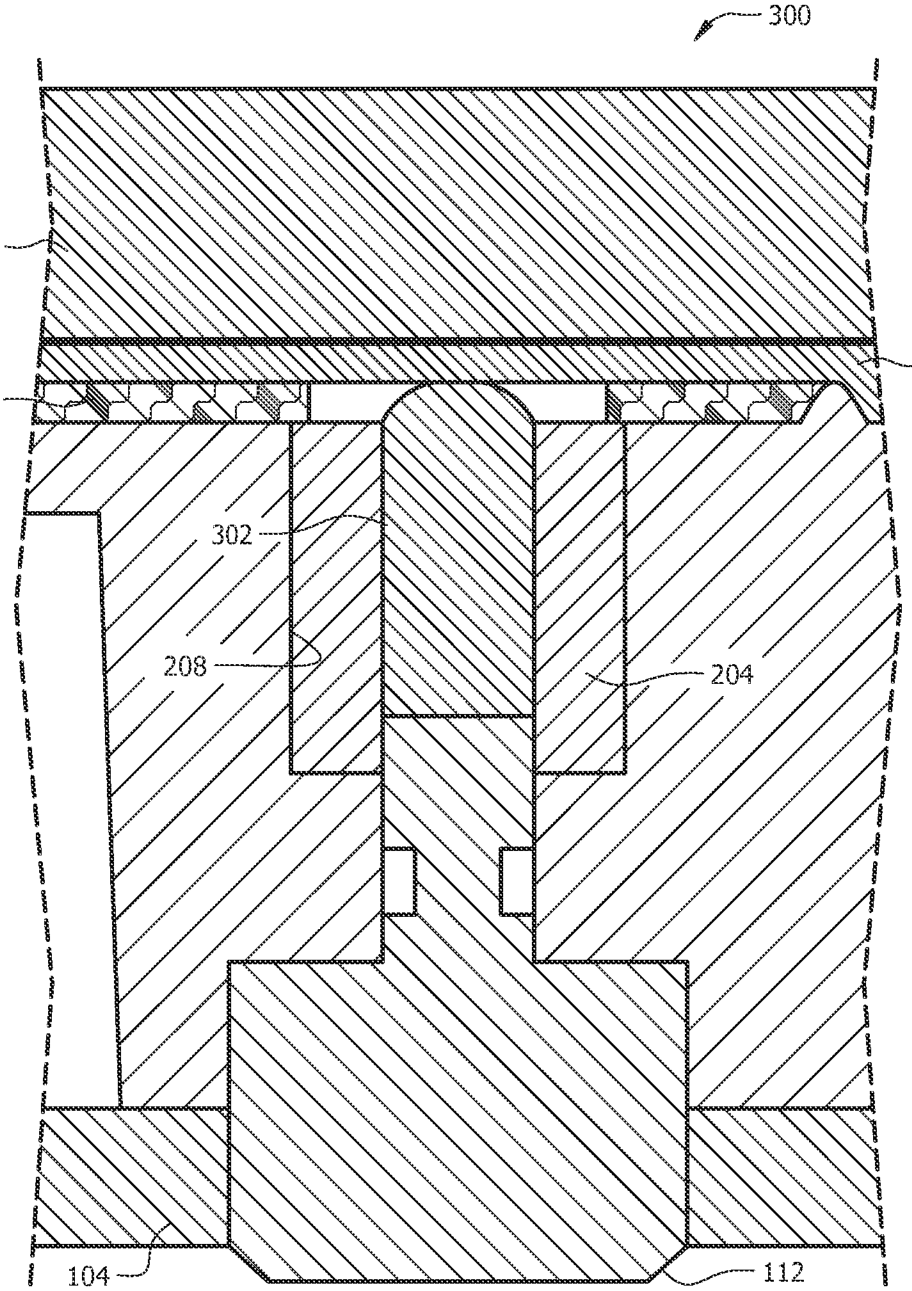

FIG. 3

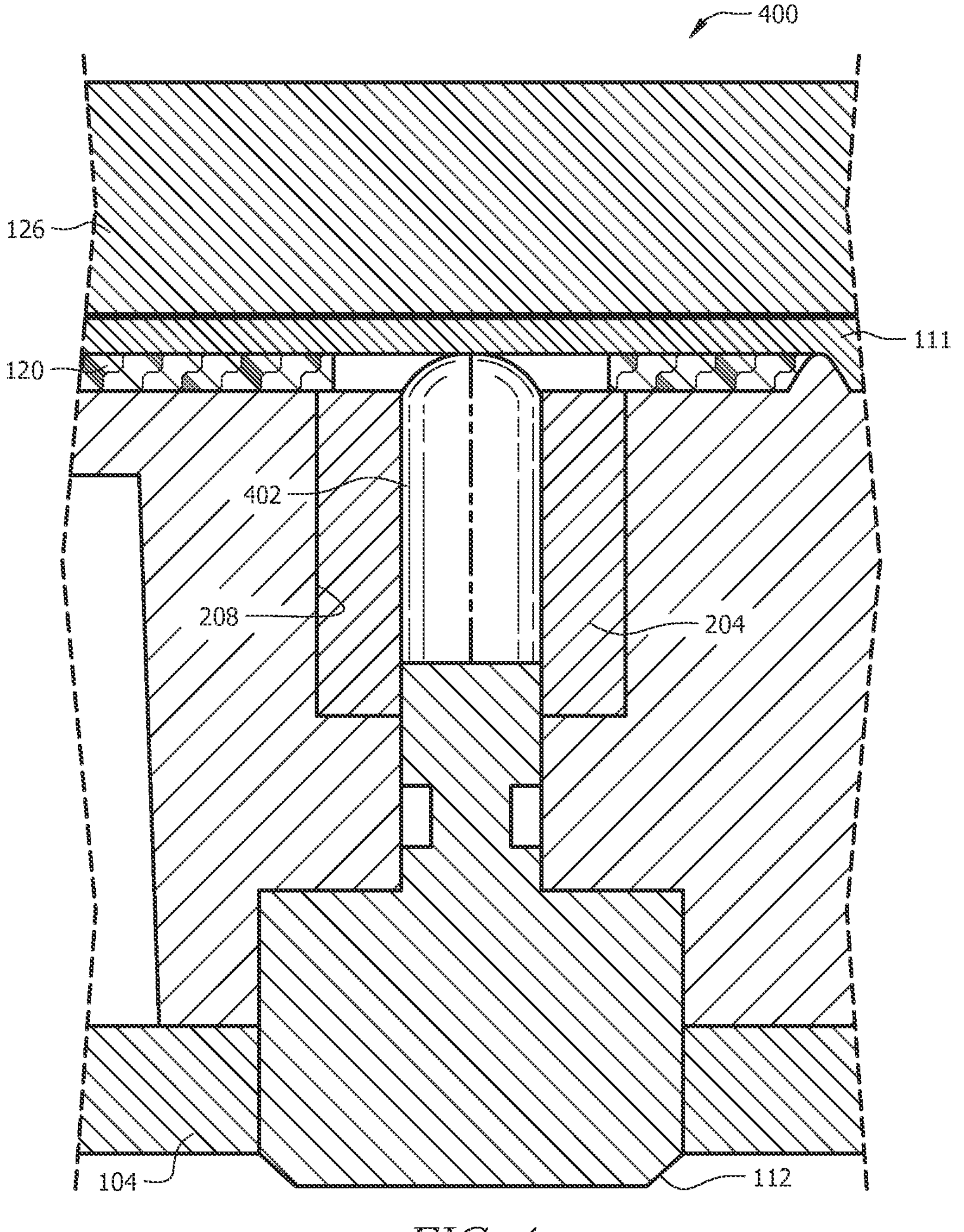

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/041449

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N27/404
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01N H01R H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 01/14868 A2 (CENTRAL RESEARCH LAB LTD [GB]; DODGSON JOHN ROBERT [GB]; AUSTIN MALCOL) 1 March 2001 (2001-03-01) page 1, lines 5-7; figures 1,2,3 page 7, lines 10-20 page 8, lines 10-14,19-25 page 9, lines 7-10 -----	1,3,4, 11,13 2,5,6, 14,15
X	EP 1 688 736 A1 (RIKEN KEIKI KK [JP]; MIZUTANI YOSHITAKA [JP]) 9 August 2006 (2006-08-09) paragraphs [0015], [0024], [0026], [0028], [0030]; figures 1,2 -----	1,4,7-12
Y	US 2009/288962 A1 (YANTASEE WASSANA [US] ET AL) 26 November 2009 (2009-11-26) paragraph [0027]; figure 3a ----- -/--	2,14

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 March 2016	24/03/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ehmer, Dorothee

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 01/14864 A2 (CENTRAL RESEARCH LAB LTD [GB]; DODGSON JOHN ROBERT [GB]; AUSTIN MALCOL) 1 March 2001 (2001-03-01) figure 1b	5,6,15
A	US 3 629 936 A (HARNONCOURT KARL) 28 December 1971 (1971-12-28) column 5, lines 64-69; figures 7,8,10,11 column 6, lines 25-28	7-10,12
A	US 2006/266647 A1 (KHALAFPOUR PEYMAN [CA] ET AL) 30 November 2006 (2006-11-30) paragraphs [0062], [0063]; figure 9	1,3,4
A	US 4 605 604 A (POLLACK WILLIAM [US] ET AL) 12 August 1986 (1986-08-12) the whole document	7-10

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/041449

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 0114868	A2	01-03-2001	AU	6713800	A	19-03-2001
			CA	2382557	A1	01-03-2001
			CN	1376266	A	23-10-2002
			EP	1272836	A2	08-01-2003
			JP	2003507738	A	25-02-2003
			US	7022213	B1	04-04-2006
			WO	0114868	A2	01-03-2001
EP 1688736	A1	09-08-2006	AU	2004286486	A1	12-05-2005
			CA	2538666	A1	12-05-2005
			CN	1875266	A	06-12-2006
			EP	1688736	A1	09-08-2006
			JP	4507235	B2	21-07-2010
			JP	2005134248	A	26-05-2005
			KR	20060090826	A	16-08-2006
			US	2007131550	A1	14-06-2007
			WO	2005043147	A1	12-05-2005
US 2009288962	A1	26-11-2009	NONE			
WO 0114864	A2	01-03-2001	AU	6714100	A	19-03-2001
			EP	1210593	A2	05-06-2002
			WO	0114864	A2	01-03-2001
US 3629936	A	28-12-1971	DE	1963525	A1	27-08-1970
			FR	2026870	A1	25-09-1970
			GB	1290394	A	27-09-1972
			US	3629936	A	28-12-1971
US 2006266647	A1	30-11-2006	NONE			
US 4605604	A	12-08-1986	NONE			