

FUEL CELL COVER

5

BACKGROUND

[0001] Electrochemical cells, such as fuel cells, may utilize oxygen from the environment as a reactant. While generating electricity, the electrochemical reaction that occurs in the cell also produces water that may be directed to other electrochemical cell uses, such as membrane hydration or to the humidification of various parts of the system. The increased functionality of fuel cells for powering electronic devices now introduces the fuel cells to various environmental conditions that may affect gas transport properties of the reactants and the water management system.

[0002] Fuel cells may require that the gas diffusion layer or the interface between at least part of the cathode and the environment be electrically conductive for proper cell functionality. Because the interface may be electrically conductive, the suitability of the interface for varying environmental conditions may be limited.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] In the drawings, which are not necessarily drawn to scale, like numerals may describe substantially similar components throughout the several views. Like numerals having different letter suffixes may represent different instances of substantially similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0004] FIG. 1 illustrates a perspective view of a fuel cell cover with features, according to the various embodiments.

[0005] FIG. 2 illustrates a perspective view of a fuel cell cover including a removable access plate, according to the various embodiments.

[0006] FIG. 3 illustrates a perspective view of an electronic device including a fuel cell cover, according to the various embodiments.

[0007] FIG. 4 illustrates a perspective view of an electronic device including a cover substantially flush with the device, according to the various embodiments.

[0008] FIG. 5 illustrates a perspective view of an electronic device with a fuel cell cover including a removable access plate, according to the various embodiments.

[0009] FIG. 6 illustrates an exploded view of an electronic device system, according to the various embodiments.

SUMMARY

[0010] The various embodiments relate to a fuel cell cover comprising an interface structure proximate to one or more fuel cells. The interface structure may affect one or more environmental conditions near or in contact with the one or more fuel cells.

[0011] The various embodiments relate to a fuel cell cover comprising an interface structure proximate to one or more fuel cells, wherein the cover may include one or more features to enhance the performance of the one or more fuel cells in a selected set of one or more environmental conditions.

[0012] The various embodiments also relate to a fuel cell cover comprising a cover in contact with one or more fuel cells. The cover may include one or more features that respond to a change in to one or more environmental conditions near or in contact with the one or more fuel cells in order to enhance the performance of the fuel cells.

[0013] The various embodiments may also relate to an electronic system comprising an electronic device, one or more fuel cells in contact with the electronic device and an adaptive interface structure. The cover may affect one or more environmental conditions near or in contact with the one or more fuel cells.

[0014] The various embodiments may relate to a method of making an electronic system comprising forming an electronic device, forming one or more fuel cells in contact with the electronic device, forming an interface structure, contacting the one or more fuel cells with the electronic device and contacting the cover with one or more of the fuel cells or electronic device.

[0014a] According to the first aspect of the invention, there is provided a fuel cell system comprising: at least one flexible fuel cell layer; and a fuel cell cover that includes an interface structure disposed proximate to the at least one flexible fuel cell layer, wherein the at least one flexible fuel cell layer includes two or more fuel cells substantially integrated within a two dimensional layer and a substrate coupled to the

two dimensional layer and forming an enclosed region between the substrate and the two dimensional layer; and, wherein the interface structure is configured to affect two or more environmental conditions proximate to the at least one fuel cell layer.

[0014b] According to the second aspect of the invention, there is provided a fuel cell cover, comprising: an interface layer coupled to a flexible fuel cell layer, wherein the interface layer includes an adaptive material that defines a plurality of apertures configured to allow oxygen to pass through the cover to contact the fuel cell, wherein the adaptive material is configured to alter a dimension of the apertures in response to a change in an environmental condition or to an applied signal.

[0014c] According to the third aspect of the invention, there is provided a method for optimizing the performance of a fuel cell system, comprising: providing a flexible fuel cell layer that includes two or more fuel cells substantially integrated within a two dimensional layer and a substrate coupled to the layer and forming an enclosure region between the substrate and the layer; and positioning an interface layer proximate to the fuel cell layer, wherein the interface layer is responsive to at least two environmental condition proximate to the fuel cell layer.

DETAILED DESCRIPTION

[0015] The following detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, various embodiments that may be practiced. These

embodiments, which are also referred to herein as “examples,” are described in enough detail to enable those skilled in the art to practice the embodiments. The embodiments may be combined, other embodiments may be utilized, or structural, and logical changes may be made without departing from the scope of the various embodiments.

5 The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the various embodiments is defined by the appended claims and their equivalents.

[0016] In this document, the terms “a” or “an” are used to include one or more than one and the term “or” is used to refer to a nonexclusive “or” unless otherwise indicated. In addition, it is understood that the phraseology or terminology employed
10 herein, and not otherwise defined, is for the purpose of description only and not of limitation.

[0017] The various embodiments relate to a fuel cell cover. Performance of fuel cell systems, including passive fuel cell systems, may be affected by environmental
15 conditions, such as humidity, ambient temperature, ambient pressure, or other environmental conditions. In order to get suitable performance out of an active area of a fuel cell, as well as substantially all of the fuel cells in a stack, or in a fuel cell layer, the reactants may be approximately evenly distributed across each active area and each cell uniformly. Fuel cells may utilize some form of gas diffusion layer (GDL) that is
20 configured to achieve this. Larger fuel cells may employ a “bipolar plate” or a “separator” plate that defines flow fields to aid in this purpose. Due to the design of most fuel cell systems, the GDL and the bipolar plate (if employed) may be electrically conductive in order to collect the electrons generated in the fuel cell reaction. Consequently, this may limit the materials that may be used to fabricate a GDL in such
25 a fuel cell. One suitable material is a form of carbon fiber paper, which is configured to be porous and electrically conductive.

[0018] In a fuel cell architecture where a generated current is collected on the edge of the cell, (instead of into a GDL and into an associated current-carrying

structure), adaptability and interchangeability in fuel cell covers may be obtained. For example, a thin layer fuel cell structure may include an ion exchange membrane with an electrochemical reaction layer disposed on each side. The ion exchange membrane may include a layer having a unitary construction, or may include a composite layer made up of more than one material. The ion exchange membrane may include, for example, a proton exchange membrane. Electrochemical cells according to the various embodiments may include a thin layer fuel cell structure where an electrical current-carrying structure at least in part underlies an electrochemical reaction layer (referred to herein as a "catalyst layer"). The various embodiments may permit construction of an electrochemical cell layer having a plurality of individual unit cells formed on a sheet of an ion exchange membrane material. Adjacent unit fuel cells may be connected in parallel by either providing current-carrying structures that are common to the adjacent unit cells, or by electrically interconnecting current-carrying structures of adjacent cells. Adjacent unit cells may also be electrically isolated from one another, in which case they may be connected in series. Electrical isolation of unit cell structures may be provided by rendering portions of a catalyst layer non-conducting electrically, by making a catalyst layer discontinuous in its portions between unit cells and/or by providing electrically insulating barriers between the unit cell structures. In this case it is possible to electrically interconnect the unit cells in arrangements other than parallel arrangements. Vias may be used to interconnect adjacent unit cells in series. In the various embodiments, unit cells may be connected in series, and adjacent catalyst layers of the series connected cells may be electrically isolated from one another.

[0019] Because the current carrying structures in such fuel cells are located at the edges of the fuel cells, planar fuel cell layers may utilize gas diffusion layers (GDL) that may not be electrically conductive. This feature may allow the use of interchangeable or adaptive covers, in accordance with the various embodiments, that may include materials and configurations not otherwise feasible for use in connection with as GDLs. Further, the various embodiments may also be utilized in conventional fuel cells with GDLs, as a feature to enhance the fuel cell performance in varying environmental conditions.

[0020] The covers according to the various embodiments may function to enable an oxidant, such as air, to contact the cathodes of the fuel cell. The material, structure, and other physical properties of the cover may affect the performance of the

fuel cells. Performance of fuel cells may be affected by both environmental conditions proximal to the fuel cell, such as temperature, humidity and reactant distribution across the fuel cell, which may be affected by selection of a cover or gas diffusion layer.

[0021] The cover, according to the various embodiments, may include an interface structure that may be interchangeable or adaptable or both interchangeable and adaptable so that, in general terms, the cover is responsive to varying environmental conditions that may affect a fuel cell or fuel cell-powered electronic device. Interchangeable covers, which may be removably coupled to one or more fuel cells, may be configured to enhance the performance of the one or more fuel cells based on a set of selected environmental conditions. Adaptable covers may include one or more adaptive materials that are responsive to environmental conditions, such that the performance of the one or more fuel cells is therefore enhanced. The cover may be utilized with one or more fuel cells that may not require the cathode-environmental interface to be electrically conductive. Such fuel cells may utilize an integrated cathode, catalyst layer and current carriers, such that the interface or cover between the cathode and environment may not be electrically conductive in addition to maintaining the proper gas transport properties. The cover may therefore be used with passive, "air breathing" fuel cells, which do not actively control distribution of one or both reactants to the fuel cell layer.

[0022] In the various embodiments, where the gas diffusion layer may not be electrically conductive, the choice of material and structure is flexible to assist in altering the environment adjacent to the fuel cell or fuel cell-powered device. In addition, the cover may be utilized with an electrically conductive layer or be conductive itself, in order to function with conventional fuel cell systems. The cover may be configured to be customizable or adaptable based on structure, material or both. For example, the interchangeable or adaptable cover may affect temperature, humidity, pollutant or contaminant level in contact with the fuel cell. In the present disclosure, affecting an environmental condition proximate to a fuel cell may refer to increasing, decreasing, enhancing, regulating, controlling, or removing an environmental condition proximate to the cell.

[0023] In the various embodiments, the fuel cell cover may comprise a porous interface structure disposed on, or proximate to the reactive surface of the fuel cell layer, or it may be integrated into a conventional gas diffusion layer (GDL) of a fuel

cell. The porous layer may be configured to employ an adaptable material. The porous layer may be configured to employ a thermo-responsive polymer. The polymer may include a plurality of pores. Adaptive materials included in the cover may be responsive to conditions external to the cover, conditions on or proximate to the fuel cells. Adaptive materials and structures may also include active control mechanisms, other stimuli, or any combination thereof. Some examples of conditions may include temperature, humidity, an electrical flow, or other conditions.

DEFINITIONS

[0024] As used herein, “electrochemical array” may refer to an orderly grouping of electrochemical cells. The array may be planar or cylindrical, for example. The electrochemical cells may include fuel cells, such as edge-collected fuel cells. The electrochemical cells may include batteries. The electrochemical cells may be galvanic cells, electrolyzers, electrolytic cells or combinations thereof. Examples of fuel cells include proton exchange membrane fuel cells, direct methanol fuel cells, alkaline fuel cells, phosphoric acid fuel cells, molten carbonate fuel cells, solid oxide fuel cells, or combinations thereof. The electrochemical cells may include metal-air cells, such as zinc air fuel cells, zinc air batteries, or a combination thereof.

[0025] As used herein, the term “flexible electrochemical layer” (or variants thereof) may include an electrochemical layer that is flexible in whole or in part, that may include, for example, an electrochemical layer having one or more rigid components integrated with one or more flexible components. A “flexible fuel cell layer” may refer to a layer comprising a plurality of fuel cells integrated into the layer.

[0026] The term “flexible two-dimensional (2-D) fuel cell array” may refer to a flexible sheet which is dimensionally thin in one direction, and which supports a number of fuel cells. The fuel cells may have active areas of one type (*e.g.*, cathodes) that may be accessible from a first face of the sheet and active areas of another type (*e.g.*, anodes) that are accessible from an opposing second face of the sheet. The active areas may be configured to lie within areas on respective faces of the sheet. For example, it is not necessary that the entire sheet be covered with active areas; however, the performance of a fuel cell may be increased by increasing its active area.

[0027] As used herein, “interface structure” or “interface layer” may refer to a fluidic interface configured to affect a local environment proximate to a fuel cell component, such as, for example, a fuel cell anode and/or a fuel cell cathode.

[0028] As used herein, “cover” may refer to an apparatus that encloses, or contacts, or is proximate to one or more fuel cells that include an interface structure that is configured to affect an environmental condition proximate to the one or more fuel cells.

5 [0029] As used herein, “feature” may refer to an aspect of a fuel cell cover, which may be structured into the cover or may be an inherent property of a material used in the cover. Examples of features may include ports, holes, slots, mesh, porous materials, filters and labyrinth passages.

[0030] As used herein, “external environment” or “external conditions” or
10 “environmental conditions” or “ambient environment” may refer to the atmospheric conditions in proximity to a cover or an interface structure, whether that environment resides inside or outside a device or housing. Accordingly, external conditions may include one or more of a temperature, a pressure, a humidity level, a pollutant level, a contaminant level, or other external conditions. “External environment” or “external
15 conditions”, or “environmental conditions” or “ambient environment” may also refer to more than one of a temperature, a pressure, a humidity level, a pollutant level, a contaminant level, or other external conditions in combination.

[0031] Referring to FIG. 1, a perspective view of a fuel cell cover 100 according to the various embodiments. The fuel cell cover 100 may include an
20 interface structure 102, which may be structured into an enclosure 104, inherent in a material used to form the enclosure 104, or otherwise proximate to a fuel cell or a fuel cell layer. The fuel cell cover 100 may be partially or fully integrated with a surface of a fuel cell or a fuel cell layer. Suitable fuel cell structures may include, for example, a plenum enclosed by flexible walls, where at least one of the flexible walls includes a
25 first flexible sheet supporting one or more fuel cells. The fuel cells may be configured with anodes that are accessible from a first side of the first flexible sheet and cathodes accessible from a second side of the first flexible sheet. An inlet for connecting the plenum to a source of a reactant may be provided. An external support structure disposed to limit outward expansion of the plenum may also be provided. A flexible
30 fuel cell layer may include two or more fuel cells, substantially integrated within a two-dimensional layer and a substrate coupled to the layer and forming an enclosed region between the substrate and layer. The layer may be positioned in a planar or non-planar configuration so that the layer may be configured such that it is operable when self-

supported. The flexible fuel cell layer may further comprise one or more internal supports in contact with the flexible layer.

[0032] An electrically powered device according to the various embodiments may include a housing defining an envelope having a surface, and at least one electrically-powered component located in an interior of the housing. A thin layer fuel cell array may be disposed on and supported by the housing, with the fuel cell coextensive with and substantially conforming to an area of the surface. The fuel cell array may include a plurality of unit fuel cells each having a cathode and an anode and connected to supply electrical power to the electrically-powered component. The cathodes of the unit fuel cells may be positioned on an outer surface of the fuel cell array that faces outwardly and may be in direct contact with ambient air on an outside of the housing. The anodes of the unit fuel cells may be positioned on an inner side of the fuel cell array toward the interior of the housing. In the various embodiments, the fuel cell cover may be positioned proximate to the outer surface of the fuel cell array, so that direct contact with the ambient air may be accomplished through the fuel cell cover 100.

[0033] For example, the cover 100 may include an interface layer that is positioned proximate to a fuel cell device. The interface structure 102 may extend across substantially an entire external surface of the enclosure 104, or it may extend across only a portion of the external surface of the enclosure 104. The interface structure 102 may be configured to enhance the performance of the one or more fuel cells (not shown) positioned within the enclosure 104 in a selected set of one or more environmental conditions. Accordingly, the interface structure 102 may include features such as ports, holes, slots, a mesh, a porous material, a filter network or any combination thereof. The interface structure 102 may also include an adaptive material, which will be described in greater detail below.

[0034] The interface structure 102 may be operable to exclude selected materials, such as atmospheric pollutants or excess water (e.g., humidity) in an external environment. The interface structure 102 may also be operable to admit selected materials, such as water, when the cover 100 is exposed to a dry external environment. The size, porosity and orientation of features in the interface structure 102 may be varied to affect the flow or to control a flow of a material to the fuel cell, depending on the desired conditions.

[0035] The interface structure 102 may be operable to affect one or more selected local environmental conditions. For example, the interface structure 102 may be incorporated into the enclosure 104 so that it is removable and may be changed to provide another interface structure 102 having different physical characteristics, which may depend on the environmental conditions present at the time of fuel cell operation. For example, one interface structure 102 may be configured for use in an environment which is hot and dry, such as a desert, while another interface structure 102 may be configured for use in an environment which is hot and wet, such as a rainforest. Still another interface structure 102 may be configured for use in an environment which is cool and wet; while another interface structure 102 may be configured for use in an environment which is cold and dry. The above examples illustrate possible variations for an interchangeable interface structure 102, depending on the ambient environment. Both the materials and the features that may be associated with the interface structure 102 may be selected and/or adapted to enable a fuel cell layer to operate over a wide range of environmental conditions. Although FIG. 1 shows the interface structure 102 disposed on a portion of the enclosure 104, it is understood that in the various embodiments, that the interface structure 102 and the enclosure 104 may be coincident structures, so that the entire enclosure 104 may constitute the interface structure 102, so that the foregoing interchangeability may extend to the entire fuel cell cover 100. It is also understood that in the various embodiments, the interface structure 102 may directly contact (or may be integrated into) the one or more fuel cells enclosed within the enclosure 104, or the interface structure 102 may be spaced apart from the one or more fuel cells enclosed within the enclosure 104. The one or more features in the interface structure 102 may respond to a change in to one or more environmental conditions near or in contact with the one or more fuel cells in order to enhance the performance of the fuel cells. The features may be incorporated into, or may be inherent to one or more adaptive materials.

[0036] The enclosure 104 may comprise materials such as paper, various polymers such as NYLON (manufactured by E. I. du Pont de Nemours and Company, Wilmington, DE), and manufactured fibers in which the fiber forming substance is a long-chain synthetic polyamide in which less than 85% of the amide-linkages are attached directly (-CO-NH-) to two aliphatic groups), polytetrafluoroethylene (PTFE), polyvinylidene difluoride (PVDF), polyvinyl alcohol or polyethylene, for example.

The enclosure 104 may comprise features that may be embodied in some combination of the above listed materials, one or more adaptive materials, or may be formed in the interface structure 102, for example.

[0037] The interface structure 102 may be comprised of adaptive materials that may physically or chemically respond to a change in one or more environmental conditions, which may include a temperature, a pressure (such as atmospheric pressure, the partial pressure of oxygen in air), a humidity, a pH level, various chemical compounds and/or light. Accordingly, the interface structure 102 may enhance the performance of the one or more fuel cells that may be positioned in the enclosure 104.

Examples of suitable adaptive materials may include waxes, fibers or coatings.

Thermo-responsive polymers may also be used as an adaptive material. A thermo-responsive polymer generally exhibits positive swelling behavior with an increase in temperature. One such material is described in "Synthesis and Swelling Characteristics of pH and Thermo-responsive Interpenetrating Polymer Network Hydrogel Composed of Poly(vinyl alcohol) and Poly(acrylic acid), authored by Young Moo Lee, et al.

(Journal of Applied Polymer Science 1996, Vol. 62, 301 311). In addition to thermo-responsive materials exhibiting positive swelling, thermo-responsive polymers with negative swelling may also be used. When using materials with negative swelling behavior, a boundary condition of the material layer should be such as to allow the pores to shrink with an increase in temperature. A combination of materials exhibiting positive and negative swelling may also be used to realize the desired variable porosity behavior of the GDL. Additional materials that exhibit variable porosity behavior are described in "Separation of Organic Substances with Thermo responsive Polymer Hydrogel" by Hisao Ichijo, et al. (Polymer Gels and Networks 2, 1994, 315 322

Elsevier Science Limited), and "Novel Thin Film with Cylindrical Nanopores That Open and Close Depending on Temperature: First Successful Synthesis", authored by Masaru Yoshida, et.al. (Macromolecules 1996, 29, 8987 8989).

[0038] Thermo-responsive polymers may also be defined as polymers with either an upper critical solution temperature (UCST), or a lower critical solution temperature (LCST). For example, below the LCST, some thermo-responsive polymers are fully hydrated, whereas above the LCST, the polymer becomes dehydrated, aggregates, and precipitates. The opposite behavior is observed for UCST thermo-responsive polymers. That is, above the UCST, the thermo-responsive polymer is fully

hydrated, whereas below the UCST, the polymer becomes dehydrated, aggregates, and precipitates. UCST (positive) thermo-responsive polymers will become hydrophilic upon increasing temperatures, where LCST (negative) thermo-responsive polymers will become hydrophobic upon increasing temperatures.

5 [0039] Polymers that exhibit changes in hydrophobicity in response to increases in temperature are known, for example, in biological systems. For example, LCST polymers have been used to make a timing layer for use in instant photography that allows uniform processing over a wide temperature range (Preparation Of Polymers, The Films Of Which Exhibit A Tunable Temperature Dependence To Permeation By Aqueous Solutions, Lloyd D. Talor, Polymer Preprints, Division of Polymer Chemistry, American Chemical Society, v 39, n 2, Aug. 1998 ACS pp. 754-755). Urry & Hayes reported polymers that exhibited inverse transitions of hydrophobic folding and assembly in response to increases in temperature, and their use in smart functions in biological systems, in Designing For Advanced Materials By The Delta Tt-Mechanism, 10 Proceedings of SPIE, The International Society for Optical Engineering v, 2716 Feb. 26-27, 1996, Bellingham, Wash. The design of advanced materials is demonstrated in terms of the capacity to control a specified temperature, at which the inverse temperature transitions occur by controlling polymer hydrophobicity and by utilizing an associated hydrophobic-induced shift. A 'smart material' is defined to be one in which 15 the material is responsive to the particular variable of interest, and under the required conditions of temperature, pH, pressure, etc. By the proper design of the polymer, two distinguishable smart functions can be coupled such that an energy input that alters one function causes a change in the second function as an output. To become coupled the two distinguishable functions need to be part of the same hydrophobic folding domain. 20 By way of example, a protein-based polymer was designed to carry out the conversion of electro-chemical energy to chemical energy, i.e., electrochemical transduction, under specified conditions of temperature and pH, using the delta T.sub.t mechanism of free energy transduction.

[0040] Research has been conducted in positive temperature-sensitive systems for, but not limited to, interpenetrating polymer networks (IPN) composed of poly(acrylic acid) (PAAc) and poly(N,N dimethylacrylamide) (PDMAAm), and PAAc and poly(acryamide-co-butyl acrylate) (poly(Aam-coBMA)) that showed attractive intermolecular polymer-polymer interaction, specifically, 30

the complex formation by hydrogen bonding. The complex formation and dissociation in the IPNs causes reversible shrinking and swelling changes.

[0041] Poly(vinyl alcohol) (PVA) and PAAc IPNs show the temperature-sensitive hydrogel behavior, and have been reported previously (Yamaguchi et al., Polym. Gels Networks, 1, 247 (1993); Tsunemoto et al., Polymer. Gels Networks, 2, 247 (1994); Ping et al., Polym. Adv. Tech., 5, 320 (1993); Rhim et al., J. Appl. Polym. Sci., 50, 679 (1993)). Recent research has shown that PVA that is heated to dissolve, then frozen and thawed, forms a matrix of physically cross linked polymeric chain to produce a highly elastic gel (Stauffer et al., Polymer, 33, 3932 (1992)). This PVA gel is stable at room temperature and can be extended to six (6) times its original shape. Properties of PVA gels depend on molecular weight, concentration of aqueous solution, temperature, time of freezing, and number of freeze-thaw cycles. The PVA gel is of particular interest in the biomedical and pharmaceutical field because of the innocuous and non-carcinogenic biocompatibility. Polyether amide elastomers such as PEBAX and polyurethane elastomers, may also be used.

[0042] Other suitable adaptive materials may include various shape memory polymers (SMP). Shape memory polymers may be stimulated by a temperature, a pH level, various chemical compounds, and/or light. In general, shape memory polymers are polymer materials configured to sense and respond to external stimuli in a predetermined manner. Additional examples of suitable shape memory polymers are any of the polyurethane-based thermoplastic polymers (SMPUs). Such materials demonstrate a shape memory effect that is temperature-stimulated based on the glass transition temperature of the polymer (which may be between approximately -30C and +65C). Fibers made from SMPs may be used to make shape memory fabrics and textiles, such as an aqueous SMPU. Another example of a suitable SMP may include a polyethylene/NYLON-66 graft copolymer.

[0043] SMPs may be suitably configured so that physical properties, such as water vapor permeability, air permeability, volume expansivity, elastic modulus, and refractive index may vary above and below the glass transition temperature. SMPs used to control water vapor permeability may include elastomeric, segmented block copolymers, such as polyether amide elastomer or polyurethane elastomer.

[0044] Shape memory alloys (SMA) are a further example of materials which may be utilized in an interface structure 102, in accordance with the various

embodiments. One or more SMA may be used, for example, to configure a pore size of the in the interface structure 102 in response to an environmental condition, such as temperature, humidity or other physical stimuli. Multiple SMAs with multiple transition temperatures may be used to provide environmental adaptability over a range of temperatures. For example, at least two SMAs with differing transition temperatures may cooperatively form actuators that provide environmental adaptability.

Accordingly, as the temperature rises, the interface structure 102, including the SMA actuators is heated. When a transition temperature of the first SMA actuator is reached, the SMA actuator contracts to reduce air access to the cathodes. As the temperature increases still further, the transition temperature of the second SMA actuator may be reached, resulting in the second SMA actuator contracting and further reducing the air access to the cathodes. Alternatively, the SMA actuators may be configured to be controlled by a current applied across the SMA actuator, which may be applied, for example, in response to an applied signal.

[0045] In accordance with the various embodiments, a property of an adaptable material may be varied in response to an environmental condition in proximity to the electrochemical cells of the array. The property of the adaptable material may include its porosity, hydrophobicity, hydrophilicity, thermal conductivity, electrical conductivity, resistivity, overall material shape or structure, for example. The environmental conditions may include one or more of a temperature, humidity, or environmental contaminants level.

[0046] In accordance with the various embodiments, a property may also be varied in response to an applied signal, for example. The adaptive material may be heated in response to the signal. For example, by heating the adaptive material, one or more of the adaptive material properties may be varied. The performance of the electrochemical cell array may also be determined periodically or continuously monitored.

[0047] Other examples of adaptive materials may include woven materials having fibers or ribbons which may increase in length as humidity increases, therefore increasing the porosity of the weave and increasing air access to the cathodes of the fuel cells. Conversely, the fibres shorten when humidity decreases, thereby decreasing the porosity of the weave and decreasing air access to the cathodes, enabling the membrane to self-humidify.

[0048] In the various embodiments, the interface structure 102 may be adaptable using a mechanical means, such as a louvre or a port having a variable aperture. Such mechanical adaptations may be accomplished automatically in response to an applied signal, such as from a sensor, or by a manual input.

5 [0049] The fuel cell cover 100 may also optionally include an attachment mechanism 106 that is suitably configured to physically and/or electrically couple to an external electronic device. The attachment mechanism 106 may be a clip, a lock, a snap or other suitable attachment devices.

[0050] Referring to FIG. 2, a perspective view of a fuel cell cover 200 is shown, according to the various embodiments. The fuel cell cover 200 may include a first interface structure 202 that is formed on at least a portion of an external surface of an enclosure 204. The fuel cell cover 200 may also include a removable access plate 206 that permits access to an interior portion of the enclosure 204. The access plate 206 may include a second interface structure 208 having different properties (e.g., a different porosity, material or response characteristic to an environmental condition) than the first interface structure 202. Accordingly, in the various embodiments, the removable access plate 206 may be interchanged with other access plates 206 having different characteristics, so that the environmental conditions proximate to the fuel cells within the enclosure 204 may be “fine-tuned”. The access plate 206 may thus allow customization of the cover 200, since interchangeable materials, meshes, porous materials, screens, vents or filters may be utilized. Optional attachment mechanisms 210 and 212 may be included that may be configured to couple the access plate 206 to the enclosure 204, and to couple the enclosure 204 to an electronic device, respectively.

15 [0051] The cover 200, or portions thereof, may be manufactured of an adaptive material, and the removable access plate 206 may be configured to take into account a set of selected environmental conditions, and may include features to enable optimized performance under such conditions. Such an arrangement allows the cover 200 to have adaptive and interchangeable capabilities. In addition, it is understood that the foregoing optimization may be accomplished where the cover 200 and/or the interface structure are interchangeable.

25 [0052] Alternatively, the cover 200, its features, materials, or components may be adaptable or may be optimized for a given set of environmental conditions. Depending on the environmental conditions, it may be configured to allow more or less

oxidant to access the cathodes of the fuel cell layer. For example, under hot and/or dry conditions, an ion exchange membrane of a fuel cell may be subject to drying out.

Under such environmental conditions, the cover 200 (and/or the first interface structure 202 and the second interface structure 208) may be configured to reduce air flow to the cathodes, to increase the ability of the ion exchange membrane to self-humidify. In contrast, under environmental conditions that include high levels of humidity, the ion exchange membrane may be prone to flooding, and therefore the cover 200 may be configured to increase air flow to the cathodes, for example by increasing the pore size of an adaptive material comprising the first interface structure 202 and the second interface structure 208, or utilizing a more porous first interface structure 202 and/or second interface structure 208. In the various embodiments, it is understood that the second interface structure 208 may be optional.

[0053] The fuel cell cover 200 (and/or the first interface structure 202 and the second interface structure 208) may affect both in-plane and through-plane conductivity and mobility of both reactants and products of the electrochemical reaction. For example, in the various embodiments, in-plane distribution of product water may be promoted across a fuel cell layer to provide even humidification of the ion-exchange membrane across the fuel cells, in addition to enabling balanced evaporation from a fuel cell system.

[0054] Further, in the various embodiments, the various attributes of the fuel cell cover 200 discussed above may be configured to be distributed in a non-uniform and/or asymmetric fashion across fuel cell layers. For example, and in accordance with the various embodiments, features (*e.g.*, holes, perforations, or other openings) closer to the edge of the active area of a fuel cell may have a relatively higher or lower porosity compared to features closer to the center of the active area of a fuel cell. Properties of the features may be varied to increase or decrease air access to the cell depending on the position relatively to the cell geometry.

[0055] In the various embodiments, aspects of the cover 200 may be exchangeable or disposable. For example, the cover 200 may comprise a filter element, which may be disposable. A filter may be used in environments where there may be excess levels of pollutants or contamination to prevent such pollutants from reaching the cathodes of the fuel cell layer. The filter may be configured to be field-replaceable at the discretion of the user of the portable electronic device, or as necessary. In the

various embodiments, the filter may be incorporated into or accessible via the removable access plate 206.

[0056] Referring to FIG. 3, a perspective view of an electronic system 300 according to the various embodiments. The electronic system 300 may include a fuel cell cover 302, which may include, for example, any of the embodiments disclosed in connection with FIG.1 and FIG.2. An electronic device 304 may be in contact with a fuel cell cover 302. The electronic device 304 may be configured to be removably engaged to the fuel cell cover 302. The fuel cell cover 302 may include one or more interface structures 306, as previously described. An optional attachment mechanism 308 may be configured to couple the fuel cell cover 302 to the electronic device 304.

[0057] The electronic device 304 may include a cellular phone, a satellite phone, a PDA, a laptop computer, an ultra mobile personal computer, a computer accessory, a display, a personal audio or video player, a medical device, a television, a transmitter, a receiver, a lighting device, a flashlight, a battery charger, a portable power source, or an electronic toy, for example. The cover 302 may contain all or part of a fuel cell or a fuel cell system, including a fuel enclosure, for example. The cover 302 alternatively may contain no components of the fuel cell system, as will be described in greater detail below.

[0058] Referring now to FIG. 4, a perspective view of an electronic system 400 according to the various embodiments. The electronic system 400 may include an electronic device 402 that may further include fuel cell cover 404 that may optionally be substantially flush with a surface of the electronic device 402. The cover 404 may include one or more interface structures 406, as previously described, and an optional attachment mechanism 308 to couple the cover 404 to the electronic device 402. The cover 404 may be flush or substantially flush with the electronic device 402, so that little to no exterior profile of the cover 404 protrudes from a face of the electronic device 402.

[0059] Referring to FIG. 5, a perspective view of an electronic system 500 is shown, according to the various embodiments. The electronic system 500 may include an electronic device 502 that may be operably coupled to a fuel cell cover 504. The cover 504 may include a removable access plate 506 that may further include one or more interface structures 508 and an optional attachment mechanism 512. The cover 504 may also include one or more interface structures 510. The cover 504 may be interchangeable, and the access plate 506 may also be interchangeable, therefore

increasing the ability to adjust the environmental conditions near or in contact with a fuel cell enclosed within the cover 504.

[0060] Referring to FIG. 6, an exploded view of an electronic system 600 is shown, according to the various embodiments. The system 600 may include an electronic device 602 that may further include a recess 604 configured to receive one or more fuel cell layers 606, and, optionally, one or more fuel cartridges, fluidics, power conditioning, or combinations thereof, which may be operably coupled to the fuel cell layers. The fuel cell layers 606 may therefore be operably coupled to the electronic device 602. A fuel cell cover 608 may be positioned on the electronic device 602 or may be positioned on the fuel cell layers 606. The fuel cell cover 608 may include one or more interface structures 610, as previously described. Attachments 612 may also optionally couple the cover 608 to the electronic device 602. In such cases, the combination of the fuel cell layers, fuel cell cover, and optionally other aspects (e.g. fuel cartridge, fluid manifold, valves, pressure regulators, etc) may form a fuel cell system, which may then be coupled as a fuel cell system to the electronic device.

[0061] The Abstract is provided to comply with 37 C.F.R. §1.72(b) to allow the reader to quickly ascertain the nature and gist of the technical disclosure. The Abstract is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

CLAIMS

What is claimed is:

1. A fuel cell system comprising:
at least one flexible fuel cell layer; and
a fuel cell cover that includes an interface structure disposed proximate to the at least one flexible fuel cell layer,
wherein the at least one flexible fuel cell layer includes
two or more fuel cells substantially integrated within a two dimensional layer and
a substrate coupled to the two dimensional layer and forming an enclosed region between the substrate and the two dimensional layer; and,
wherein the interface structure is configured to affect two or more environmental conditions proximate to the at least one fuel cell layer.
2. The fuel cell system of claim 1, wherein the at least one flexible fuel cell layer further comprises one or more internal supports in contact with the flexible layer.
3. The fuel cell system of claim 1 or 2, wherein the interface structure comprises an adaptive material configured to affect two or more environmental conditions proximate to the one or more fuel cells.
4. The fuel cell system of any of claims 1-3, wherein the interface structure includes a removable porous structure configured to affect two or more environmental conditions proximate to the one or more fuel cells.
5. The fuel cell system of any of claims 1-4, wherein the interface structure includes a filter element configured to exclude an atmospheric contaminant.

6. The fuel cell system of any of claims 1-5, wherein the interface structure comprises at least one of a mechanically actuated vent and a porous material having mechanically actuated apertures.
7. The fuel cell system of any of claims 1-6, wherein the interface structure comprises a shape memory adaptive material.
8. The fuel cell system of any of claims 1-7, wherein the adaptive material is responsive to a change in one or more environmental conditions proximate to the one or more fuel cells.
9. The fuel cell system of claim 7, wherein the shape memory adaptive material comprises at least one of a shape memory alloy and a shape memory polymer.
10. The fuel cell system of any of claims 1-9, wherein the interface structure is configured to affect a humidity level, a temperature, a pollutant level and a contaminant level proximate to the one or more fuel cells.
11. The fuel cell system of any of claims 1-10, further comprising an access plate positioned on the fuel cell cover that includes an additional interface structure.
12. The fuel cell system of claim 11, wherein the additional interface structure on the access plate comprises one of an adaptive material and a removable porous structure.
13. The fuel cell system of claim 11 or 12, wherein the access plate is removably engageable with the fuel cell cover.
14. The fuel cell system of any of claims 1-13, wherein the interface structure is electrically conductive.

15. The fuel cell system of any of claims 1-14, wherein the interface structure is electrically non-conductive.
16. The fuel cell system of claim 15, further comprising an electrically conductive gas diffusion layer in contact with an electrically non-conductive interface structure and the one or more fuel cells.
17. The fuel cell system of any of claims 1-16, wherein the interface structure is removably coupled to the fuel cell layer.
18. A fuel cell cover, comprising:
an interface layer coupled to a flexible fuel cell layer, wherein the interface layer includes an adaptive material that defines a plurality of apertures configured to allow oxygen to pass through the cover to contact the fuel cell, wherein the adaptive material is configured to alter a dimension of the apertures in response to a change in an environmental condition or to an applied signal.
19. The fuel cell cover of claim 18, wherein the plurality of apertures are arranged in a non-uniform active area, the active area having a pore density at the center that is different than the pore density near an outer perimeter.
20. An electronic system comprising:
the fuel cell system of any of claims 1-17, operably coupled to
an electronic device.
21. The electronic system of claim 20, wherein the electronic device comprises one of a cellular phone, a satellite phone, a personal digital assistant, a laptop computer, an ultra mobile personal computer, a computer accessory, a display, a personal audio or video player, a medical device, a television, a transmitter, a receiver, a lighting device, a flashlight, a battery charger, a portable power source and an electronic toy.

22. A method for optimizing the performance of a fuel cell system, comprising:
providing a flexible fuel cell layer that includes
two or more fuel cells substantially integrated within a two
dimensional layer and
a substrate coupled to the layer and forming an enclosure region
between the substrate and the layer; and
positioning an interface layer proximate to the fuel cell layer, wherein the
interface layer is responsive to at least two environmental condition proximate to
the fuel cell layer.
23. The method of claim 22, wherein positioning the interface layer comprises
contacting the fuel cell layer and the interface layer.
24. The method of claim 22 or 23, wherein positioning the interface layer comprises
positioning an adaptive material proximate to the fuel cell layer.
25. The method of any of claims 22-24, wherein the interface layer is a removably
coupleable interface layer and positioning the interface layer comprises positioning the
removably coupleable interface layer adjacent to the fuel cell layer.
26. The method of any of claims 22-25, further comprising selecting a property of the
interface layer by manually replacing the interface layer.
27. The method of any of claims 22-26, further comprising automatically selecting a
property of the interface layer in response to a change in at least one environmental
condition proximate to the fuel cell layer.