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(54) FUEL CELL MODULES HAVING CURVED MEMBRANE ELECTRODE ASSEMBLY

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H01M 8/00	(2016.01)
H01M 8/1006	(2016.01)
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(58) **Field of Classification Search**

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See application file for complete search history.

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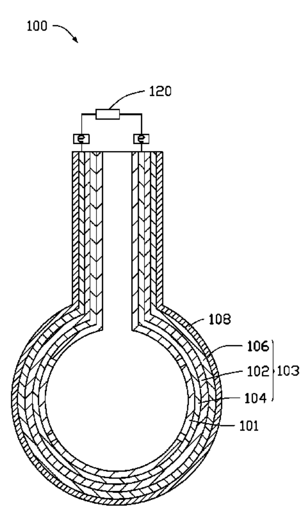
(57) **ABSTRACT**

The disclosure relates to a fuel cell module. The fuel cell module includes a container and a membrane electrode assembly located on the container. The container includes a housing and a nozzle connected to the housing. The container defines a number of through holes located on the housing and covered by the membrane electrode assembly. The membrane electrode assembly includes a proton exchange membrane having a first surface and a second surface opposite to the first surface, a cathode electrode located on the first surface and an anode electrode located on the second surface.

19 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

H01M 8/04082	(2016.01)
H01M 8/1007	(2016.01)
H01M 8/0606	(2016.01)

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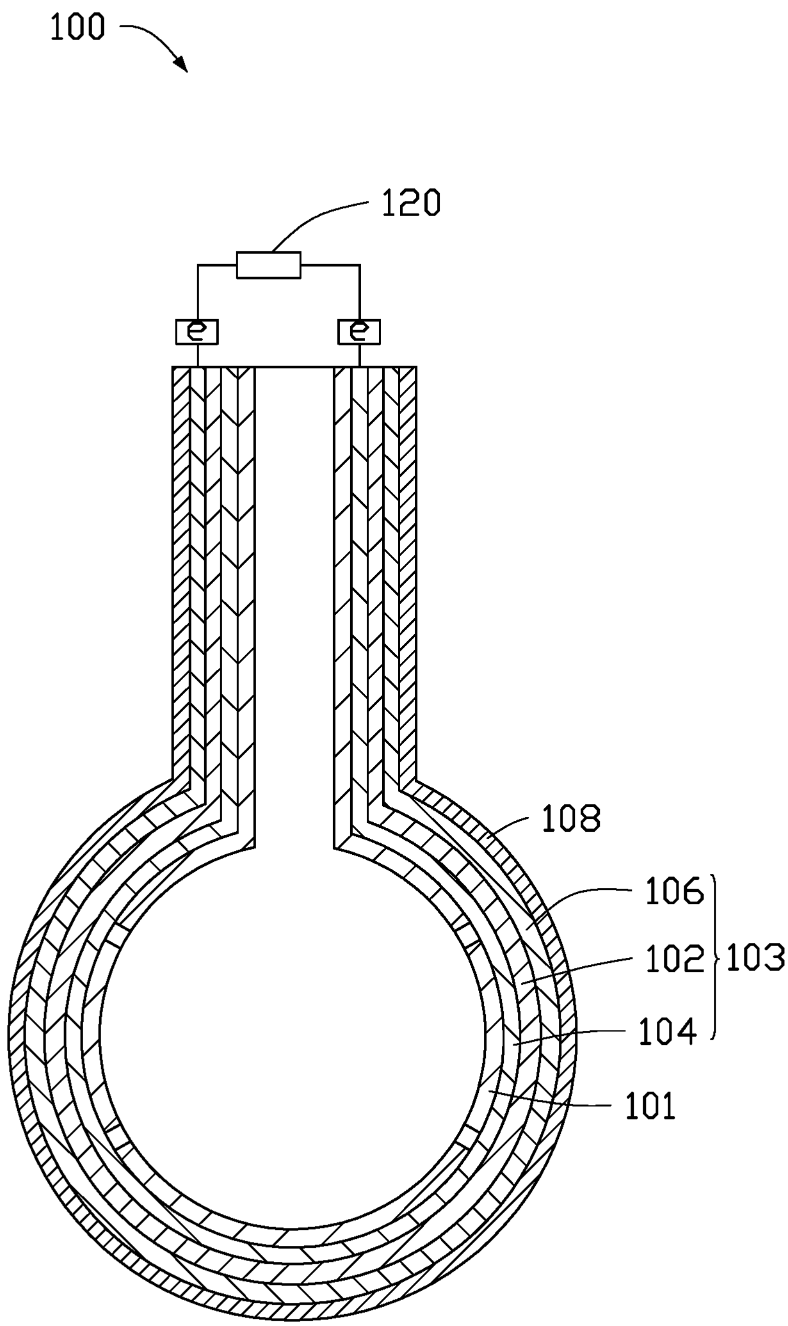

FIG. 1

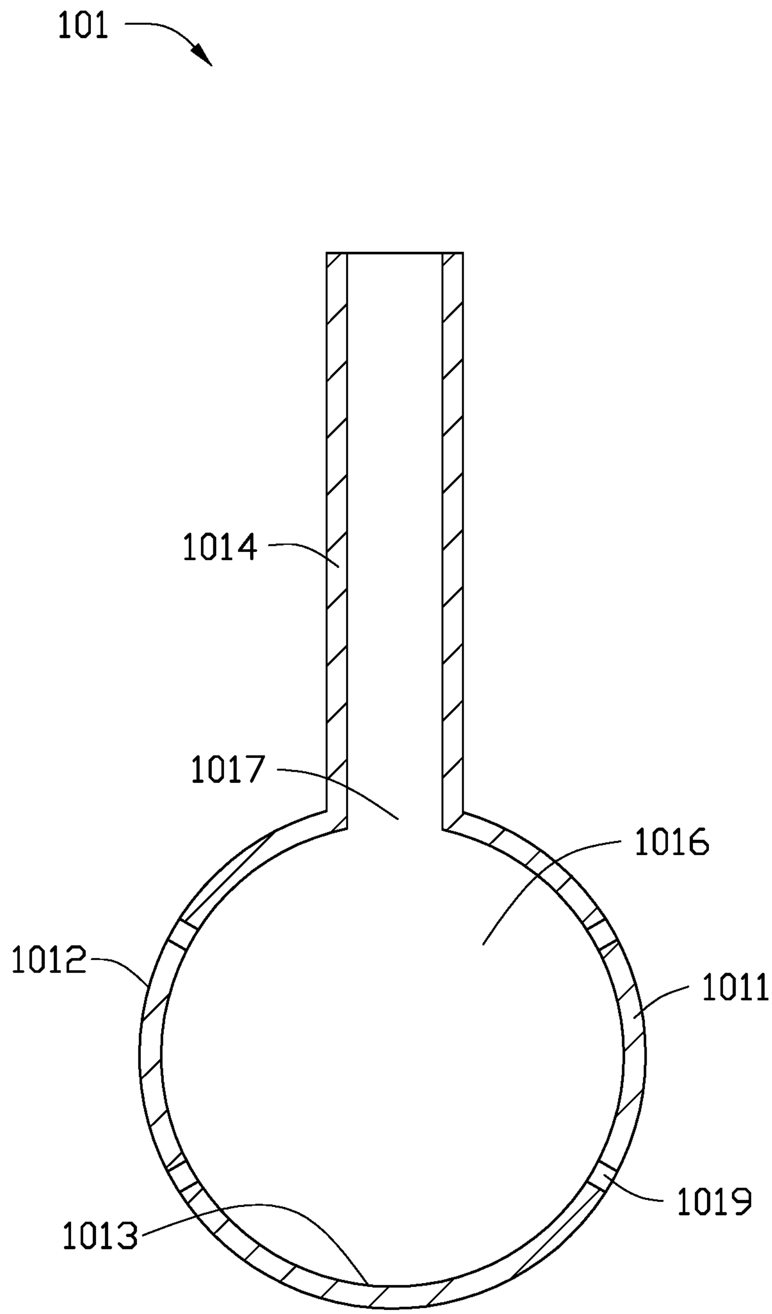

FIG. 2

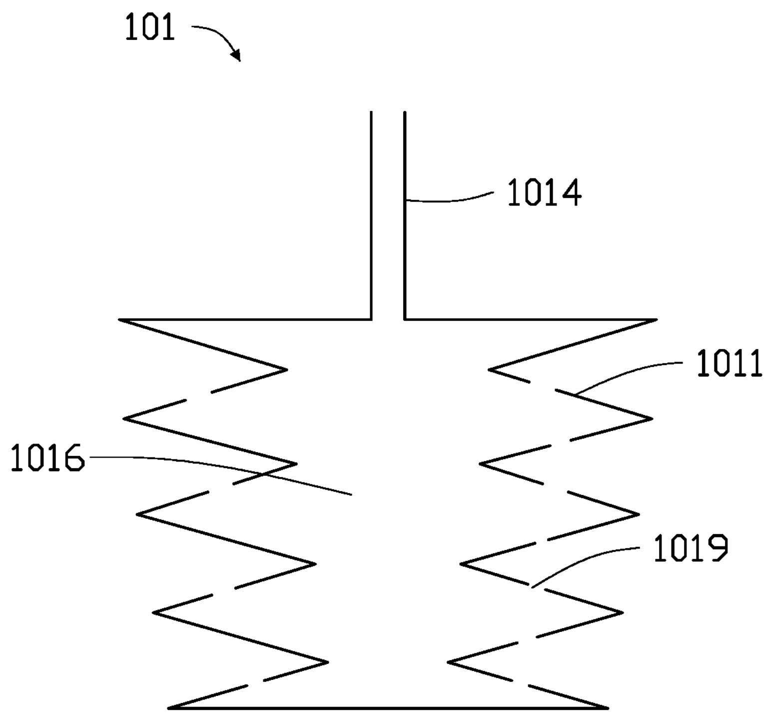

FIG. 3

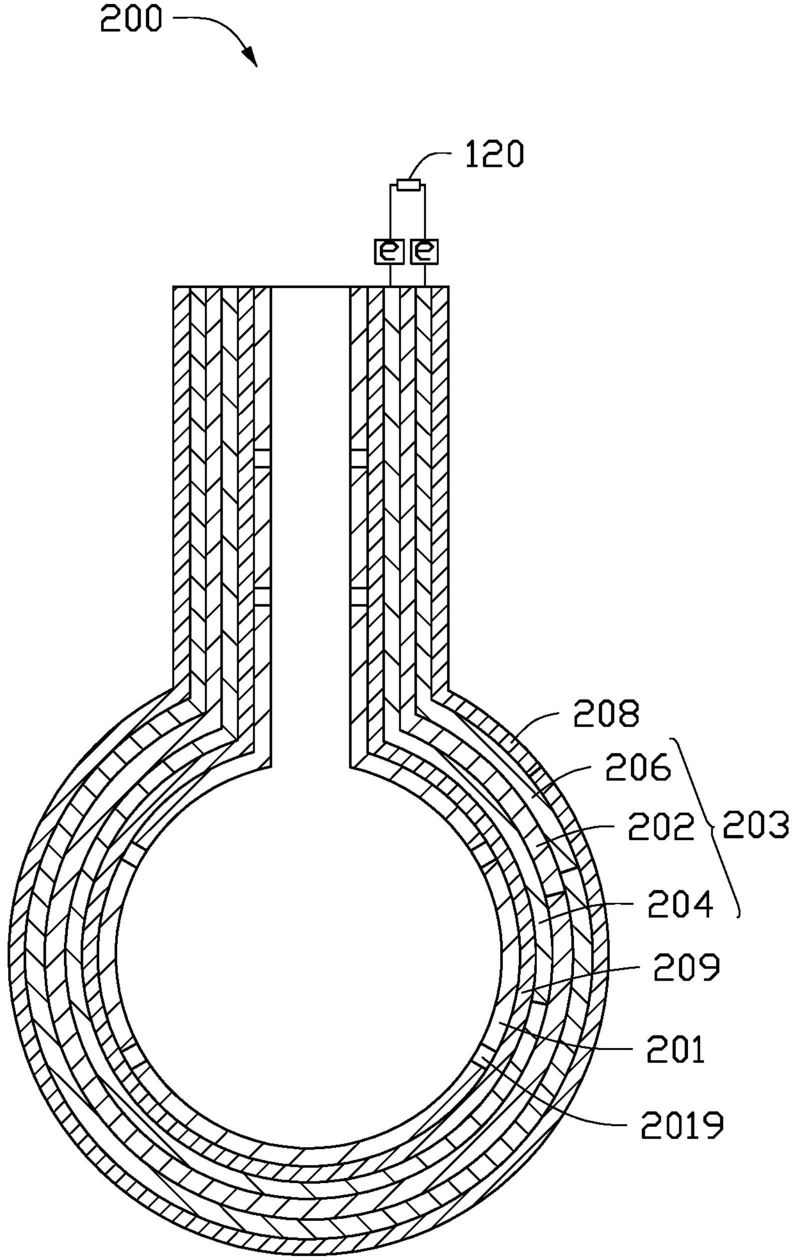

FIG. 4

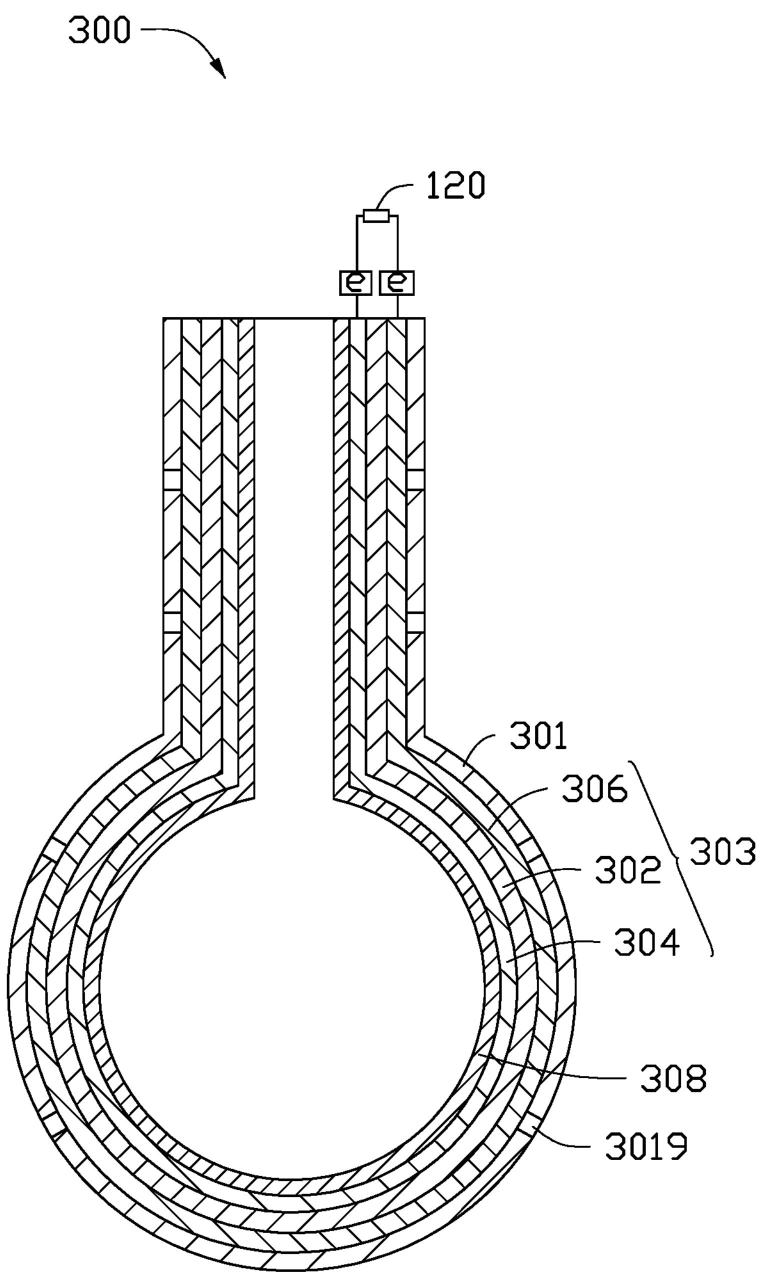

FIG. 5

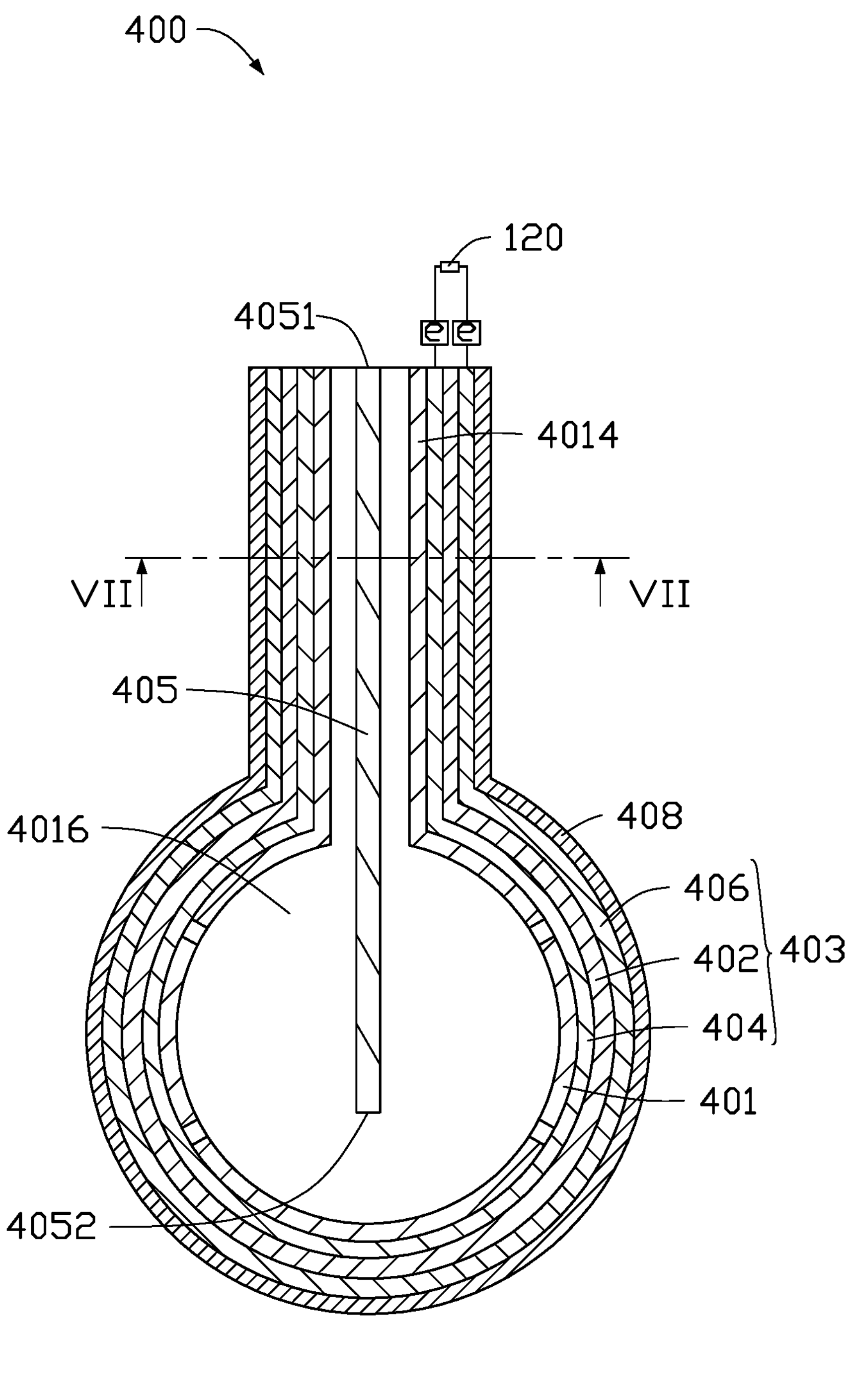

FIG. 6

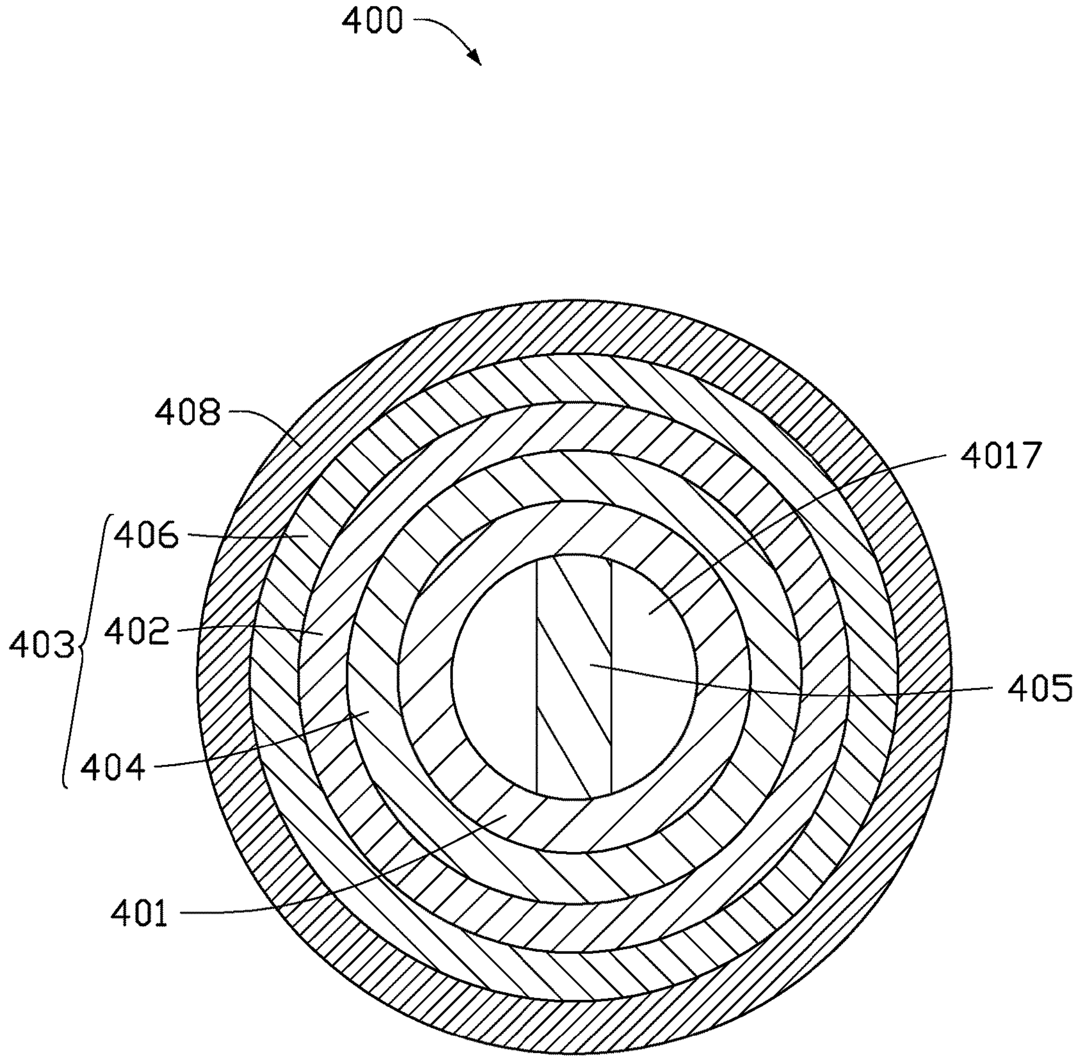

FIG. 7

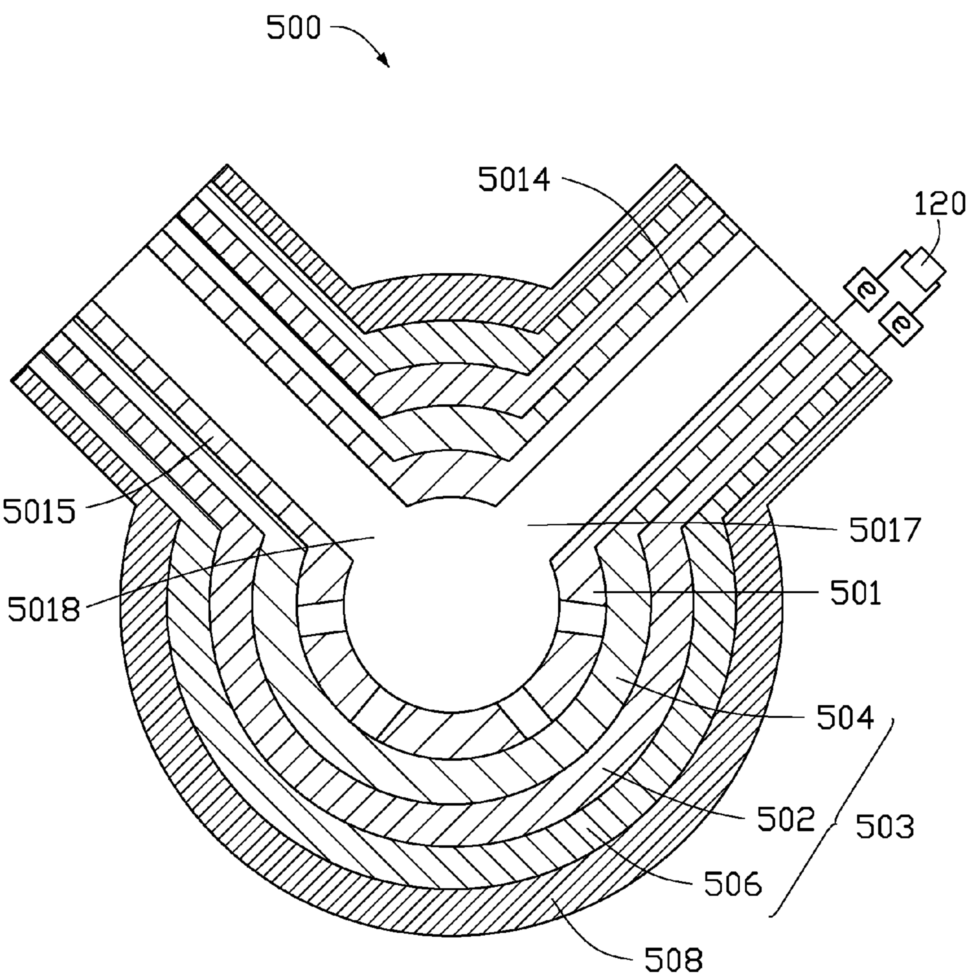

FIG. 8

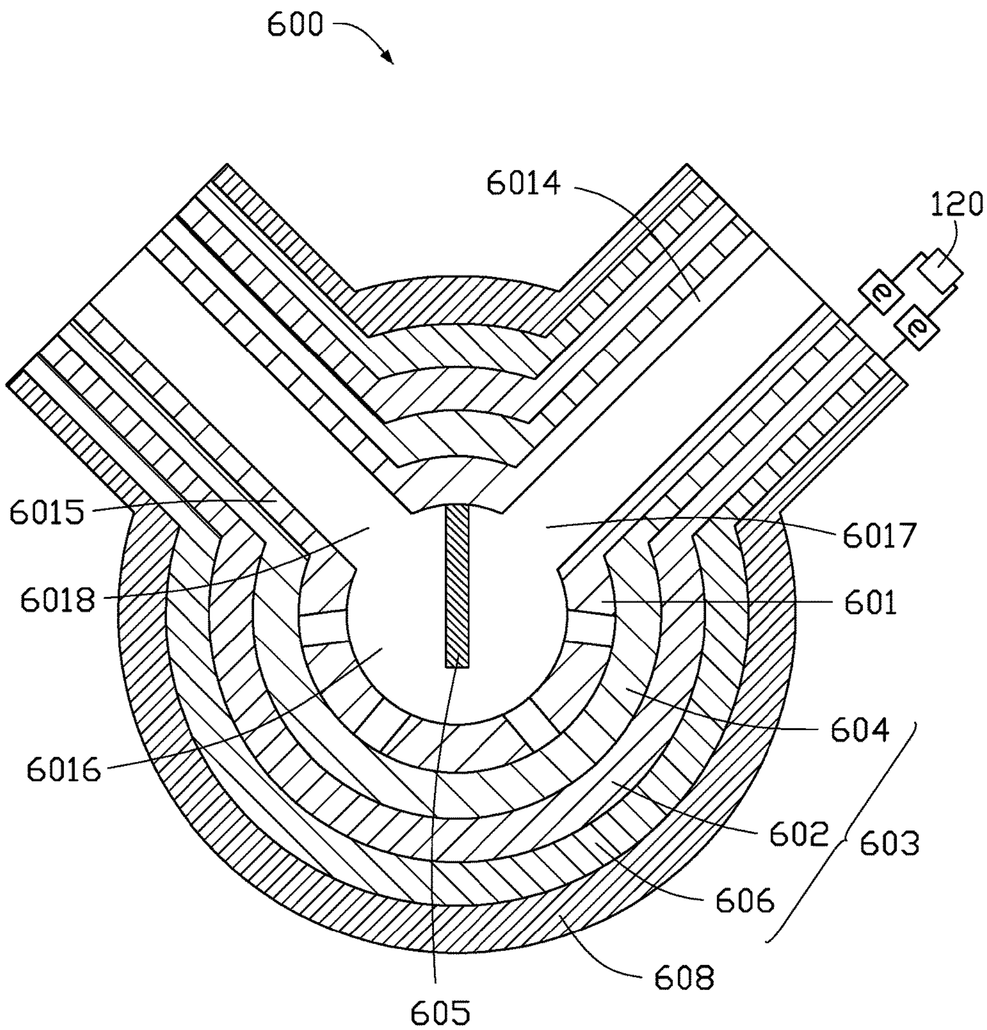

FIG. 9

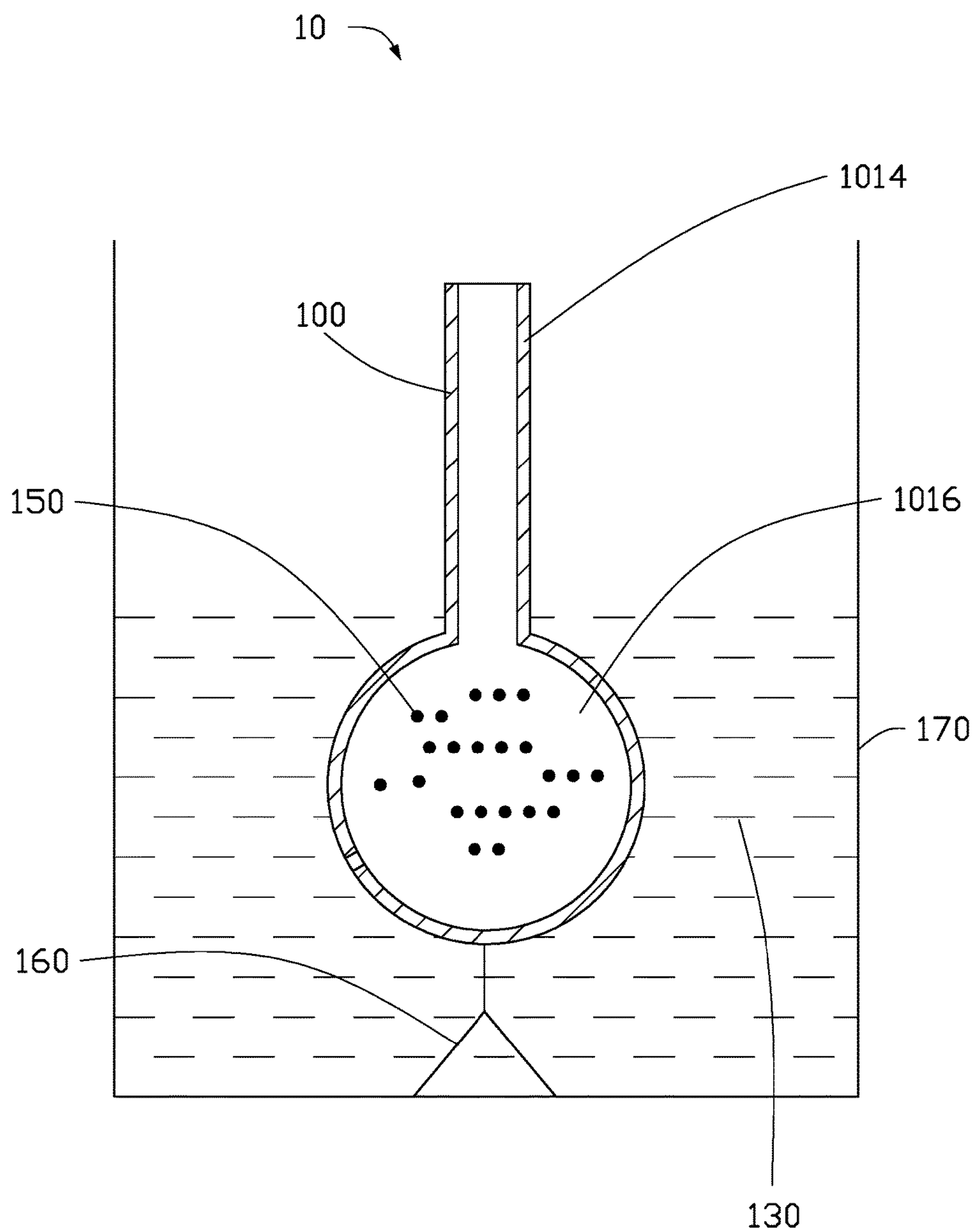

FIG. 10

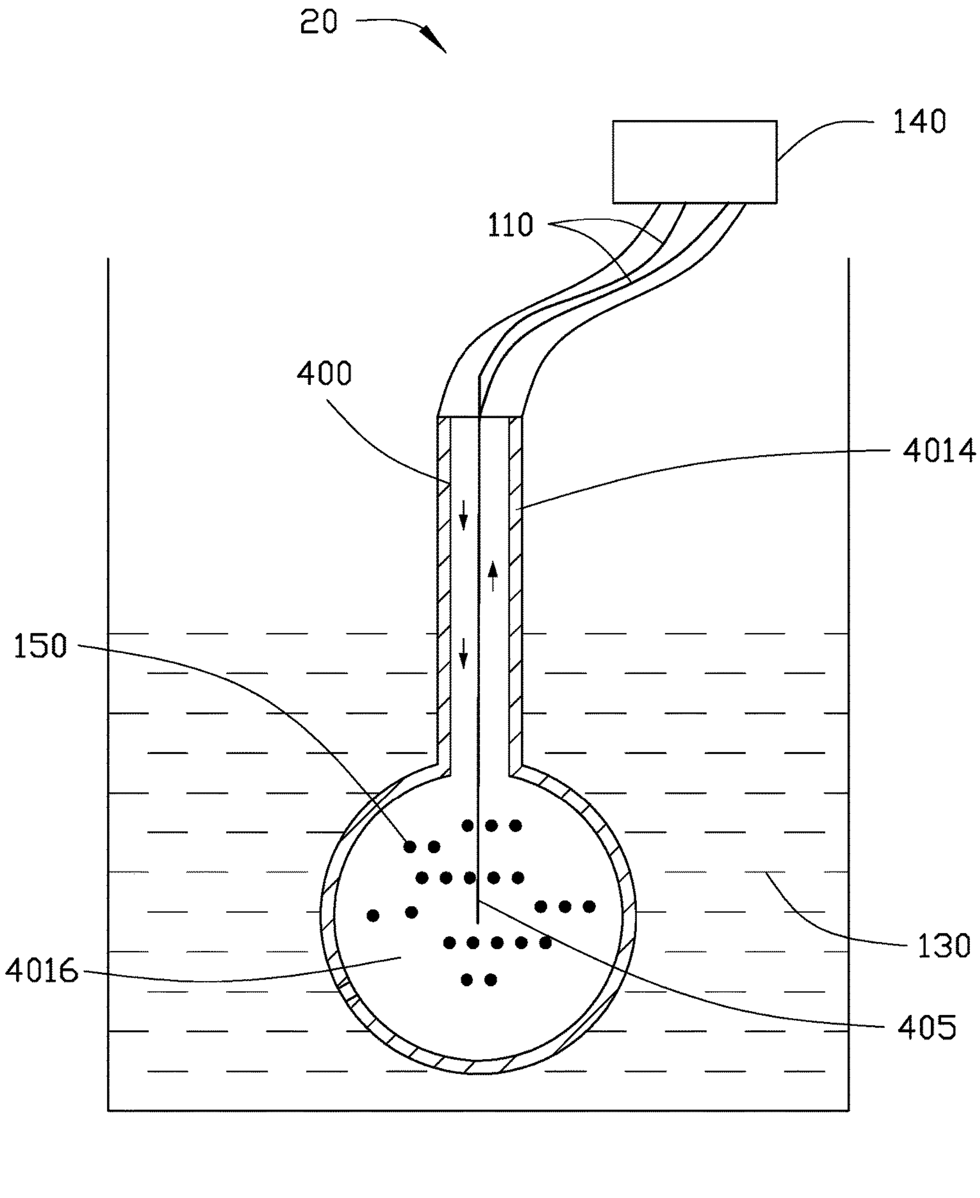

FIG. 11

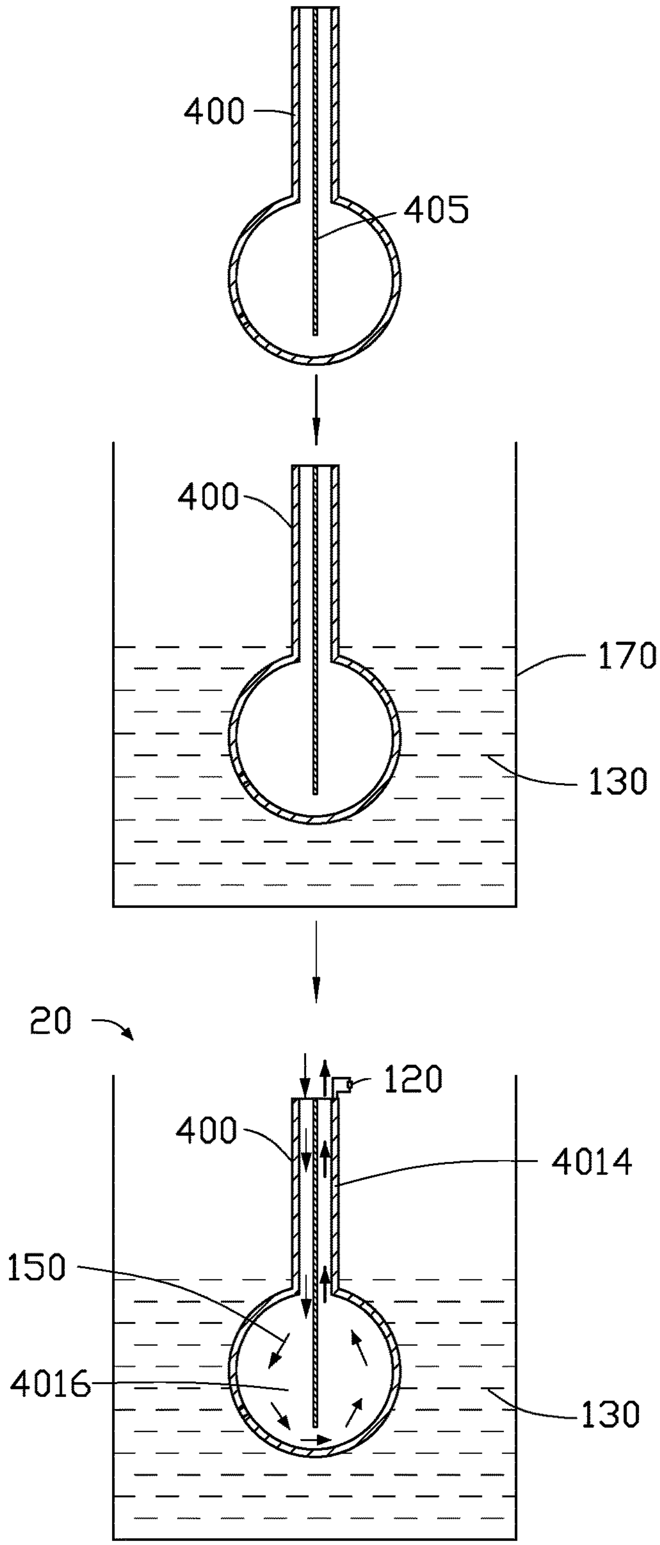

FIG. 12

FUEL CELL MODULES HAVING CURVED MEMBRANE ELECTRODE ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims all benefits accruing under 35 U.S.C. § 119 from China Patent Application No. 201510281370.1, filed on May 28, 2015, in the China Intellectual Property Office, disclosure of which is incorporated herein by reference.

FIELD

The subject matter herein generally relates to fuel cell modules and fuel cell systems using the same.

BACKGROUND

Fuel cells can generally be classified into alkaline, solid oxide, and proton exchange membrane fuel cells. The proton exchange membrane fuel cell has received increasingly more attention and has developed rapidly in recent years.

Typically, the proton exchange membrane fuel cell includes a number of separated fuel cell work units. Each work unit includes a fuel cell membrane electrode assembly (MEA), flow field plates (FFP), current collectors plate (CCP), as well as related support equipment, such as blowers, valves, and pipelines. The membrane electrode assembly generally includes a proton exchange membrane, and an anode electrode and a cathode electrode. The proton exchange membrane is sandwiched between the anode electrode and the cathode electrode to form a planar sandwich structure. However, the planar sandwich structure has a relative small contacting surface with fuel and low energy conversion efficiency.

What is needed, therefore, is to provide fuel cells for solving the problem discussed above.

BRIEF DESCRIPTION OF THE DRAWINGS

Implementations of the present technology will now be described, by way of example only, with reference to the attached figures, wherein:

FIG. **1** is a schematic view of one embodiment of a fuel cell module.

FIG. **2** is a schematic view of one embodiment of a container of the fuel cell module of FIG. **1**.

FIG. **3** is a schematic view of one embodiment of a container.

FIG. **4** is a schematic view of one embodiment of a fuel cell module.

FIG. **5** is a schematic view of one embodiment of a fuel cell module.

FIG. **6** is a schematic view of one embodiment of a fuel cell module.

FIG. **7** is a cross-sectional view along line VII-VII of FIG. **6**.

FIG. **8** is a schematic view of one embodiment of a fuel cell module.

FIG. **9** is a schematic view of one embodiment of a fuel cell module.

FIG. **10** is a schematic view of one embodiment of a fuel cell system.

FIG. **11** is a schematic view of one embodiment of a fuel cell system.

FIG. **12** is a flowchart of one embodiment of a method for making a fuel cell system.

DETAILED DESCRIPTION

It will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures and components have not been described in detail so as not to obscure the related relevant feature being described. The drawings are not necessarily to scale and the proportions of certain parts may be exaggerated to better illustrate details and features. The description is not to be considered as limiting the scope of the embodiments described herein.

Several definitions that apply throughout this disclosure will now be presented.

The term "coupled" is defined as connected, whether directly or indirectly through intervening components, and is not necessarily limited to physical connections. The connection can be such that the objects are permanently connected or releasably connected. The term "outside" refers to a region that is beyond the outermost confines of a physical object. The term "inside" indicates that at least a portion of a region is partially contained within a boundary formed by the object. The term "substantially" is defined to be essentially conforming to the particular dimension, shape or other word that substantially modifies, such that the component need not be exact. For example, substantially cylindrical means that the object resembles a cylinder, but can have one or more deviations from a true cylinder. The term "comprising" means "including, but not necessarily limited to"; it specifically indicates open-ended inclusion or membership in a so-described combination, group, series and the like. It should be noted that references to "an" or "one" embodiment in this disclosure are not necessarily to the same embodiment, and such references mean at least one.

References will now be made to the drawings to describe, in detail, various embodiments of the present fuel cell modules fuel cell systems using the same, and methods for making the fuel cell systems.

Referring to FIG. **1**, a fuel cell module **100** of one embodiment includes a container **101** and a membrane electrode assembly **103** located on the container **101**. The membrane electrode assembly **103** comprises a proton exchange membrane **102** having two opposite surfaces, a cathode electrode **104** and an anode electrode **106**. The cathode electrode **104** and the anode electrode **106** are respectively disposed on the two opposite surfaces of the proton exchange membrane **102**.

Referring to FIG. **2**, the container **101** includes a housing **1011** and a nozzle **1014**. The housing **1011** defines a chamber **1016** and an opening **1017**. The nozzle **1014** has a first end connected to the opening **1017** and a second end opposite to the first end. The nozzle **1014** extends away from the housing **1011**. The chamber **1016** is communicated to outside of the housing **1011** through the nozzle **1014**. The nozzle **1014** is configured to input and output a reacting gas, such as oxidizing gas or fuel gas. The container **101** has a plurality of first through holes **1019** on the wall of the container **101**. The membrane electrode assembly **103** is disposed on a surface of the container **101** and covers the plurality of first through holes **1019**. The container **101** includes an outside surface **1012** and an inside surface **1013** opposite to the outside surface **1012**. The membrane electrode assembly **103** can be located on the outside surface **1012** or the inside surface **1013**.

The shape of the housing **1011** can be spherical, hemispherical, cylindrical or bellows shape. The container **101** is configured to support the membrane electrode assembly **103** and define the chamber **1016** and the plurality of first through holes **1019**. The plurality of first through holes **1019** allows the reacting gas in the container **101** diffuse to the membrane electrode assembly **103**. The maximum diameter of the chamber **1016** is greater than the maximum diameter of the nozzle **1014**. The ratio between the maximum diameter of the chamber **1016** and the maximum diameter of the nozzle **1014** can be in a range from about 1.5:1 to about 100:1.

In one embodiment, the ratio is in a range from about 5:1 to about 50:1. The container **101** can be made of rigid materials such as metal, ceramic, glass, quartz, diamond, plastic or any other suitable material. In one embodiment, the container **101** is a hollow copper sphere, both the housing **1011** and the nozzle **1014** have the first through holes **1019** thereon, and the membrane electrode assembly **103** is located on outside surface **1012** of the container **101** and covers entire outside surface **1012**. The cathode electrode **104** is in direct contact with and covers entire outside surface **1012**. The proton exchange membrane **102** covers entire cathode electrode **104**. The anode electrode **106** covers entire proton exchange membrane **102**. Alternatively, when the membrane electrode assembly **103** is fixed on the outside surface **1012**, the anode electrode **106** can be in direct contact with the outside surface **1012**.

Referring to FIG. **3**, in another embodiment, the housing **1011** is a bellows made of polymer. In uses, the bellows shaped housing **1011** can be contracted and stretched along the height direction so the housing **1011** can input and out put reacting gas. Thus, the fuel cell system using the fuel cell module **100** does not need gas supplying and extracting device.

The proton exchange membrane **102** can be perfluorosulfonic acid, polystyrene sulfonic acid, polystyrene trifluoroacetic acid, phenol-formaldehyde resin acid, or hydrocarbons. Each of the cathode electrode **104** and the anode electrode **106** includes a gas diffusion layer (not shown) and catalyst (not shown) dispersed on the gas diffusion layer. In one embodiment, each of the cathode electrode **104** and the anode electrode **106** includes a carbon nanotube layer located on the proton exchange membrane **102** and a catalyst layer located between the proton exchange membrane **102** and the carbon nanotube layer. The catalyst layer includes catalyst materials and carrier. The catalyst materials include metal particles or enzymatic catalyst. The metal particles can be platinum particles, gold particles, ruthenium particles or combination thereof. The distribution of the metal particles is less than 0.5 mg/cm^2. The enzymatic catalyst can be oxidase, dehydrogenase or thereof. The carrier can be graphite, carbon black, carbon fiber or carbon nanotubes.

In one embodiment, the carbon nanotube layer is a free-standing structure and can be drawn from a carbon nanotube array. The term "free-standing structure" means that the carbon nanotube layer can sustain the weight of itself when it is hoisted by a portion thereof without any significant damage to its structural integrity. The carbon nanotubes of the carbon nanotube layer can be orderly arranged to form an ordered carbon nanotube structure or disorderly arranged to form a disordered carbon nanotube structure. The term 'disordered carbon nanotube structure' includes, but is not limited to, a structure wherein the carbon nanotubes are arranged along many different directions, and the aligning directions of the carbon nanotubes are random. The number of the carbon nanotubes arranged along each different direction can be almost the same (e.g. uniformly disordered). The disordered carbon nanotube structure can be isotropic. The carbon nanotubes in the disordered carbon nanotube structure can be entangled with each other. The term 'ordered carbon nanotube structure' includes, but is not limited to, a structure wherein the carbon nanotubes are arranged in a consistently systematic manner, e.g., the carbon nanotubes are arranged approximately along a same direction and/or have two or more sections within each of which the carbon nanotubes are arranged approximately along a same direction (different sections can have different directions).

In one embodiment, the carbon nanotubes in the carbon nanotube layer are arranged to extend along the direction substantially parallel to the surface of the carbon nanotube layer so that it is easy to obtain a pattern having greater light transmission. After placement on the proton exchange membrane **102**, the carbon nanotubes in the carbon nanotube layer can be arranged to extend along the direction substantially parallel to the proton exchange membrane **102**. A majority of the carbon nanotubes in the carbon nanotube layer are arranged to extend along the same direction. Some of the carbon nanotubes in the carbon nanotube layer are arranged to extend along a first direction, and the rest of the carbon nanotubes in the carbon nanotube layer are arranged to extend along a second direction, substantially perpendicular to the first direction.

The carbon nanotube layer can include at least one carbon nanotube film, at least one carbon nanotube wire, or combination thereof. In one embodiment, the carbon nanotube layer can include a single carbon nanotube film or two or more carbon nanotube films stacked together. Thus, the thickness of the carbon nanotube layer can be controlled by the number of the stacked carbon nanotube films. The number of the stacked carbon nanotube films can be in a range from about 2 to about 100. For example, the number of the stacked carbon nanotube films can be 10, 30, or 50. In one embodiment, the carbon nanotube layer can include a layer of parallel and spaced carbon nanotube wires. Also, the carbon nanotube layer can include a plurality of carbon nanotube wires crossed or weaved together to form a carbon nanotube net. The distance between two adjacent parallel and spaced carbon nanotube wires can be in a range from about 0.1 micrometers to about 200 micrometers. In one embodiment, the distance between two adjacent parallel and spaced carbon nanotube wires is in a range from about 10 micrometers to about 100 micrometers.

In one embodiment, the carbon nanotube layer includes at least one drawn carbon nanotube film. A drawn carbon nanotube film can be drawn from a carbon nanotube array that is able to have a film drawn therefrom. The drawn carbon nanotube film includes a plurality of successive and oriented carbon nanotubes joined end-to-end by van der Waals attractive force therebetween. The drawn carbon nanotube film is a free-standing film. Each drawn carbon nanotube film includes a plurality of successively oriented carbon nanotube segments joined end-to-end by van der Waals attractive force therebetween. Each carbon nanotube segment includes a plurality of carbon nanotubes parallel to each other, and combined by van der Waals attractive force therebetween. Some variations can occur in the drawn carbon nanotube film. The carbon nanotubes in the drawn carbon nanotube film are oriented along a preferred orientation. The drawn carbon nanotube film can be treated with an organic solvent to increase the mechanical strength and toughness and reduce the coefficient of friction of the drawn carbon nanotube film. A thickness of the drawn carbon nanotube film can range from about 0.5 nanometers to about 100 micrometers.

The carbon nanotube layer can include at least two stacked drawn carbon nanotube films. In other embodiments, the carbon nanotube layer can include two or more coplanar carbon nanotube films, and can include layers of coplanar carbon nanotube films. Additionally, when the carbon nanotubes in the carbon nanotube film are aligned along one preferred orientation (e.g., the drawn carbon nanotube film), an angle can exist between the orientation of carbon nanotubes in adjacent films, whether stacked or adjacent. Adjacent carbon nanotube films can be combined by only the van der Waals attractive force therebetween. An angle between the aligned directions of the carbon nanotubes in two adjacent carbon nanotube films can range from about 0 degrees to about 90 degrees. When the angle between the aligned directions of the carbon nanotubes in adjacent stacked drawn carbon nanotube films is larger than 0 degrees, a plurality of micropores is defined by the carbon nanotube layer. The carbon nanotube layer is shown with the aligned directions of the carbon nanotubes between adjacent stacked drawn carbon nanotube films at 90 degrees. Stacking the carbon nanotube films will also add to the structural integrity of the carbon nanotube layer.

In another embodiment, the carbon nanotube layer can include a pressed carbon nanotube film. The pressed carbon nanotube film can be a free-standing carbon nanotube film. The carbon nanotubes in the pressed carbon nanotube film are arranged along a same direction or arranged along different directions. The carbon nanotubes in the pressed carbon nanotube film can rest upon each other. Adjacent carbon nanotubes are attracted to each other and combined by van der Waals attractive force. An angle between a primary alignment direction of the carbon nanotubes and a surface of the pressed carbon nanotube film is about 0 degrees to approximately 15 degrees. The greater the pressure applied, the smaller the angle formed. If the carbon nanotubes in the pressed carbon nanotube film are arranged along different directions, the carbon nanotube layer can be isotropic.

In another embodiment, the carbon nanotube layer includes a flocculated carbon nanotube film. The flocculated carbon nanotube film can include a plurality of long, curved, disordered carbon nanotubes entangled with each other. Furthermore, the flocculated carbon nanotube film can be isotropic. The carbon nanotubes can be substantially uniformly dispersed in the carbon nanotube film. Adjacent carbon nanotubes are acted upon by van der Waals attractive force to form an entangled structure with micropores defined therein. Sizes of the micropores can be less than 10 micrometers. The porous nature of the flocculated carbon nanotube film will increase the specific surface area of the carbon nanotube layer. Further, due to the carbon nanotubes in the carbon nanotube layer being entangled with each other, the carbon nanotube layer employing the flocculated carbon nanotube film has excellent durability, and can be fashioned into desired shapes with a low risk to the integrity of the carbon nanotube layer. The flocculated carbon nanotube film, in some embodiments, is free-standing due to the carbon nanotubes being entangled and adhered together by van der Waals attractive force therebetween.

The carbon nanotube wire can be untwisted or twisted. Treating the drawn carbon nanotube film with a volatile organic solvent can form the untwisted carbon nanotube wire. Specifically, the organic solvent is applied to soak the entire surface of the drawn carbon nanotube film. During the soaking, adjacent parallel carbon nanotubes in the drawn carbon nanotube film will bundle together, due to the surface tension of the organic solvent as it volatilizes, and thus, the drawn carbon nanotube film will be shrunk into an untwisted carbon nanotube wire. The untwisted carbon nanotube wire includes a plurality of carbon nanotubes substantially oriented along a same direction (i.e., a direction along the length of the untwisted carbon nanotube wire). The carbon nanotubes are substantially parallel to the axis of the untwisted carbon nanotube wire. More specifically, the untwisted carbon nanotube wire includes a plurality of successive carbon nanotube segments joined end to end by van der Waals attractive force therebetween. Each carbon nanotube segment includes a plurality of carbon nanotubes substantially parallel to each other, and combined by van der Waals attractive force therebetween. The carbon nanotube segments can vary in width, thickness, uniformity, and shape. The length of the untwisted carbon nanotube wire can be arbitrarily set as desired. A diameter of the untwisted carbon nanotube wire ranges from about 0.5 nanometers to about 100 micrometers.

The twisted carbon nanotube wire can be formed by twisting a drawn carbon nanotube film using a mechanical force to turn the two ends of the drawn carbon nanotube film in opposite directions. The twisted carbon nanotube wire includes a plurality of carbon nanotubes helically oriented around an axial direction of the twisted carbon nanotube wire. More specifically, the twisted carbon nanotube wire includes a plurality of successive carbon nanotube segments joined end to end by van der Waals attractive force therebetween. Each carbon nanotube segment includes a plurality of carbon nanotubes parallel to each other, and combined by van der Waals attractive force therebetween. The length of the carbon nanotube wire can be set as desired. A diameter of the twisted carbon nanotube wire can be from about 0.5 nanometers to about 100 micrometers. Further, the twisted carbon nanotube wire can be treated with a volatile organic solvent after being twisted to bundle the adjacent paralleled carbon nanotubes together. The specific surface area of the twisted carbon nanotube wire will decrease, while the density and strength of the twisted carbon nanotube wire will increase.

In one embodiment, each of the cathode electrode **104** and the anode electrode **106** may include a carbon nanotube layer and a plurality of catalyst particles dispersed in the carbon nanotube to obtain a carbon nanotube composite structure. The cathode electrode **104** can be made by depositing a plurality of metal catalyst particles on a plurality of drawn carbon nanotube films to form a plurality of drawn carbon nanotube film composites and then stacking or twisting the plurality of drawn carbon nanotube film composites. The plurality of metal catalyst particles can be deposited by chemical vapor deposition (CVD), sputtering, or plasma-assisted chemical vapor deposition. The anode electrode **106** can be made by immerging the carbon nanotube layer into a catalyst-containing solution to obtain a carbon nanotube composite structure.

In one embodiment, the anode electrode **106** can be made by: step (a) functionalizing the carbon nanotube layer to form a functionalized the carbon nanotube layer; step (b) putting the functionalized the carbon nanotube layer into the catalyst-containing solution; and step (c) drying the functionalized carbon nanotube layer to obtain a carbon nanotube composite structure.

In step (a), the functionalizing can be performed by treating the carbon nanotube layer with acid such as hydrochloric acid, sulfuric acid or nitric acid. In one embodiment, the carbon nanotube layer is put into a mixture of sulfuric acid and nitric acid and treating by ultrasonic for about 2 hours. Then, the carbon nanotube layer is put into an oxydol and treating by ultrasonic for about 1 hour. Finally, the carbon nanotube layer is put into a water and treating by ultrasonic till a PH value of the become 7.

In step (b) the catalyst-containing solution can be a solution of metal or metal-salt, or a solution of enzymatic. In one embodiment, the catalyst-containing solution is a solution of glucose oxidase. Then, the carbon nanotube layer is put into the solution of glucose oxidase for 1~5 days at the temperature of 4° C.

Furthermore, the fuel cell module **100** includes at least one current collector **108**. The current collector **108** is made of conductive material, such as metal, and configured to collect and conduct electrons. The current collector **108** is located on surface of the cathode electrode **104** and/or the anode electrode **106**. When the container **101** is made of conductive material, the container **101** can be used as collector. Thus, only one collector **108** is needed. In one embodiment, the container **101** is a made of copper, and the current collector **108** is a copper mesh.

In use, a load **120** can be electrically connected to the cathode electrode **104** and the anode electrode **106**. The fuel cell module **100** has following advantages. First, the membrane electrode assembly **103** is located on the container **101** and has a curved or folded surface, thus, the membrane electrode assembly **103** can have relative large contacting surface with fuel or reacting gas. The energy conversion efficiency of the membrane electrode assembly **103** is improved. Second, the container **101** can be used to carry the fuel or reacting gas, and the fuel cell system using the fuel cell module **100** has a simple structure.

Referring to FIG. **4**, a fuel cell module **200** of one embodiment includes a container **201**, a membrane electrode assembly **203** located on the container **201**, a first collector **208**, and a second collector **209**. The membrane electrode assembly **203** comprises a proton exchange membrane **202** having two opposite surfaces, a cathode electrode **204** and an anode electrode **206**.

The fuel cell module **200** is similar to the fuel cell module **100** above except that the container **201** is made of insulative material, and the second collector **209** is located between the container **201** and the membrane electrode assembly **203**. The second collector **209** can be formed on the outer surface of the container **201** by bonding, coating or deposition. In one embodiment, the second collector **209** cover entire outer surface of the container **201** and defines a plurality of second through holes (not shown) corresponding to the plurality of first through holes **2019**. The first collector **208** cover entire outer surface of the membrane electrode assembly **203** and defines a plurality of third through holes (not shown) allowing the reacting gas to pass through. Both the first collector **208** and the second collector **209** is a copper metal mesh.

Referring to FIG. **5**, a fuel cell module **300** of one embodiment includes a container **301**, a membrane electrode assembly **303** located on the container **301**, and a first collector **308**. The membrane electrode assembly **303** comprises a proton exchange membrane **302** having two opposite surfaces, a cathode electrode **304** and an anode electrode **306**.

The fuel cell module **300** is similar to the fuel cell module **100** above except that the membrane electrode assembly **303** is located on the inner surface of the container **301** and the first collector **308** is located on the inner surface of the membrane electrode assembly **303**. The first collector **308** covers entire inner surface of the membrane electrode assembly **303** and defines a plurality of third through holes (not shown) allowing the reacting gas to pass through. In one embodiment, the container **301** is a hollow copper sphere having a plurality of first through holes **3019**. The first collector **308** is a copper metal mesh.

Referring to FIGS. **6-7**, a fuel cell module **400** of one embodiment includes a container **401**, a membrane electrode assembly **403** located on the container **401**, and a first collector **408**. The membrane electrode assembly **403** comprises a proton exchange membrane **402** having two opposite surfaces, a cathode electrode **404** and an anode electrode **406**.

The fuel cell module **400** is similar to the fuel cell module **100** above except that the container **401** further includes a baffle **405** located therein. The baffle **405** is located in both the nozzle **4014** and the chamber **4016**. The baffle **405** extends from the free end of the nozzle **4014** in to the chamber **4016** so that the space in the nozzle **4014** and the chamber **4016** is divided in to two spaces. The baffle **405** has a first side **4051** parallel with the free end of the nozzle **4014** and a second side **4052** opposite to the first side **4051**. The second side **4052** is spaced from the bottom inner wall of the container **401**. Thus, the two spaces in the container **401** are communicated with each other at bottom. Alternatively, when the second side **4052** of the baffle **405** is in direct contact with the bottom inner wall of the container **401**, the baffle **405** can have a plurality of through holes. The reacting gas can be input the chamber **4016** from one side of the baffle **405** and output the chamber **4016** from the other side of the baffle **405**. The fuel cell module **400** can improve the cycle efficiency of the reacting gas and the energy conversion efficiency of the membrane electrode assembly **403**.

Referring to FIG. **8**, a fuel cell module **500** of one embodiment includes a container **501**, a membrane electrode assembly **503** located on the container **501**, and a first collector **508**. The membrane electrode assembly **503** comprises a proton exchange membrane **502** having two opposite surfaces, a cathode electrode **504** and an anode electrode **506**.

The fuel cell module **500** is similar to the fuel cell module **100** above except that the container **501** defines a first opening **5017** and a second opening **5018** spaced from the first opening **5017**; and the container **501** includes a first nozzle **5014** connected to the first opening **5017** and a second nozzle **5015** connected to the second opening **5018**. The first nozzle **5014** and the second nozzle **5015** can be parallel with each other or form an angle less than 90 degrees. The first nozzle **5014** can be used to input reacting gas, and the second nozzle **5015** can be used to output reacting gas. The fuel cell module **500** can improve the cycle efficiency of the reacting gas and the energy conversion efficiency of the membrane electrode assembly **403**.

Referring to FIG. **9**, a fuel cell module **600** of one embodiment includes a container **601**, a membrane electrode assembly **603** located on the container **601**, and a first collector **608**. The membrane electrode assembly **603** comprises a proton exchange membrane **602** having two opposite surfaces, a cathode electrode **604** and an anode electrode **606**.

The fuel cell module **600** is similar to the fuel cell module **500** above except that the container **601** further includes a baffle **605** located in the chamber **6016**. The first opening **6017** and the second opening **6018** are located on two opposite sides of the baffle **605**. The baffle **605** divides the chamber **6016** in to a first space connected to the first nozzle **6014** and a second space connected to the second nozzle **6015**. The baffle **605** has a side spaced from the inner wall of the container **601** so that the first space and the second space are communicated with each other.

Referring to FIG. **10**, a fuel cell system **10** of one embodiment includes a fuel cell module **100**, fuel **130** and oxidizing gas **150**. The fuel cell module **100** can also be the fuel cell modules **200**, **300**, **400**, **500**, **600**.

The fuel cell module **100** is at least partially immerged in the fuel **130** and configured to separate the fuel **130** and the oxidizing gas **150**. The oxidizing gas **150** is inside of the chamber **1016**, and the fuel **130** is outside of the fuel cell module **100** and surrounds the fuel cell module **100**. The fuel **130** can be in direct contact with the anode electrode **106** or diffuse to the anode electrode **106** through the through holes of the first collector **108**.

The depth h of the fuel cell module **100** in the fuel **130** satisfies the condition: $h<P/(\rho_1-\rho_2)g$, where, P represents the maximum pressure the fuel cell module **100** can bear, ρ_1 represents the density of the fuel **130**, ρ_2 represents the density of the oxidizing gas **150**, and g is a constant 9.8 N/kg. When the fuel cell module **100** is immerged in the fuel **130** with a depth h greater than $P/(\rho_1-\rho_2)g$, the pressure of the fuel **130** may damage the fuel cell module **100**.

The fuel **130** is not limited and can be bioethanol, methane gas or glucose solution. The fuel cell module **100** is immerged in the fuel **130** and the nozzle **1014** extends out of the fuel **130** so that the fuel **130** would not flow in to the chamber **1016**. The oxidizing gas **150** can be pure oxygen or air containing oxygen. In one embodiment, the fuel **130** is glucose solution, and the oxidizing gas **150** is air.

Furthermore, the fuel cell system **10** can include a fixing element **160** connected to the fuel cell module **100**. The fixing element **160** is configured to fix the fuel cell module **100** in the fuel **130**. The fixing element **160** can be a sucker or hook. In one embodiment, the fixing element **160** is a sucker in connected to the bottom of the fuel cell module **100**. When the fuel cell module **100** is immerged in the fuel **130**, the sucker can be fixed on the bottom surface of the pool **170**.

When the fuel cell module **100** is in the shape as shown in FIG. **3**, the fuel cell system **10** can further includes an device to contract and stretch the fuel cell module **100** so that the fuel cell module **100** can exchange gas with outside.

Referring to FIG. **11**, a fuel cell system **20** of one embodiment includes a fuel cell module **400**, fuel **130**, a gas supplying and extracting device **140** and oxidizing gas **150**. The fuel cell system **20** is similar to the fuel cell system **10** above except that further includes the gas supplying and extracting device **140**. The gas supplying and extracting device **140** includes blower, pump and valves (not shown). The gas supplying and extracting device **140** is connected to the end of the nozzle **1014** by two pipelines **110**. The baffle **405** divides the space in the nozzle **4014** and the chamber **4016** in to two spaces. The blower of the gas supplying and extracting device **140** is connected to one of the spaces and configured to supply the oxidizing gas **150**. The pump of the gas supplying and extracting device **140** is connected to the other one of the spaces and configured to extract the oxidizing gas **150**.

Furthermore, when the fuel cell module **400** is replaced by the fuel cell module **500**, **600** above, the blower of the gas supplying and extracting device **140** can be connected to the first nozzle **5014**, **6014** and configured to supply the oxidizing gas **150**. The pump of the gas supplying and extracting device **140** can be connected to the second nozzle **5015**, **6015** and configured to extract the oxidizing gas **150**.

Referring to FIG. **12**, the method of making the fuel cell system **20** includes following steps:

step (S**10**), providing the fuel cell module **400**;

step (S**20**), at least partially immerging the fuel cell module **400** in the fuel **130**; and

step (S**30**), supplying the oxidizing gas **150** into the chamber **4016** of the fuel cell module **400**.

In step (S**10**), the fuel cell module **400** can also be the fuel cell modules **100**, **200**, **300**, **500**, **600** above.

In step (S**20**), the fuel **130** is filled in a pool **170**. The fuel **130** can be made by placing the rotten materials, such as rotten fruit, rotten food or rotten vegetables, in the pool **170** filed with water and decomposing the rotten materials to form the fuel **130** in the pool **170**. In one embodiment, the fuel **130** is made by placing the rotten fruit in the pool **170** filed with water and decomposing the rotten fruit to form glucose solution in the pool **170**. Thus, rotten materials can be used to produce electric energy.

In step (S**30**), the nozzle **4014** can be connected to the gas supplying and extracting device **140** as shown in FIG. **10**. The oxidizing gas **150** can be supplied and extracted by the gas supplying and extracting device **140**.

In the working process of the fuel cell system **20**, the reaction of glucose molecule at the anode electrode **106** is as follows: glucose→gluconic acid+$2H^+$+2e. The hydrogen ions generated by the above-described reaction reach the cathode electrode **104** through the proton exchange membrane **102**. At the same time, the electrons generated by the reaction above also arrive at the cathode electrode **104** by an external electrical circuit. The oxygen of the oxidizing gas **150** reacts with the hydrogen ions and electrons at the cathode electrode **104** as the following equation: $\frac{1}{2}O_2+2H^++2e\rightarrow H_2O$. In the electrochemical reaction process, the electrons form an electrical current flowing through the load **120** in the external electrical circuit.

The embodiments shown and described above are only examples. Even though numerous characteristics and advantages of the present technology have been set forth in the foregoing description, together with details of the structure and function of the present disclosure, the disclosure is illustrative only, and changes may be made in the detail, including in matters of shape, size and arrangement of the parts within the principles of the present disclosure up to, and including, the full extent established by the broad general meaning of the terms used in the claims.

Depending on the embodiment, certain of the steps of methods described may be removed, others may be added, and the sequence of steps may be altered. The description and the claims drawn to a method may include some indication in reference to certain steps. However, the indication used is only to be viewed for identification purposes and not as a suggestion as to an order for the steps.

What is claimed is:

1. A fuel cell module, comprising:

a container, wherein the container comprises a housing and a nozzle, and the housing defines a plurality of through holes; the housing defines a chamber and an opening; the nozzle has a first end connected to the opening and a second end opposite to the first end; and

a membrane electrode assembly located on the container and covering the plurality of through holes, wherein the membrane electrode assembly comprises a proton exchange membrane having a first surface and a second surface opposite to the first surface, a cathode electrode located on the first surface and an anode electrode located on the second surface; the membrane electrode assembly is curved and surrounds the chamber.

2. The fuel cell module of claim **1**, wherein the container further comprises a baffle located in both the nozzle and the chamber.

3. The fuel cell module of claim **1**, wherein the housing defines a first opening and a second opening; and the container comprises a first nozzle in connected to the first opening and a second nozzle in connected to the second opening.

4. The fuel cell module of claim **3**, wherein the container further comprises a baffle located in the chamber to divide the chamber in to a first space connected to the first nozzle and a second space connected to the second nozzle.

5. The fuel cell module of claim **1**, wherein a ratio between the maximum diameter of the chamber and the maximum diameter of the nozzle is in a range from about 1.5:1 to about 100:1.

6. The fuel cell module of claim **1**, wherein the container comprises rigid materials selected from the group consisting of metal, ceramic, glass, quartz, diamond and plastic.

7. The fuel cell module of claim **1**, wherein a shape of the housing is spherical, hemispherical, cylindrical or bellows shape.

8. The fuel cell module of claim **1**, wherein the container comprises an outside surface and an inside surface opposite to the outside surface; and the membrane electrode assembly is located on the inside surface.

9. The fuel cell module of claim **1**, wherein the container comprises an outside surface and an inside surface opposite to the outside surface; and the membrane electrode assembly is located on the outside surface.

10. The fuel cell module of claim **1**, wherein the container is made of conductive material and used as a first current collector; and further comprises a second current collector so that the membrane electrode assembly is located between the first current collector and the second current collector.

11. The fuel cell module of claim **1**, wherein the container is made of insulative material; the fuel cell module further comprises a first current collector located between the container and the membrane electrode assembly and a second current collector, and the membrane electrode assembly is located between the first current collector and the second current collector.

12. The fuel cell module of claim **1**, wherein each of the cathode electrode and the anode electrode comprises a gas diffusion layer and catalyst dispersed on the gas diffusion layer.

13. The fuel cell module of claim **12**, wherein the gas diffusion layer is a carbon nanotube layer.

14. The fuel cell module of claim **1**, wherein the membrane electrode assembly is located on entire outside surface or entire inside surface of the housing.

15. The fuel cell module of claim **14**, wherein the membrane electrode assembly is further located on entire outside surface or entire inside surface of the nozzle.

16. The fuel cell module of claim **1**, wherein the housing is a bellows.

17. A fuel cell module, comprising:

a container, wherein wall of the container is curved to form a chamber and defines a plurality of through holes on wall of the container; and

a membrane electrode assembly located on the container and covering the plurality of through holes, wherein the membrane electrode assembly comprises a proton exchange membrane having a first surface and a second surface opposite to the first surface, a cathode electrode located on the first surface and an anode electrode located on the second surface: the membrane electrode assembly is curved and surrounds the chamber.

18. The fuel cell module of claim **17**, wherein the membrane electrode assembly is located on entire outside surface or entire inside surface of the container.

19. The fuel cell module of claim **17**, wherein the container comprises a bellows.

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