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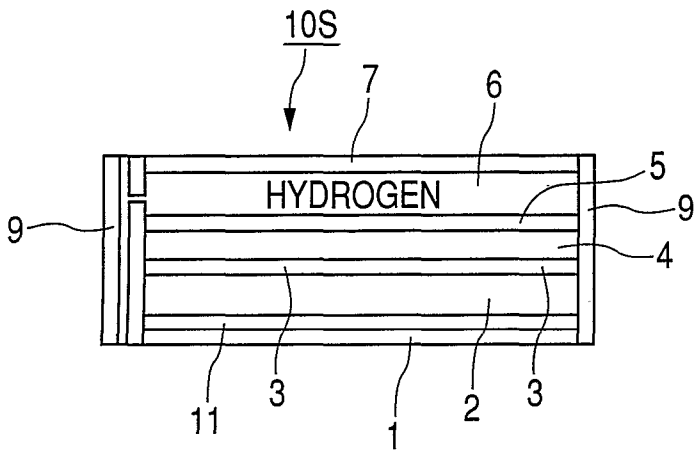
(54) **Title:** FUEL CELL



(57) **Abstract:** There is provided a fuel cell including an electrolyte film, a catalyst layer, two diffusion layers, a fuel supply layer, an oxygen supply layer, a water-absorbing layer, and a collector, in which the fuel cell has an opening at least in a part of a side surface parallel to a proton conduction direction of the electrolyte film among side surfaces of the fuel cell; the water-absorbing layer is present between the oxygen supply layer and the collector; and an end portion of the water-absorbing layer is present on one of a plane including the opening and an opposite side ., of the fuel cell with the plane including the opening being a reference, and a fuel cell system having a fue.l cell stack including the fuel cells. The fuel cell has high dischargeability, is capable of stably maintaining a high generation efficiency and realizes a high output even in a small size and a light weight.

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DESCRIPTION

FUEL CELL

TECHNICAL FIELD

The present invention relates to a fuel cell including an oxygen supply layer that functions as a supply path for oxygen with respect to a power generation layer member and a discharge path for water molecules generated by the power generation layer member. More specifically, the present invention relates to a fuel cell capable of efficiently removing unnecessary liquid water from the power generation layer member, and a fuel cell system using the fuel cells.

BACKGROUND ART

A fuel cell system has been put into practical use, which includes a sealed fuel gas supply space on one surface side of a power generation layer member and an oxygen supply layer on the other surface side of the power generation layer member. The power generation layer member takes in hydrogen ions from the fuel gas supply space, and allows the hydrogen ions to react with oxygen on a surface on the oxygen supply layer side, thereby generating power. The oxygen supply layer is not only a supply path for supplying a

required amount of oxygen to the surface of the power generation layer member but also a diffusion (or forceful discharge) path for transporting out water molecules generated in the power generation layer member.

US Patent No. 6,423,437 shows a fuel cell system in which fuel cells each having a power generation layer member are stacked and connected in series. Oxygen in the atmosphere is taken in through an opening on a side surface of each fuel cell, and water in the oxygen supply layer is evaporated and diffuses to the atmosphere through the same opening. As the power generation layer member, a membrane electrode assembly in which a porous conductive catalyst layer is formed on both surfaces of a polymer eletrolyte film is adopted, a side surface bordering the opening in a plate-shaped oxygen supply layer having three-dimensional air permeability is opened to the atmosphere. Oxygen taken in from the side surface of the oxygen supply layer diffuses three-dimensionally in the oxygen supply layer, and is supplied to the entire surface of the membrane electrode assembly through one bottom surface of the oxygen supply layer. Water molecules generated in the membrane electrode assembly are taken in the oxygen supply layer as water vapor, moves to the side surface in accordance with the concentration gradient of water vapor, and diffuses to

the atmosphere through the opening.

Japanese Patent Application Laid-Open No. 2005-174607 shows a fuel cell system which forcefully sends the atmosphere from one side surface to the other side surface of an oxygen supply layer to allow it flow through. Herein, a separator, in which a groove-shaped air flow path passing through the opposed side surfaces of the fuel cell system is placed so as to be stacked on the oxygen supply layer. Then, the tissue density of the oxygen supply layer being in contact with the air flow path is changed in the thickness direction, and the tissue density of a surface layer being in contact with the air flow path and a surface layer being in contact with the membrane electrode assembly is set to be higher than that of an intermediate layer, whereby the water-retaining property of the intermediate layer is enhanced.

Japanese Patent Application Laid-Open No. 2002-110182 shows a fuel cell system in which a catalyst layer is formed on a surface on a polymer eletrolyte film side of an oxygen diffusion layer stacked on a power generation layer member. The supply of oxygen and the discharge of water vapor in the oxygen diffusion layer are performed passively by natural diffusion. The oxygen diffusion layer is allowed to pass through in the thickness direction to form an infinite number of through-holes with an

aperture of 100 μm or less at a density of 400 holes per mm^2, whereby the diffusion performance in the thickness direction is enhanced. Each through-hole (in a cone shape) whose cross-sectional area increases from a polymer eletrolyte film side to a surface on the opposite side increases the contact area on the polymer eletrolyte film side and the strength of the oxygen diffusion layer, while decreasing the passage resistance of oxygen and water vapor.

Japanese Patent Application Laid-Open No. 2005-353605 discloses a fuel cell system including a water-absorbing material at an oxygen electrode, which sucks out water using the capillary action, thereby suppressing flooding.

It is desirable that the fuel cell system carried integrally with equipment perform the supply of oxygen and the discharge of water vapor through the oxygen supply layer passively by natural diffusion. It is desirable that such a fuel cell system require no supply of power from outside for activation, because a circulation mechanism and a blower of the atmosphere increases a parts count, which contradicts the miniaturization and reduction in weight of the fuel cell system. A fuel cell system shown by Japanese Patent Application Laid-Open No. 2005-174607 is predicated upon such a circulation mechanism and blower of the atmosphere.

However, in the case where the supply of oxygen and the discharge of water vapor in the oxygen supply layer are performed totally by natural diffusion, the movement directions of oxygen and water vapor are opposite to each other. Therefore, if the output current of the fuel cell system increases to increase the discharge amount of water vapor, there is a possibility that the supply of oxygen may be prevented. Particularly, in the case where fuel cells are stacked and water vapor is discharged through an opening on a side surface of each fuel cell, oxygen is hindered by the flow of water vapor directed to the opening, with the result that the oxygen is unlikely to reach a portion away from the opening.

When the supply of oxygen to the power generation layer member is hindered, the electromotive power decreases to reduce the power generation efficiency of the fuel cell. When the heat generation amount increases to cause a further increase in temperature as a result of the reduction in the power generation efficiency, the water vapor partial pressure in the oxygen supply layer increases, and the oxygen partial pressure decreases, with the result that the supply of oxygen with respect to the power generation layer member is further hindered.

Further, when the water vapor partial pressure of the oxygen supply layer increases, the evaporation of

generated water at the interface of the power generation layer member is hindered to accumulate liquid water, and the interface is covered with liquid water locally to cause flooding. In the flooded portion, the supply of oxygen ceases, and the power generation stops. Therefore, the current density in a portion that is not flooded increases, and the electromotive force of the fuel cell decreases. Then, when an operation is continued as it is, the flooded region spreads to a region where the current density has increased, leading to the flooding of the entire surface of the power generation layer member, which may result in the overall suspension of the power generation of the fuel cell.

Thus, compared with the active type in which the atmosphere is forcefully circulated to the oxygen supply layer to forcefully discharge water vapor, in the passive type depending upon natural diffusion, it is necessary to set a current value per unit surface area of the power generation layer member to be extremely small. When the current value per unit surface area is set to be extremely small, the area of the power generation layer member increases to enlarge a power generation portion, which may enlarge the fuel cell system to be even larger than that of the active type.

A fuel cell system shown by Japanese Patent

Application Laid-Open No. 2005-174607 sets the density of a surface layer of an oxygen supply layer being in contact with a power generation layer member to be higher than that of an intermediate layer, thereby sucking up liquid water at an interface of the power generation layer member to the intermediate layer efficiently to vaporize and diffuse the liquid water. However, the water vapor supplied to the intermediate layer is accumulated in the intermediate layer to hinder the diffusion of oxygen and the supply of oxygen to the power generation layer member through the intermediate layer until the water vapor is discharged through a surface layer on an opposite side where the density has increased. Then, the surface layer for actively accumulating water in the intermediate layer member increases the water vapor pressure in the intermediate layer, thereby making it difficult for oxygen to reach the power generation layer member.

A fuel cell system shown by Japanese Patent Application Laid-Open No. 2002-110182 is predicated upon the passive type depending upon natural diffusion, thereby enhancing the water discharge performance from a power generation layer member to an oxygen supply layer. However, the water taken in the oxygen supply layer still moves in an opposite direction to that of oxygen in the oxygen supply layer due to natural diffusion of water vapor. That is, the water vapor

partial pressure of the oxygen supply layer is not decreased so as to facilitate the evaporation of generated water in the power generation layer member, and the movement/diffusion of oxygen through the oxygen supply layer is not facilitated.

A fuel cell system shown by Japanese Patent Application Laid-Open No. 2005-353605 has a configuration in which a catalyst is surrounded by a water-absorbing material, so that a catalyst portion cannot help being reduced in size, which makes it difficult to exhibit sufficient performance.

DISCLOSURE OF THE INVENTION

The present invention provides a fuel cell capable of discharging generated water generated in accordance with the power generation from an oxygen supply layer easily without depending upon a forceful and active procedure, maintaining a high power generation efficiency stably even at a high current value, and realizing a high output even with a small size and a light weight, and a fuel cell system including the fuel cells.

According to the present invention, there is provided a fuel cell including: a power generation layer member for moving hydrogen ions from one surface to another surface, and causing the hydrogen ions to react with oxygen on the another surface; and an oxygen

supply layer for diffusing oxygen in an atmosphere taken in from a side surface to supply the oxygen to the another surface, in which: the fuel cell has a water-absorbing layer; and the water-absorbing layer whose stability of holding liquid water is higher than that of the oxygen supply layer, is communicated with the oxygen supply layer and is placed opposed to the power generation layer member with at least the oxygen supply layer interposed therebetween.

It is preferable that the water-absorbing layer be a sheet-shaped member made of a material different from that of the oxygen supply layer, and the material for the water-absorbing layer have hydrophilicity higher than that of the material for the oxygen supply layer.

It is preferable that air permeability of the oxygen supply layer in a direction communicating the power generation layer member with the water-absorbing layer be higher than that in a direction along a surface of the power generation layer member.

It is preferable that the fuel cell include a diffusion layer placed between the oxygen supply layer and the power generation layer member, whose average opening size of a tissue is smaller than that of the oxygen supply layer and larger than that of the power generation layer member, and a number of through-holes communicating the oxygen supply layer with the power

generation member be formed in the diffusion layer.

It is preferable that at least a part of the water-absorbing layer be directly opened to an atmosphere outside of the oxygen supply layer.

It is preferable that the water-absorbing layer at a plane position close to the side surface from which oxygen is taken in have the stability for holding liquid water higher than that at a plane position away from the side surface from which oxygen is taken in.

It is preferable that supply of oxygen from the side surface from which oxygen is taken in to the power generation layer member depend upon natural diffusion of oxygen through the oxygen supply layer.

Further, according to the present invention, there is also provided a fuel cell including an electrolyte film, a catalyst layer, two diffusion layers, a fuel supply layer, an oxygen supply layer, a water-absorbing layer, and a collector, in which: the fuel cell has an opening at least in a part of a side surface parallel to a proton conduction direction of the electrolyte film among side surfaces of the fuel cell; the water-absorbing layer is present between the oxygen supply layer and the collector; and an end portion of the water-absorbing layer is present on one of a plane including the opening and an opposite side of the fuel cell with the plane including the opening being a reference.

It is preferable that the water-absorbing layer include a plurality of regions each having hydrophilicity different from that of a different region, and the hydrophilicity be higher in a region closer to the opening among the plurality of regions.

It is preferable that the oxygen supply layer have a groove on a surface thereof in the collector side, and at least a part of the water-absorbing layer be present in the groove.

It is preferable that the oxygen supply layer have a plurality of holes each of whose depth direction being a direction parallel to the proton conduction direction.

It is preferable that the water-absorbing layer be present in the hole.

It is preferable that the water-absorbing layer present between the oxygen supply layer and the collector be connected to the water-absorbing layer present in the hole.

It is preferable that the water-absorbing layer be not in contact with the diffusion layer.

It is preferable that an end portion of the collector be present on the opposite side of the fuel cell with the plane including the opening being a reference, and at least a part of a region present on an opposite side of the fuel cell with the plane including the opening in the collector being a

reference be in contact with the water-absorbing layer.

It is preferable that the collector have a comb shape.

It is preferable that a fuel cell system include a fuel cell stack made of the fuel cells.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view illustrating an entire configuration of a fuel cell system in Embodiment 1.

FIG. 2 is a cross-sectional view in which the fuel cell in Embodiment 1 is cut along a plane parallel to a plane including openings.

FIG. 3 is a cross-sectional view in which a membrane electrode assembly in Embodiment 1 is cut along the plane parallel to the plane including the openings.

FIG. 4 is a cross-sectional view in which a fuel cell including a plurality of water-absorbing layers is cut along the plane parallel to the plane including the openings in Embodiment 1.

FIG. 5 is a projected view in which light is irradiated in a direction parallel to a proton conduction direction from a collector side to a plurality of water-absorbing layers and an oxygen supply layer in Embodiment 1.

FIG. 6 is a cross-sectional view in which the

fuel cell in Embodiment 1 is cut along a plane perpendicular to the plane including the openings.

FIG. 7 is a cross-sectional view in which a fuel cell in Embodiment 2 is cut along the plane perpendicular to the plane including the openings.

FIG. 8 is a projected view in which light is irradiated in a direction parallel to a proton conduction direction from a collector side to a plurality of water-absorbing layers and an oxygen supply layer in Embodiment 2.

FIG. 9 is a cross-sectional view in which a fuel cell in Embodiment 3 is cut along a plane perpendicular to a plane including openings.

FIG. 10 is a cross-sectional view in which a fuel cell in Embodiment 4 is cut along a plane perpendicular to a plane including openings.

FIG. 11 is a cross-sectional view in which a fuel cell in Embodiment 5 is cut along a plane perpendicular to a plane including openings.

FIG. 12 is a cross-sectional view in which the fuel cell in Embodiment 5 is cut along the plane parallel to the plane including the openings.

FIG. 13 is a cross-sectional view in which a fuel cell in Embodiment 6 is cut along a plane perpendicular to a plane including openings.

FIG. 14 is a cross-sectional view in which a collector in Embodiment 6 is cut along a plane

perpendicular to a proton conduction direction.

FIG. 15 is a projected view in which light is irradiated in a direction parallel to the proton conduction direction from an oxygen supply layer side to the collector and water-absorbing layer in Six Embodiment.

FIG. 16 is a projected view in which light is irradiated in a direction parallel to the proton conduction direction from an outside of the fuel cell to the collector and water-absorbing layer in Embodiment 6.

FIG. 17 is a cross-sectional view in which a collector in Embodiment 7 is cut along a plane perpendicular to a proton conduction direction.

FIG. 18 is a projected view in which light is irradiated in a direction parallel to the proton conduction direction from an oxygen supply layer side to the collector and water-absorbing layer in Embodiment 7.

FIG. 19 is a cross-sectional view in which the collector and water-absorbing layer in Embodiment 7 are cut along the plane perpendicular to the plane including the openings.

FIG. 20 is a cross-sectional view in which a fuel cell in Comparative Embodiment 1 is cut along a plane parallel to a plane including openings.

FIG. 21 is a cross-sectional view in which the

fuel cell in Comparative Embodiment 1 is cut along a plane perpendicular to the plane including the openings.

FIG. 22 is a cross-sectional view in which a fuel cell in Comparative Embodiment 2 is cut along a plane perpendicular to a plane including openings.

FIG. 23 is a cross-sectional view in which a fuel cell in Comparative Embodiment 3 is cut along a plane perpendicular to a plane including openings.

FIGS. 24A, 24B, and 24C are views illustrating water-absorbing layers and an oxygen supply layer in Example 1.

FIGS. 25A, 25B, and 25C are views illustrating water-absorbing layers and an oxygen supply layer in Example 2.

FIG. 26 is a graph illustrating the performance of the fuel cells in Example 1, Example 2, and Comparative Example 1.

FIGS. 27A, 27B, 27C, and 27D are views illustrating water-absorbing layers and an oxygen supply layer in Example 3.

FIG. 28 is a graph illustrating the performance of the fuel cells in Example 3 and Comparative Example 1.

FIGS. 29A, 29B, and 29C are views illustrating water-absorbing layers and an oxygen supply layer in Comparative Example 2.

FIG. 30 is a graph illustrating the performance

of the fuel cells in Example 1 and Comparative Example 2.

FIGS. 31A, 31B, and 31C are views illustrating water-absorbing layers and an oxygen supply layer in Comparative Example 3.

FIG. 32 is a graph illustrating the performance of the fuel cells in Example 1 and Comparative Example 3.

FIG. 33 is a graph illustrating the performance of the fuel cells in Example 1 and Comparative Example 3.

FIGS. 34A, 34B, 34C, and 34D are views illustrating a collector and water-absorbing layers in Example 4.

FIGS. 35A, 35B, 35C, and 35D are views illustrating a collector and water-absorbing layers in Example 5.

FIG. 36 is a graph illustrating the performance of the fuel cells in Example 1, Example 4, and Example 5, and Comparative Example 1.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, embodiments of a fuel cell and a fuel cell system of the present invention will be described in detail with reference to the drawings. The fuel cell and fuel cell system of the present invention are not limited to the configuration

described below. A fuel cell at least including a membrane electrode assembly (power generation layer member), two diffusion layers, an oxygen supply layer, a water-absorbing layer, and a fuel supply layer can be realized even in another embodiment in which a part or an entirety of the configuration is replaced by an alternative configuration.

In the fuel cell and the fuel cell system of this embodiment, power is generated using fuel gas stored in a fuel tank. However, liquid fuel containing hydrogen atoms such as methanol may be stored in the fuel tank and reformed to fuel gas in a required amount every moment.

Further, the fuel cell system of this embodiment can be used for portable electronic equipment, such as a digital camera, a digital video camera, a small projector, a small printer, and a notebook personal computer. In such a case, the fuel cell system of the present invention can also be used as an independent fuel cell to be mounted attachably/detachably, and only a power generation portion of the fuel cell system is incorporated integrally with electronic equipment so that a fuel tank is attached/detached.

The respective embodiments of the present invention are as follows.

Embodiment 1 provides a fuel cell with a configuration in which a water-absorbing layer is

provided between an oxygen supply layer and a collector, and an end portion of the water-absorbing layer is present on a plane including openings, and a fuel cell system including the fuel cells.

Embodiment 2 provides a fuel cell with a configuration in which a water-absorbing layer is provided between an oxygen supply layer and a collector, and an end portion of the water-absorbing layer is present on an opposite side of the fuel cell with a plane identical with openings being a reference, and a fuel cell system including the fuel cells.

Embodiment 3 provides a fuel cell with a configuration in which the water-absorbing layer in Embodiment 2 includes a plurality of regions with different hydrophilicity, and the hydrophilicity is higher in a region closer to an opening among the plurality of regions, and a fuel cell system including the fuel cells.

Embodiment 4 provides a fuel cell with a configuration in which the oxygen supply layer in Embodiment 2 has a through-hole, and a fuel cell system including the fuel cells.

Embodiment 5 provides a fuel cell with a configuration in which the oxygen supply layer in Embodiment 2 has a groove and a hole, and a water-absorbing layer is present in the groove and the hole, and a fuel cell system including the fuel cells.

Embodiment 6 provides a fuel cell with a configuration in which a collector being in contact with an oxygen supply layer also has an end portion on an opposite side from the fuel cell, with a plane including openings being a reference in Embodiment 2, and a fuel cell system including the fuel cells.

Embodiment 7 provides a fuel cell with a configuration in which a portion present on an opposite side from the fuel cell has a comb shape with a plane including openings in the collector being a reference in Embodiment 6, and a fuel cell system including the fuel cells.

(Embodiment 1)

FIG. 1 is a perspective view illustrating an entire configuration of a fuel cell system in Embodiment 1, and FIG. 2 is a cross-sectional view in which a fuel cell constituting the fuel cell system is cut along a plane parallel to a plane including openings. Further, FIG. 6 is a cross-sectional view in which the fuel cell is cut along a plane perpendicular to the plane including the openings. In FIG. 6, right and left ends 8 on the drawing surface of the fuel cell are openings.

As illustrated in FIG. 1, a fuel cell system 10 includes a cell stack (fuel stack) 10A in which fuel cells (power generation cells) 10S are stacked to be connected in series. A fuel tank 10B for storing fuel

gas and supplying it to the fuel cells 10S is present below the cell stack 10A, and the cell stack 10A and the fuel tank 10B are connected to each other through a flow path (not shown) of the fuel gas. The fuel gas taken out from the fuel tank 10B is adjusted to a pressure slightly higher than the atmospheric pressure, and supplied to each fuel cell 10S.

The fuel cell 10S has openings 8 in end surfaces S1 and S2 of the cell in a direction parallel to a proton conduction direction of an eletrolyte film, among side surfaces of the fuel cell. More specifically, the fuel cell 10S has the openings 8 on two side surfaces among the side surfaces parallel to the proton conduction direction among the side surfaces of the oxygen supply layer. The opening 8 functions as an air intake port for taking air in the atmosphere in the fuel cell 10S by natural diffusion, and the fuel cell 10S generates power by allowing the fuel gas supplied from the fuel tank 10B to react with oxygen in the air taken in through the openings 8. As in this embodiment, due to the presence of the openings on the side surfaces parallel to the proton conduction direction among the side surfaces of the fuel cell, even in the case of forming a fuel cell system in which a plurality of fuel cells are stacked to be connected, there is no possibility that the openings of one fuel cell are closed by another fuel cell to hinder the

intake of air. In the case where the fuel cell is a rectangular solid as illustrated in FIG. 2, it is preferable that openings are provided on two opposed side surfaces. Further, in the case where a side surface has a cylindrical shape, it is preferable that an opening becomes a part of a side surface of a cylinder, and openings are provided respectively on opposed side surfaces of the cylinder.

As illustrated in FIG. 2, the fuel cell 10S includes at least a membrane electrode assembly (MEA) 4, diffusion layers 3 and 5, a fuel supply layer 6, an oxygen supply layer 2, a water-absorbing layer 11, a collector 1, and separators 7 and 9.

As illustrated in FIG. 6, the oxygen supply layer 2 plays two roles of: supplying and diffusing oxygen in the atmosphere which is an oxidizer taken in through the openings 8 to the oxygen supply layer; and flowing electrons required for an electrode reaction in a catalyst layer (oxygen electrode) to a catalyst layer (oxygen electrode) of the membrane electrode assembly 4 through the diffusion layer 3. Further, the oxygen supply layer 2 also has a function of guiding water (water vapor) generated in the membrane electrode assembly 4 in accordance with the power generation from the diffusion layer 3 to the openings 8 to discharge the water from the inside of the cell to the atmosphere. Therefore, as the oxygen supply layer 2, a porous body

having conductivity is preferable. As the oxygen supply layer 2 satisfying such a condition, it is preferable that the porosity is 80% or more, and the hole diameter is 0.1 mm or more. As specific examples for the oxygen supply layer 2, foam metal, stainless wool, and the like are preferable.

In this example, it is described that the collector 1 has the function as a partition (separator) with respect to an adjacent fuel cell 10S, and the function of collecting electricity as a collector. Thus, the collector 1 may be described as a separator. Further, in the case where the collector 1 does not have the function as a separator, and a separator is present separately, the separator is formed at a position opposed to the oxygen supply layer 2 with the collector 1 interposed therebetween.

The separators 7 and 9 are sealed so that a passage portion for fuel gas which is fuel of the fuel cell 10S is not mixed with outside air. Further, the fuel supply layer 6 and the diffusion layer 5 are present between the separator 7 and the membrane electrode assembly 4. In this example, the separator 7 also has a function as the collector.

The fuel gas taken out from the fuel tank 10B illustrated in FIG. 1 is supplied to the fuel supply layer 6 illustrated in FIG. 2, and after that, diffuses in the diffusion layer 5. As the fuel supply layer 6,

carbon cloth and carbon paper having a carbon particle layer on its surface can be used.

It is preferable that the average opening diameter of a material for constituting the fuel supply layer 6 is in a range of 100 μm to 900 μm. The fuel gas is separated from a main flow path of the fuel gas present in parallel to the proton conduction direction in the separator 9, and supplied to the fuel supply layer in the fuel cell 10S.

The diffusion layer 5 is present between the membrane electrode assembly 4 and the fuel supply layer 6 so as to be in contact with both of them, diffuses hydrogen gas that is fuel, and collects electrons that become a residual due to the ionization of hydrogen from the catalyst layer of the membrane electrode assembly 4. Further, the diffusion layer 3 is present between the membrane electrode assembly 4 and the oxygen supply layer 2 so as to be in contact with both of them, and plays the role of diffusing oxygen, and supplying electrons required for an electrode reaction in the catalyst layer (oxygen electrode) to the catalyst layer (oxygen electrode) of the membrane electrode assembly 4. The diffusion layer 5 has conductivity, and is made of a material having a hole smaller than that of the material of the fuel supply layer 6. In the present invention, the tissue of the diffusion layer refers to a material constituting the

diffusion layer. Further, "the diffusion layer 5 is made of a material having a hole smaller than that of the material of the fuel supply layer 6" means that the average hole diameter of a material constituting the diffusion layer 5 is smaller than the average hole diameter of a material constituting the fuel supply layer 6. Further, the average opening diameter (hole diameter) of a material constituting the diffusion layer 5 has an opening diameter (1 μm), which is an intermediate value between the average opening diameter of a material constituting the catalyst layer that is a fuel electrode and the average opening diameter of a material constituting the fuel supply layer. Thus, the fuel supply layer 6 functions as a diaphragm resistor, and supplies fuel gas at an equal pressure and an equal flow rate density over the entire surface of the membrane electrode assembly 4.

Further, the diffusion layer 3 also has conductivity, and is made of a material having a hole smaller than that of the material of the oxygen supply layer 2. The average opening diameter of a material constituting the diffusion layer 3 is similarly larger than the average opening diameter of a material constituting the catalyst layer that is an oxygen electrode and smaller than the average opening diameter of a material constituting the oxygen supply layer 2. With such an opening diameter, the oxygen supply layer

2 functions as a diaphragm resistor, and supplies oxygen at an equal pressure and an equal flow rate density over the entire surface of the membrane electrode assembly 4. The hole of the diffusion layer 3 may be a through-hole communicating the oxygen supply layer 2 with the membrane electrode assembly 4. Since the diffusion layer 3 has a though-hole at a high density, generated water accumulated between the membrane electrode assembly 4 and the diffusion layer 3 can also be sucked up to the oxygen supply layer 2. As materials constituting the diffusion layer 3 and the diffusion layer 5, carbon paper and carbon cloth can be used.

As illustrated in FIG. 3, the membrane electrode assembly 4 includes an eletrolyte film 12 and two catalyst layers 13 and 14 (a fuel electrode and an oxygen electrode, respectively) formed so as to be in contact with both surfaces of the eletrolyte film. The eletrolyte film may be made of any material, as long as proton conduction can be performed in a direction from the fuel supply layer to the oxygen supply layer. Among such eletrolyte films, a solid polymer eletrolyte film is preferable, and examples thereof include Nafion (Trade Mark) produced by Dupont, which is a perfluorocarbon polymer with a sulfonic group.

Two catalyst layers constituting the membrane electrode assembly 4 contain at least a substance

having a catalytic activity. In the case where a substance having a catalytic activity cannot be present as a single substance, a catalyst layer may be formed by allowing a carrier to carry a catalytic active substance. As an example of the catalytic active substance present as a single substance, there is a platinum catalyst in a resin shape formed by sputtering. On the other hand, as an example of a carrier carrying a catalytic active substance, there is a carbon particle carrying platinum. The catalyst layer may contain an electron conductor and a proton conductor (polymer electrolyte material) such as carbon particles. The catalyst layer may be integrated so as to be in contact with the surface of the eletrolyte film, but as long as the catalyst layer is in contact with the eletrolyte film and chemical species such as hydrogen ions can be delivered, it is not necessary that the catalyst layer is formed integrally with the membrane electrode assembly 4. Further, the average opening diameter of the catalyst layer is preferably in a range of 10 nm to 100 nm. In the following description, the catalyst layer on the fuel supply layer side may be called a fuel electrode, and the catalyst layer on the oxygen supply layer side may be called an oxygen electrode.

The fuel cell of the present invention is of a passive type which performs the supply of oxygen and

the discharge of water vapor through an opening by natural diffusion of oxygen. As is understood from the figures, the region of the oxygen supply layer 2 other than the openings 8 is surrounded by the collector 1. Thus, water generated at the oxygen electrode becomes vapor through the diffusion layer 3, and after that, is cooled by the collector 1 to become water droplets in the oxygen supply layer 2. When the amount of water droplets becomes excessive, the water droplets may close the oxygen supply layer 2. Therefore, the decrease in oxygen diffusion causes a voltage drop, which is caused by flooding.

In order to solve the above-mentioned problem, the water-absorbing layer 11 is formed in a region between the collector 1 and the oxygen supply layer 2, where water droplets are generated. The water-absorbing layer 11 are formed so that it is communicated with the oxygen supply layer 2 and an end portion of the water-absorbing layer 11 is present on a plane including the openings 8. That is, the water-absorbing layer 11 is formed at a position opposed to the membrane electrode assembly 4 at a distance from the diffusion layer 3 and the oxygen supply layer 2, and at a position where the end portion of the water-absorbing layer 11 is likely to come into contact with outside air through the openings 8. The water-absorbing layer 11 is placed only in a part between the

collector 1 and the oxygen supply layer 2. Because of this, the electrical contact between the collector 1 and the oxygen supply layer 2 is not hindered. Examples of a method of arranging as such include a method of providing a groove in at least one of the oxygen supply layer 2 and the collector 1, and arranging the water-absorbing layer 11 in the groove.

Further, only one water-absorbing layer 11 may be formed as illustrated in FIG. 2, or a plurality of water-absorbing layers 11 may be formed as illustrated in FIG. 4. FIG. 5 is a projected view in which light is irradiated in a direction parallel to a proton conduction direction from the collector 1 side to the water-absorbing layer 11 and the oxygen supply layer 2 in the fuel cell of FIG. 4.

In the case where the water-absorbing layer 11 is formed in the groove of the oxygen supply layer 2, it is preferable that the thickness of the water-absorbing layer 11 be smaller than that of the oxygen supply layer 2 so that the water-absorbing layer 11 does not hinder the oxygen diffusion in the oxygen supply layer 2. For example, in the case where the thickness of the oxygen supply layer 2 is 1 mm or more and 3 mm or less, the thickness of the water-absorbing layer 11 is preferably 1 μm or more and less than 1 mm.

Further, the water-absorbing layer 11 includes a water-absorbing material. The water-absorbing material

constituting the water-absorbing layer 11 is preferably a sheet-shaped material which is made of fibers having a quick-drying property as well as water absorptivity, and is more preferably a sheet-shaped material which has hydrophilicity higher than that of the material for the oxygen supply layer 2 and is independent from the oxygen supply layer 2. When the hydrophilicity of a material constituting the water-absorbing layer 11 is higher than that of a material for the oxygen supply layer 2, water is more likely to move from the oxygen supply layer 2 to the water-absorbing layer 11. In the present invention, "stability for holding liquid water" has the same meaning as that of "hydrophilitic". In the case where the surface is made of a hydrophilic material, hydrophilicity is higher than that of the case where a water-repellent (hydrophobic) material is used, so that the stability for holding liquid water can be considered to be high. Further, in the case of using a hydrophilic material, it can be considered that hydrophilicity is higher (stability for holding liquid is higher) when the average opening diameter (gap) of the surface of the hydrophilic material is smaller. If the surface is made of a water-repellent (hydrophobic) material, it can be considered that hydrophilicity is higher (stability for holding liquid is higher) when the average opening diameter (gap) of a tissue is larger.

Further, in the present invention, the "water-absorbing material" refers to a material capable of sucking up water by capillary phenomenon, and more specifically, a water-absorbing material with a water suction height of 30 mm or more 10 seconds after the material is soaked in water. Further, the "quick-drying material" refers to a material capable of easily drying and releasing absorbed water, and more specifically, a material with a drying ratio of 80% or more after the elapse of one hour in an atmosphere of 50% and 25°C. Herein, the drying ratio refers to a ratio of the weight of water remaining in the water-absorbing layer after being left for one hour in a constant temperature and constant humidity tank in a windless state, with respect to the weight of water absorbed by the water-absorbing layer by capillary phenomenon. For example, in the case where the weight of water-absorbing fibers is 0.5 g, and the total weight of the water-absorbing fibers after absorbing water by capillary phenomenon becomes 1.5 g, the weight of absorbed water is 1 g. Assuming that the total weight of the fibers is 0.6 g after being left for one hour in a constant temperature and constant humidity tank of 50% at 25°C in a windless state, the weight of water remaining in the water-absorbing fibers is 0.1 g, i.e., the weight of dried water is 0.9 g. Since 0.9 g of water is dried among 1 g of water, the drying ratio

at this time is 90%.

Examples of such a material having a water-absorbing property and a quick-drying property include a porous material with high hydrophilicity on the surface. Herein, the "material having high hydrophilicity" in the present invention refers to that the contact angle of a water droplet formed on the material is 90° or less.

The roles of the water-absorbing layer 11 are roughly classified into two.

The first role of the water-absorbing layer 11 is to absorb water which coagulates (is generated) in the oxygen supply layer 2, and to allow the oxygen supply layer 2 to keep an oxygen diffusion flow path. The water generated in the membrane electrode assembly 4 by the power generation activity is discharged to the oxygen supply layer 2 through the diffusion layer 3 placed on the outer side of the membrane electrode assembly 4. In the case where there is no water-absorbing layer 11, the generated water discharged to the oxygen supply layer 2 is not removed from the oxygen supply layer 2 except for being evaporated to diffuse (to be released) outside of the cell through the openings 8. Only with the natural diffusion from the oxygen supply layer 2, the generated water discharged to the oxygen supply layer 2 cannot be evaporated sufficiently, which narrows the oxygen

diffusion flow path of the oxygen supply layer 2, and enhances the water vapor partial pressure of the oxygen supply layer 2, thereby hindering the flow of the generated water and water vapor discharged to the oxygen supply layer 2 through the diffusion layer 3. That is, when the water in the oxygen supply layer 2 becomes excessive, the discharge of water from the membrane electrode assembly 4 through the diffusion layer 3 is hindered, and the surface of the membrane electrode assembly 4 is partially submerged in water (flooding). Because of this, the supply of oxygen to the membrane electrode assembly 4 is hindered.

On the other hand, in the case where there is the water-absorbing layer 11 made of a water-absorbing material, water vapor and fog drops are collected actively from the oxygen supply layer 2 by capillary phenomenon of the water-absorbing layer 11, and generated water is formed in the water-absorbing layer 11. Thus, even in the case where a hole diameter is larger or a hole ratio is higher as the oxygen supply layer 2 has less capillary phenomenon, the generated water in the oxygen supply layer 2 is taken in the water-absorbing layer 11 by the capillary phenomenon of the water-absorbing layer 11. That is, the water-absorbing layer 11 can alleviate the inhibition of the supply of oxygen and the discharge of water vapor through the openings 8.

Further, due to the presence of the end portion of the water-absorbing layer on a plane including the openings, liquid water absorbed by the water-absorbing layer 11 is likely to come into contact with outside air, and is evaporated to diffuse efficiently. In the present invention, in the case where the opening has a curved surface, the plane including the openings refers to a curved surface formed by moving the curved surface in parallel to the proton conduction direction. Further, in the case where the opening has a curved surface, the plane perpendicular to the plane including openings refers to a plane parallel to a symmetric plane of the plane including the curved surface.

The surface of the collector 1 on the water-absorbing layer 11 side may be subjected to special surface treatment for enhancing hydrophilicity. Examples of such a method include coating of a hydrophilic coating with respect to the collector 1, sandblast treatment of the surface of the collector 1 using a material with very high hydrophilicity, and sputter coating of titanium oxide and silicon oxide with respect to the collector 1. Needless to say, due to such a method, liquid water coagulates on the surface, and permeates and diffuses along the surface.

The second role of the water-absorbing layer 11 is to keep the humidity in the oxygen supply layer 2 to be constant.

When the water of the membrane electrode assembly 4 becomes insufficient, dryout phenomenon in which an eletrolyte film is dried, and hydrogen ions are not conducted occurs. Thus, it is desirable that the humidity in the fuel cell 10S be kept at an appropriate humidity. Since the humidity is kept to be constant owing to the presence of the water-absorbing layer 11, in the case where the membrane electrode assembly 4 is dried, the water evaporated from the water-absorbing layer 11 is absorbed by the eletrolyte film. That is, the water-absorbing layer 11 plays a role of preventing dryout simultaneously with flooding during extreme drying or when the fuel cell 10S is not used, and keeping the fuel cell 10S to be an appropriately humidity.

(Embodiment 2)

FIG. 7 is a cross-sectional view in which a fuel cell in Embodiment 2 is cut along a plane perpendicular to a plane including openings. In Embodiment 2, a fuel cell system can be assembled in the same way as those in Embodiment 1, except that the shape of the water-absorbing layer 11 is different from that of Embodiment 1. Thus, when this embodiment is described, FIG. 1 is also referred to, and the constitutions common in FIGS. 2 and 6 are denoted with the common reference numerals, and the detailed description thereof will be omitted.

As illustrated in FIG. 7, a fuel cell 20S in

Embodiment 2 is a fuel cell having a configuration in which, in the fuel cell 10S in Embodiment 1, a water-absorbing layer is formed so that an end portion is placed on an opposite side of the fuel cell 10S with a plane including openings being a reference. Further, FIG. 8 illustrates the water-absorbing layers 11 and the oxygen supply layer 2 in the case where a plurality of water-absorbing layers are formed in this embodiment, which is a projected view in which light is irradiated to the fuel cell of FIG. 7 in the case of a plurality of water-absorbing layers in a direction parallel to the proton conduction direction from the collector 1 side.

More specifically, the modified point from Embodiment 1 lies in that the water-absorbing layer 11 is extended (expanded) from the openings 8 that are oxide supply ports to be exposed to the outside of the fuel cell 20S. Owing to such a configuration, at least a part of the water-absorbing layer 11 comes into direct contact with outside air (atmosphere) of the cell.

By adopting the configuration in which the water-absorbing layer 11 is exposed to the outside of the fuel cell 20S as in this embodiment, the contact area with respect to outside air increases, whereby water in the water-absorbing layer can be transpired more efficiently than Embodiment 1. Particularly, in an

environment with a large amount of generated water such as an environment under high humidity, water in the water-absorbing layer can be transpired more efficiently than the configuration as in this embodiment. The phrase "at least a part of the water-absorbing layer is directly opened to the atmosphere outside of the oxygen supply layer" refers to that, in a cross-section obtained by cutting a fuel cell along a cross-section perpendicular to the openings, the end portion of the water-absorbing layer is present on the opposite side of the fuel cell with a plane including the openings being a reference, and the water-absorbing layer is exposed directly to the atmosphere.

It is further desirable that a portion (portion extending off from the fuel cell 20S) present on the opposite side of the fuel cell 20S with a plane including the openings in the water-absorbing layer 11 being a reference, be not only extended simply, but also be shaped so that the surface area is further increased by artificially forming unevenness, because the contact area with respect to outside air increases. (Embodiment 3)

FIG. 9 is a view illustrating a configuration of a fuel cell in Embodiment 3. FIG. 9 is a cross-sectional view in which the fuel cell in this embodiment is cut along a plane perpendicular to a plane including openings. In Embodiment 3, components

similar to those in Embodiment 2 are used, except that the internal configuration of the water-absorbing layer 11 is different from that in Embodiment 2, and the fuel cells in this embodiment are stacked and connected similarly to those in Embodiment 1, whereby a fuel cell system in this embodiment can be assembled. Thus, the configurations common to those of FIG. 7 are denoted with the common reference numerals, and the detailed description thereof will be omitted.

In a fuel cell 30S in Embodiment 3, by using a water-absorbing layer 11D with the strength of hydrophilicity varied depending upon a place, instead of the water-absorbing layer 11 of FIG. 7, the discharge performance of discharging water toward the opening 8 is enhanced. Specifically, in the water-absorbing layer, a plane position closer to the side surface from which oxygen is taken in has higher stability of holding liquid water, compared with a plane position away from the side surface from which oxygen is taken in. More specifically, by allowing a place closer to the opening 8 to have stronger hydrophilicity, water can be attracted from the center portion of the oxygen supply layer 2 to the outside, i.e., in a direction of the opening 8 where evaporation and diffusion (transpiration) are likely to occur.

A description will be made specifically with reference to FIG. 9. The water-absorbing layer 11D

includes a water-absorbing layer 11e on an outer side closer to the opening 8 and a water-absorbing layer 11f in a center portion, and the hydrophilicity of 11e is set to be higher than that of 11f. The strength of hydrophilicity can be determined based on the contact angle of a member with respect to a water droplet formed on the surface of the member. The smaller contact angle of water with respect to a member shows that the member has larger strength of hydrophilicity (higher hydrophilicity).

Thus, when the contact angle of water in the water-absorbing layer 11f is θ_f, and the contact angle of water in the water-absorbing layer 11e is θ_e, it is desirable to satisfy the relation of be larger than $\theta_e < \theta_f < 90°$.

With such a configuration, the liquid water in the water-absorbing layer 11 naturally permeates from a region (11f) having lower hydrophilicity to a region (11e) having higher hydrophilicity, and moves in a plane direction (direction perpendicular to the proton conduction direction).

In the case of forming a water-absorbing layer of at least three kinds of regions, similarly, a region closer to the opening (closer to the outside of the cell) is set to be a region having higher hydrophilicity. In order to form the water-absorbing layer 11D of at least two regions having partially

different hydrophilicity so as to enhance discharge performance, it is not necessarily to prepare at least two kinds of members (materials). For example, a method of performing hydrophobic treatment with respect to a part (center portion) of a water-absorbing layer member using one kind of material, or performing further hydrophilic treatment in the vicinity of the opening 8 is also considered.

Further, a change in hydrophilicity in the water-absorbing layer 11D is not limited to a step-by-step change. For example, in a water-absorbing layer of cellulose fibers such as filter paper, the hydrophilicity can be enhanced by plasma treatment. The case where the plasma treatment time of filter paper is increased gradually from the center side toward the opening 8, thereby forming gradation with hydrophilicity enhanced continuously is also included in this embodiment.

(Embodiment 4)

FIG. 10 illustrates a fuel cell in this embodiment, which is a cross-sectional view in which the fuel cell in this embodiment is cut along a plane perpendicular to a plane including openings. Further, the fuel cells in this embodiment are stacked and connected similarly to those in Embodiment 1, whereby the fuel cell system of this embodiment can be assembled.

The first object of the water-absorbing layer 11 made of a hydrophilic water-absorbing material set in a supply path of oxygen is to prevent generated water from hindering the supply of oxygen. Therefore, it is desirable that the entire fuel cell system be configured so as to induce excessive generated water in the fuel cell to the water-absorbing layer 11.

In this embodiment, the oxygen supply layer 2 has through-holes 15, whereby excessive generated water in the fuel cell is induced to the water-absorbing layer 11. Embodiment 4 has the same configuration as that of Embodiment 2, except that the oxygen supply layer 2 has a through-hole.

The generated water generated by the power generation activity is accumulated not only in the oxygen supply layer 2, but also between the diffusion layer 3 and the membrane electrode assembly 4 to hinder the supply of oxygen to the membrane electrode assembly 4. By using a material having fine through-holes 15 as the oxygen supply layer 2, the generated water accumulated between the membrane electrode assembly 4 and the diffusion layer 3 can be sucked up to the contact surface between the oxygen supply layer 2 and the water-absorbing layer 11 by a capillary force of the through-holes 15 of the oxygen supply layer 2. The water thus sucked up is absorbed by the water-absorbing layer 11 being in contact with the oxygen supply layer

2.

With such a configuration, even in the case where the thickness of the oxygen supply layer 2 in a direction parallel to the proton conduction direction is sufficiently large, and the generated water cannot be absorbed only with a capillary force of the water-absorbing layer 11, the generated water to be a factor for inhibiting the supply of oxygen can be discharged efficiently.

(Embodiment 5)

FIGS. 11 and 12 illustrate a fuel cell in this embodiment. FIG. 11 is a cross-sectional view in which the fuel cell in this embodiment is cut along a plane perpendicular to a plane including openings. Further, FIG. 12 is a cross-sectional view in which the fuel cell in this embodiment is cut along a plane parallel to a plane including openings. The fuel cells in this embodiment are stacked and connected similarly to those in Embodiment 1, whereby a fuel cell system in this embodiment can be assembled.

In this embodiment, a contact surface between the oxygen supply layer 2 and the collector 1 in Embodiment 2 has a plurality of grooves with a direction perpendicular to a plane including the openings being a length direction and the proton conduction direction being a depth direction. Further, a plurality of holes with a direction parallel to the proton conduction

direction being a depth direction are formed in the oxygen supply layer 2. Then, at least in a part of the grooves and the holes, a water-absorbing layer is placed. Herein, the groove refers to the one in which the maximum length parallel to the proton conduction direction in a groove taken in a cross-section parallel to the proton conduction direction is smaller than the maximum length perpendicular to the proton conduction direction taken in a cross-section perpendicular to the proton conduction direction. On the other hand, the hole refers to the one in which the maximum length parallel to the proton conduction direction in a groove taken in a cross-section parallel to the proton conduction direction is larger than the maximum length perpendicular to the proton conduction direction taken in a cross-section perpendicular to the proton conduction direction. The holes may or may not pass through the oxygen supply layer 2. In the case where the holes pass through and are formed at a high density, any of the following two embodiments is preferable. Embodiment 1 is that at least partial holes among the plurality of holes do not have a water-absorbing layer over the entire region in the depth direction. Embodiment 2 is that the water-absorbing layer is formed only in partial holes among the plurality of holes. The reason for this is as follows. When the area of a contact portion between the water-absorbing

layer and the oxygen electrode side diffusion layer increases too much, the oxygen diffusion in the oxygen electrode and the diffusion layer may be inhibited. Specifically, assuming a contact plane between the water-absorbing layer and the oxygen supply layer, it is preferable that the area of the contact portion between the water-absorbing layer and the oxygen electrode side diffusion layer is 20% or less with respect to the area of the contact portion between the water-absorbing layer and the oxygen supply layer in the contact plane. In the present invention, it is assumed that "parallel" is a concept which includes being substantially parallel, and is a range of ±10° in a parallel direction.

Further, it is preferable that the depth of the groove to be formed is 10% or more and 50% or less with respect to the thickness of the oxygen supply layer 2. Further, it is preferable that the length of the groove is the same as the distance between the end surface of the oxygen supply layer 2 present in a plane identical with that of the openings, and the end surface of the oxygen supply layer 2 opposed to the above-mentioned end surface of the oxygen supply layer 2 present in a plane identical with that of the openings in the oxygen supply layer 2, in the case where the openings have a shape of a plane. The number of grooves to be formed can be adjusted by the amount of generated water

generated by the power generation.

Further, a material for the water-absorbing layer placed in the grooves of the oxygen supply layer 2 may or may not be the same as a material for the water-absorbing layer placed in the holes. However, it is preferable that the water-absorbing layer placed in the grooves is connected to the water-absorbing layer placed in the holes.

The fuel cell in this embodiment is capable of efficiently absorbing water even in the case where the thickness of the oxygen supply layer 2 is sufficiently large. Thus, the fuel cell in this embodiment is preferably used in the case where the thickness of the oxygen supply layer 2 is further larger than that of Embodiment 4.

(Embodiment 6)

This embodiment provides a fuel cell with a configuration in which the end portion of the collector 1 in Embodiment 2 is present on the opposite side of the fuel cell with a plane including the openings 8 being a reference. That is, this embodiment provides a fuel cell with a configuration in which the collector 1 with which the water-absorbing layer 11 comes into contact, as well as the water-absorbing layer 11 is exposed to the outside of the fuel cell. Further, the fuel cells in this embodiment are stacked and connected similarly to those in Embodiment 1, whereby a fuel cell

system in this embodiment can be assembled.

FIGS. 13 to 16 illustrate the fuel cell in this embodiment.

FIG. 13 is a cross-sectional view in which the fuel cell in this embodiment is cut along a plane perpendicular to a plane including openings. FIG. 14 is a cross-sectional view in which the collector 1a is cut along a plane perpendicular to the proton conduction direction. FIG. 15 is a projected view in which light is irradiated to the collector 1a and the water-absorbing layer 11 in a direction parallel to the proton conduction direction from the oxygen supply layer 2 side, when the collector 1a and the water-absorbing layer 11 of FIG. 14 are incorporated in a fuel cell. Further, FIG. 16 is a projected view in which light is irradiated to the collector 1a and the water-absorbing layer 11 in a direction parallel to the proton conduction direction from outside of the fuel cell on the opposite side of the oxygen supply layer 2 when the collector 1 is assumed to be a reference.

In this embodiment, in a cross-section in a direction perpendicular to the proton conduction direction, the length of the collector in a direction perpendicular to a plane including openings is larger than the length of the fuel cell (the width of the collector is larger than a cell width of the fuel cell), and the collector and the water-absorbing layer are in

contact with each other outside of the cell. Because of this, even under a high humidity environment in which transpiration is difficult to be performed, the transpiration can be promoted using the heat of the collector generated at the power generation efficiently. That is, the discharge performance can be enhanced.

As the shape of such a collector, as represented by 1a of FIG. 14, the collector can be simply shaped in such a manner that the length of the collector in a direction perpendicular to the plane including openings is larger than the length (cell width) of the fuel cell in a direction perpendicular to the plane including the openings.

Regarding the water-absorbing layer 11, a plurality of water-absorbing layers may be placed as described in Embodiment 2, or the water-absorbing layer 11 may have a ladder shape as illustrated in FIG. 15.

In the case where the collector has a shape as illustrated in FIG. 14, the water-absorbing layer can be placed over the entire collector, so that more water-absorbing material can be placed, which makes it easy to miniaturize the cell.

(Embodiment 7)

A fuel cell in this embodiment is a fuel cell having a configuration in which the shapes of the collector and the water-absorbing layer are different from those in Embodiment 6, and has the same

configuration as that of Embodiment 6 except that the shapes of the collector and the water-absorbing layer are different. Further, the fuel cells in this embodiment are also stacked and connected similarly to those in Embodiment 1, whereby the fuel cells in this embodiment can be assembled.

FIG. 17 is a cross-sectional view in which the shape of the collector in this embodiment is cut along a plane perpendicular to the proton conduction direction, and FIG. 18 is a projected view in which light is irradiated in a direction parallel to the proton conduction direction from an oxygen supply layer side to the collector and water-absorbing layer in Embodiment 7. Further, FIG. 19 is a cross-sectional view in which the water-absorbing layer and the collector in this embodiment are cut along a plane perpendicular to a plane including openings.

The collector and the water-absorbing layer in this embodiment have a comb shape, as illustrated in FIGS. 17 and 18. In the comb-shaped collector in this embodiment, only a comb portion is exposed to the outside from the side surface of the fuel cell. In the case where the collector 1b is a comb-shaped collector, it is preferable that the width and length of a comb have the same size as that of the water-absorbing layer exposed to the outside of the cell, and further, as illustrated in FIG. 19, it is preferable that a

plurality of water-absorbing layers cover each tooth end portion of the comb-shaped collector.

In this embodiment, compared with Embodiment 6, there is an advantage that the performance is enhanced owing to the easy intake of air. Thus, in the case where the performance of a cell is prioritized, compared with the miniaturization of the cell, a fuel cell with a configuration in this embodiment is preferable.

As described above, by setting the configuration of a fuel cell as in Embodiments 1 to 7, even when a current value per unit surface area of the membrane electrode assembly 4 is set to be high, a local flooded region of the membrane electrode assembly 4 is unlikely to be generated, and a high power generation efficiency is maintained stably. Thus, using the membrane electrode assembly 4 with a small area, a large current can be output even without depending upon a circulation mechanism and a blower of the atmosphere. An inexpensive fuel cell system with a small size and a light weight having less parts count can be provided while high reliability, long life, and high performance are being realized.

(Fuel cell in Comparative Embodiments)

Next, fuel cells in Comparative Embodiments will be described.

(Comparative Embodiment 1)

FIG. 20 is a cross-sectional view in which a conventional passive solid polymer fuel cell that is Comparative Embodiment 1 is cut along a plane parallel to a plane including openings, and FIG. 21 is a cross-sectional view in which the conventional passive fuel cell that is Comparative Embodiment 1 is cut along a plane perpendicular to a plane including openings. As illustrated in FIG. 20, the fuel cell 100S of the solid polymer fuel cell includes at least a membrane electrode assembly 104, diffusion layers 103 and 105, a fuel supply flow path (fuel supply layer) 106, an oxygen supply flow path (oxygen diffusion layer) 102, and separators 101 and 107. The membrane electrode assembly 104 includes an eletrolyte film and a catalyst layer (fuel electrode and oxygen electrode). The membrane electrode assembly 104 is placed in a center portion of the fuel cell 100S, and a catalyst layer that is an oxygen electrode is present on one surface of the eletrolyte film, and another catalyst layer that is a fuel electrode is present on the other surface thereof. Then, at a position opposed to the eletrolyte film with the fuel electrode interposed therebetween, the diffusion layer 105 is present, and on an outer side of the catalyst layer that is an oxygen electrode, the diffusion layer 103 is present at a position opposed to the eletrolyte film. The fuel electrode and the oxygen electrode respectively have a role of

allowing fuel or an oxidizer to diffuse outside, and a role of generating electrons. On an outer side of the diffusion layers 103 and 105, the oxygen supply layer 102 and the fuel supply layer 106 that are supply flow paths for supplying the fuel or oxidizer to the entire fuel cell 100S are present.

As a member for the diffusion layers 103 and 105, a porous medium having conductivity is used. An example of the conductive porous medium includes carbon cloth. Nothing is placed in the oxygen supply layer 102 and the fuel supply layer 106, and a porous medium with a high porosity is set as a collecting and supporting member.

The fuel moves in the fuel supply layer 106 due to the forceful circulation such as a pump, for example. The oxidizer moves in the oxygen supply layer 102 by a procedure such as natural diffusion and natural convection. The oxidizer and the fuel diffuse from the oxygen supply layer 102 and the fuel supply layer 106 through the diffusion layers 103 and 105, and respectively reach the eletrolyte film in the membrane electrode assembly 104.

In the contact portion between the fuel electrode and the eletrolyte film in the membrane electrode assembly 104, the fuel having reached the fuel electrode is oxidized by an oxidation action due to a catalyst to become hydrogen ions, and move in the

eletrolyte film toward a cathode. As such fuel, gas such as hydrogen gas, and liquid such as methanol and ethanol are used.

In the contact portion between the oxygen electrode and the eletrolyte film in the membrane electrode assembly 104, the oxidizer (e.g., oxygen) having reached from the oxygen supply layer 102 through the diffusion layer 103, and the hydrogen ions having moved in the eletrolyte film react with each other to generate water molecules. Then, a part of the energy generated in a series of chemical reactions is taken out as electric energy.

As described above, in the cathode of the membrane electrode assembly 104, water is generated by the power generation reaction. The water generally becomes water vapor or generated water to move from the diffusion layer 103 to the oxygen supply layer 102, and discharged from the openings 108 due to transpiration. The water may also be discharged from an anode side after passing through the eletrolyte film. At this time, in the case where the fuel is supplied with a pump, the water also moves together with the fuel as it is due to the pressure of the pump and is discharged from a discharge port.

As illustrated in FIG. 21, in a fuel cell 100S of the conventional passive fuel cell system, the eletrolyte film is placed at the center. Then, a

catalyst layer is formed on both the front and back surfaces of the eletrolyte film to serve as the membrane electrode assembly 104. On an outer side of the membrane electrode assembly 104, the diffusion layers 103 and 105 are present. The diffusion layer 105 is supplied with hydrogen as fuel, and the diffusion layer 103 is supplied with oxygen in the atmosphere as an oxidizer. Since the anode side is supplied with hydrogen, it is sealed with the separators 107 and 109 so that leakage does not occur. Further, the cathode side has the opening 108 so as to be supplied with air.

The generated water generated by the power generation becomes water vapor to diffuse naturally, and is discharged to the atmosphere through the openings 108. Alternatively, the generated water is liquefied in the diffusion layer 103 and the supply layer 102 to be accumulated. In particular, the water liquefied inside the diffusion layer 103 and the oxygen supply layer 102 continues to be accumulated at the positions until it is evaporated to be discharged. Therefore, when being left, the water has an effect on the supply of oxygen to the cathode.

In the passive fuel cell, there is no means for sending out water discharged to the oxygen supply layer 102. Thus, the water once discharged from the diffusion layer 103 to the oxygen supply layer 102

continues to be accumulated at that position as it is, and finally stops the supply of an oxidizer. Thus, in the case of the configuration of the fuel cell without a discharge unit, when driving is performed for a long period of time, the performance of the fuel cell is degraded.

(Comparative Embodiment 2)

Further, FIG. 22 is a cross-sectional view in which a conventional passive solid polymer fuel cell 100s that is Comparative Embodiment 2 is cut along a plane perpendicular to a plane including openings. Although the fuel cell in this comparative embodiment has the water-absorbing layer 110 between the oxygen supply layer 102 and the diffusion layer 103 in Comparative Embodiment 1, the end surface of the water-absorbing layer is present on a cell side with respect to the plane identical with the openings 108, i.e., in the cell. In FIG. 22, only right and left ends 108 on the drawing surface of the fuel cell are openings.

In the case where the end portions of the water-absorbing layer are present in the cell as in this comparative embodiment, since the amount of water generated immediately after the commencement of power generation is small, the generated water is absorbed by the water-absorbing layer. However, the end portions of the water-absorbing layer in this comparative embodiment are present in the cell and do not come into

contact with air outside the cell, so that the transpiration of the water absorbed by the water-absorbing layer is poor. Thus, in the case where the amount of generated water is large, e.g., in the case where driving is performed for a long period of time, the water-absorbing layer cannot absorb water, so that the generated water is accumulated. Because of this, the supply of an oxidizer becomes insufficient, and the performance of a fuel cell and a fuel cell system using the fuel cells are degraded.

(Comparative Embodiment 3)

Further, FIG. 23 is a cross-sectional view in which a conventional passive solid polymer fuel cell 100s that is Comparative Embodiment 3 is cut along a plane perpendicular to a plane including openings. Each of a fuel cell system and a fuel cell in this comparative embodiment is a fuel cell with a configuration in which the water-absorbing layer 110 is provided between the oxygen supply layer 102 and the diffusion layer 103 in Comparative Embodiment 1.

In the case where the water-absorbing layer is formed between the oxygen supply layer and the oxygen electrode side diffusion layer, instead of between the oxygen supply layer and the collector as in this embodiment, the water-absorbing layer 110 inhibits the diffusion of oxygen taken in by the fuel cell through the openings 108 to the diffusion layer 103. Because

the diffusion of oxygen to the diffusion layer 103 is inhibited, the supply of oxygen to the membrane electrode assembly 104 is also inhibited, and the performance of the fuel cell is degraded.

Next, specific examples will be described in detail based on the above-mentioned embodiments. It should be noted that materials for the catalyst layer (oxygen electrode and fuel electrode), the eletrolyte film, the diffusion layer, the oxygen supply layer, and the fuel supply layer are not limited to the following, and any materials may be used as long as they have similar functions.

(Example 1)

This example provides a fuel cell in which an absorbing layer is formed on the surface of an oxygen supply layer on a collector side, and an end portion of the water-absorbing layer is present on an opposite side of the fuel cell, with a plane including openings being a reference. Hereinafter, production processes of the fuel cell according to this example will be described in detail.

(Process 1)

A platinum oxide catalyst having a dendrite structure was formed so as to have a thickness of 2,000 nm by reactive sputtering on a PTFE sheet (Nitfron produced by Nitto Denko Corporation) as a transcription layer to an eletrolyte film. The Pt carrying amount at

this time was 0.68 mg/cm^2. The reactive sputtering was performed under the conditions of a total pressure of 4 Pa, an oxygen flow ratio ($Q_{O2}/(Q_{Ar} + Q_{O2})$ of 70%, a substrate temperature of 300°C, and a switch power of 4.9 W/cm^2. Continuously, the platinum oxide catalyst having a dendrite structure was subjected to reducing treatment at 120°C for 30 minutes in a 2% H_2/He atmosphere (1 atm), whereby a platinum catalyst layer with a dendrite structure was obtained on the PTFE sheet.

Further, the above-mentioned PTFE sheet was impregnated with a mixed suspension solution of the PTFE and Nafion (registered trademark), whereby an electrolyte channel was formed effectively on the surface of the catalyst, and appropriate water-repellent treatment was conducted.

(Process 2)

A platinum carrying carbon catalyst is formed on a PTFE sheet as a transcription layer to an electrolyte film, using a doctor blade. A catalyst slurry used herein is a kneaded substance of platinum-carrying carbon (HiSPEC 4000 produced by Johnson Matthey Inc.), Nafion, PTFE, IPA, and water. The platinum-carrying amount at this time was 0.35 mg/cm^2.

(Process 3)

Using the catalyst layer produced in Process 1 as an oxygen electrode and the catalyst layer produced in

Process 2 as a fuel electrode, a solid polymer electrolyte film (Nafion 112 produced by DuPont Corp.) was sandwiched by the above-mentioned pair of catalyst layers (an oxygen electrode and a fuel electrode), and the resultant stack was subjected to hot pressing under press conditions of 8 MPa, 150°C, and 1 min.

The PTFE sheet was peeled to transcribe the pair of catalyst layers to the polymer electrolyte film to connect the electrolyte film to the pair of catalyst layers, whereby a membrane electrode assembly (MEA) was obtained.

(Process 4)

As an oxygen supply layer, foam metal with a length of 28 mm, a width of 10 mm, and a thickness of 2 mm was used. Further, as an end plate, a plate with a length of 37 mm and a width of 10 mm was used, and the length and width thereof were set to be those of a cell. Four grooves having a length of 10 mm, a width of 2.5 mm, and a depth of 500 μm were formed on one surface of the oxygen supply layer, i.e., on a side being in contact with an oxygen electrode side collector at an equal interval in a direction parallel to the width of 10 mm of the oxygen supply layer. A water-absorbing material cut to a length of 2 cm, a width of 2.5 mm, and a thickness of 500 μm was placed in each groove so as to extend off the cell by 5 mm each on right and left sides to form a water-absorbing layer. Herein, as

the water-absorbing material, liquid diffusion non-woven fabric P type produced by ANBIC Co., Ltd. was used. As a result, the water-absorbing layer 11 and the oxygen supply layer 2 were obtained.

(Process 5)

An assembly of the MEA obtained as described above, the oxygen supply layer, and the water-absorbing layer, a fuel electrode side collector, a fuel electrode side diffusion layer, an oxygen electrode side diffusion layer, and an oxygen electrode side collector were stacked as illustrated in FIG. 2 to obtain a fuel cell. The fuel electrode side collector in this example corresponds to a separator 7 of FIG. 2. Further, carbon cloth (LT2500-W produced by E-TEK Inc.) was used for the fuel electrode side diffusion layer, and carbon cloth (LT1200-W produced by E-TEK Inc.) was used for the oxygen electrode side diffusion layer.

FIGS. 24A to 24C illustrate the water-absorbing layers 11 and the oxygen supply layer 2 produced in Process 4. FIG. 24A is a cross-sectional view in which the water-absorbing layer and the oxygen supply layer are cut along a plane parallel to openings, FIG. 24B is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the collector side in a direction parallel to the proton conduction direction, and FIG. 24C is a projected view in which light is irradiated to the

water-absorbing layer and the oxygen supply layer from the oxygen electrode side diffusion layer side in a direction parallel to the proton conduction direction.

(Example 2)

This example provides a fuel cell system in which a water-absorbing layer is placed only between the oxygen supply layer and the collector described in the embodiments, and an end portion of the water-absorbing layer is present on a plane including openings. That is, the end portion of the water-absorbing layer is present on a plane identical with a plane including openings. Example 2 is the same as Example 1 except for this point. FIGS. 25A to 25C illustrate the water-absorbing layer 11 and the oxygen supply layer 2 thus produced. FIG. 25A is a cross-sectional view in which the water-absorbing layer and the oxygen supply layer are cut along a plane parallel to a plane including openings, FIG. 25B is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the collector side in a direction parallel to the proton conduction direction, and FIG. 25C is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the oxygen electrode side diffusion layer side in a direction parallel to the proton conduction direction.

Flooding resistance characteristics were

evaluated based on a fluctuation of a voltage measured at a constant current of 400 mA/cm^2 of the fuel cell produced as described above. The flooding resistance characteristics were evaluated by natural aspiration without using an auxiliary appliance such as a compressor under the following measurement conditions. The cell was placed in a constant temperature and constant humidity tank in a windless state at a temperature of 25°C and a humidity of 50%. Further, at this time, the fuel cell produced as Comparative Example 1, using the same processes except that the water-absorbing layer was not formed, and evaluated similarly.

FIG. 26 illustrates evaluation results of the fuel cells of Example 1, Example 2, and Comparative Example 1. There was no difference in voltage at the commencement of measurement among Example 1, Example 2, and Comparative Example 1, and the degradation in performance caused by forming the water-absorbing layer was not recognized. The reason for this is assumed as follows. Since the water-absorbing layer is not in contact with the diffusion layer on the oxygen electrode side, the water-absorbing layer does not inhibit the diffusion of gas. However, the difference in voltage between Example 1 and Comparative Example 1 increases gradually 20 minutes after the commencement of measurement, and a large difference was generated

after the elapse of 90 minutes.

Next, the weights of water remaining in both of the fuel cells were compared with each other after the elapse of 90 minutes of the measurement at a constant current. Consequently, the weight of water remaining in the cell in Comparative Example 1 was 0.2852 g, whereas the weight of water remaining in the cell in Example 1 exhibited a smaller value of 0.1265 g.

It is understood from those results that the fuel cell in Example 1 has a function of discharging generated water outside the cell, and has a function of suppressing flooding.

Further, the amount of water remaining in the cell in Example 2 was 0.1798 g, and thus, even in the cell of Example 2, the amount of remaining water was smaller than that in Comparative Example 1. That is, it is understood that the discharge function in the embodiment mode of Example 2 is higher than that in the embodiment mode of Comparative Example 1.

The discharge function in the embodiment mode of Example 1 is further higher than that in the embodiment mode of Example 2, so that the embodiment mode in Example 1 is preferable in the case of obtaining a higher discharge function. On the other hand, in the embodiment mode of Example 2, the water-absorbing layer is small, so that a cell structure that is more compact than that in the embodiment mode of Example 1 can be

obtained. Thus, it is preferable that the embodiment mode of Example 1 is used for an application in which an emphasis is placed on the discharge function, and the embodiment mode in Example 2 is used for an application in which an emphasis is placed on the space efficiency while having a discharge function.

As described above, by forming a water-absorbing layer on the surface of the oxygen supply layer on the collector side, flooding resistance characteristics were enhanced remarkably without causing a decrease in performance.

(Example 3)

This example is an example in which water-absorbing layers are placed between an oxygen supply layer and a collector, and in the oxygen supply layer, respectively. This example is very effective in the case where the thickness of the oxygen supply layer is larger, and water vapor generated from the diffusion layer become water droplets in the oxygen supply layer before reaching the collector. The processes other than Process 4 are the same as those in Example 1, so that only Process 4 will be described.

(Process 4) (Processes 1 to 3, and 5 are the same as those in Example 1)

Four grooves with a length of 10 mm, a width of 2.5 mm, and a depth of 500 μm are formed on the surface of the oxygen supply layer on the collector (oxygen

electrode side collector) side at an equal interval. Two non-through holes of 2 mmϕ were formed at an equal interval with respect to one groove in a portion where the grooves were formed. The non-through holes were filled with a water-absorbing material to form a water-absorbing layer, and a water-absorbing material cut to a length of 2 cm, a width of 2.5 mm, and a thickness of 500 μm was set in the grooves to form another water-absorbing layer. At this time, the water-absorbing material present in the non-through holes and the water-absorbing material in the grooves were placed so as to come into contact with each other. FIGS. 27A to 27D illustrate the water-absorbing layer 11 and the oxygen supply layer 2. At this time, foam metal used for the oxygen supply layer was set to have a length of 28 mm, a width of 10 mm, and a thickness of 2 mm in the same way as in Example 1. Further, a cell size was set to be 37 mm × 10 mm. Water-absorbing fibers were placed in a short direction so as to extend off by 5 mm on the right and left sides.

FIG. 27A is a cross-sectional view in which the water-absorbing layer and the oxygen supply layer are cut along a plane parallel to a plane including openings, FIG. 27B is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the collector side in a direction parallel to the proton conduction direction,

FIG. 27C is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the oxygen electrode side diffusion layer side in a direction parallel to the proton conduction direction, and FIG. 27D is a cross-sectional view in which the oxygen supply layer and the water-absorbing layer placed in the holes of the oxygen supply layer are cut along a plane perpendicular to the proton conduction direction.

Flooding resistance characteristics were evaluated based on a fluctuation of a voltage measured at a constant current of 400 mA/cm^2 of the fuel cell produced as described above. The flooding resistance characteristics were evaluated by natural aspiration without using an auxiliary appliance such as a compressor under the following measurement conditions. The cell was placed in a constant temperature and constant humidity tank in a windless state at 25°C and a humidity of 50%. At this time, the fuel cell in Comparative Example 1 was similarly evaluated.

FIG. 28 illustrates the results. There was no difference in voltage at the commencement of measurement in Example 3 and Comparative Example 1, so that it is understood that the decrease in gas diffusion caused by the water-absorbing layer did not occur. In the same way as in FIG. 26, the difference in voltage between Example 3 and Comparative Example 1

increases gradually 20 minutes after the commencement of measurement, and a large difference occurred after the elapse of 90 minutes.

Next, the weights of water remaining in both of the cells were compared with each other after the elapse of 90 minutes of the measurement at a constant current, whereby the discharge functions were compared. Consequently, the weight of water remaining in the cell in Comparative Example 1 was 0.2394 g, whereas the weight of remaining water in the cell in Example 3 was 0.1338 g, which exhibited a remarkably small value. It is understood from those results that the fuel cell in Example 3 has a function of discharging generated water outside the cell, and has a function of suppressing flooding.

Next, the superiority of the presence of the end portion of the water-absorbing layer on a plane identical with a plane including openings, or the presence of the end portion on the opposite side of the fuel cell with the plane including openings being a reference, and the superiority of the presence of the water-absorbing layer between the collector and the oxygen supply layer will be shown. In order to show the superiority, the configuration in which the end portion of the water-absorbing layer is in the cell is set to be Comparative Example 2, and the configuration in which the water-absorbing layer is present between

the oxygen supply layer and the oxygen electrode side diffusion layer is set to be Comparative Example 3, and both of them were compared with each other.

(Comparative Example 2)

This comparative example provides the case where, although the water-absorbing layer is placed between the oxygen supply layer and the collector in the same way as in Example 1, the water-absorbing layer does not extend off the cell, and an end portion of the water-absorbing layer is placed on the same side as that of the fuel cell with a plane including openings being a reference. The processes other than Process 4 are the same as those in Example 1, so that only Process 4 will be described.

(Process 4) (Processes 1 to 3, and 5 are the same as those in Example 1)

On the surface of the oxygen supply layer on the collector side, four grooves each having a length of 10 mm, a width of 2.5 mm, and a depth of 500 μm are formed at an equal interval in parallel to the width of 10 mm of the oxygen supply layer. A water-absorbing material cut to a length of 5 mm, a width of 2.5 mm, and a thickness of 500 μm is set in each groove so that the end portion of the water-absorbing layer is placed on the same side as that of the fuel cell with a plane including openings being a reference. FIGS. 29A to 29C illustrate the water-absorbing layer 11 and the oxygen

supply layer 2 thus formed. FIG. 29A is a cross-sectional view in which the water-absorbing layer and the oxygen supply layer are cut along a plane parallel to a plane including openings, FIG. 29B is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the collector side in a direction parallel to the proton conduction direction, and FIG. 29C is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the oxygen electrode side diffusion layer side in a direction parallel to the proton conduction direction.

The fuel cell produced as described above was set to be Comparative Example 2, and compared with Example 1 for flooding resistance characteristics. The flooding resistance characteristics were evaluated based on a fluctuation of a voltage measured at a constant current of 400 mA/cm^2. The flooding resistance characteristics were evaluated by natural aspiration without using an auxiliary appliance such as a compressor under the following measurement conditions. The cell was placed in a constant temperature and constant humidity tank in a windless state at 25°C and a humidity of 50%.

FIG. 30 illustrates the results. In the configuration of Comparative Example 2, a decrease in voltage occurred after the elapse of about 60 minutes.

Further, when the weight of water remaining in both of the cells after the elapse of about 90 minutes from the constant current measurement, the weight was 0.1265 g in Example 1, whereas the weight was 0.209 g in Comparative Example 2. From the above-mentioned results, in the configuration in Comparative Example 2, it is presumed that the discharge function of generated water was low, which caused a decrease in voltage caused by flooding. The reason for this is considered as follows. Since the end portion of the water-absorbing layer is in the cell, the generated water absorbed by the water-absorbing layer is accumulated in the oxygen supply layer without being perspired, with the result that the oxygen supply layer is closed by the generated water. As a result, it was shown that even when the water-absorbing layer is formed between the oxygen supply layer and the collector, a sufficient discharge effect is not exhibited in the case where the end portion of the water-absorbing layer is in the cell.

(Comparative Example 3)

This comparative example provides a fuel cell system with a configuration in which although the end portion of the water-absorbing layer is present on an opposite side of the fuel cell with a plane including openings being a reference, the water-absorbing layer is placed between the oxygen supply layer and the oxygen electrode side diffusion layer. The processes

other than Process 4 are the same as those in Example 1, so that only Process 4 will be described.

(Process 4) (Processes 1 to 3, and 5 are the same as those in Example 1)

Foam metal with a length of 28 mm, a width of 10 mm, and a thickness of 2 mm was used as the oxygen supply layer 2.

On the surface of the oxygen supply layer 2 on the oxygen electrode side diffusion layer 3 side, four grooves with a length of 10 mm, a width of 2.5 mm, and a depth of 500 μm were formed at an equal interval in a direction parallel to the width of the oxygen supply layer 2. The water-absorbing layer cut to a length of 2 cm, a width of 2.5 mm, and a thickness of 500 μm was set in each groove, and the end portions of the water-absorbing layer was set so as to extend off by 5 mm on the right and left sides from the cell in such a manner that the end portion of the water-absorbing layer was present on an opposite side of the fuel cell with a plane including openings being a reference. An end plate with a length of 37 mm and a width of 10 mm was used, and the length and the width were set to be those of the cell. FIGS. 31A to 31C illustrate the water-absorbing layer 11 and the oxygen supply layer 2 thus obtained. FIG. 31A is a cross-sectional view in which the water-absorbing layer and the oxygen supply layer are cut along a plane parallel to a plane including

openings, FIG. 31B is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the collector side in a direction parallel to the proton conduction direction, and FIG. 31C is a projected view in which light is irradiated to the water-absorbing layer and the oxygen supply layer from the oxygen electrode side diffusion layer side in a direction parallel to the proton conduction direction.

The fuel cell in Comparative Example 3 produced as described above was compared with the fuel cell in Example 1 for performance, whereby flooding resistance characteristics were evaluated. Flooding resistance characteristics were evaluated based on a fluctuation of a voltage measured at a constant current of 400 mA/cm^2. Further, by comparing the I-V characteristics, the cell characteristics of both of the cells were compared with each other. The flooding resistance characteristics were evaluated by natural aspiration without using an auxiliary appliance such as a compressor under the following measurement conditions. The cell was placed in a constant temperature and constant humidity tank in a windless state at 25°C and a humidity of 50%.

FIG. 32 illustrates I-V curves in Example 1 and Comparative Example 3. When both of them were compared with each other, substantially the same characteristics

were exhibited in a low-current region, whereas a difference was found in a high-current region of 500 mA/cm^2 or more, and a difference was observed even at a limiting current. This is considered to be caused as follows. In the fuel cell in Comparative Example 3, since the water-absorbing layer with low diffusion of air is present in a wide region between the oxygen supply layer and the oxygen electrode side diffusion layer, the supply amount of air to the catalyst layer is small, and a decrease in performance occurs particularly in a high-current region.

Next, FIG. 33 illustrates a fluctuation in voltage during constant current measurement in comparison between the flooding resistance characteristics in Example 1 and those in Comparative Example 3. In Comparative Example 3 that provides a cell with a configuration in which the water-absorbing layer is placed between the oxygen supply layer and the oxygen electrode side diffusion layer, a decrease in voltage was observed in a short period of time. However, when the weights of water remaining in both of the cells after the elapse of 90 minute from the constant current measurement were compared with each other, the weight was 0.1265 g in the cell of Example 1, whereas the weight was 0.129 g in the cell of Comparative Example 3. Thus, it is understood that even the configuration of Comparative Example 3 has

high discharge ability equal to that of Example 1. The factor for the observation of a decrease in voltage irrespective of the high discharge ability is considered as follows. Since the water-absorbing layer is placed in a wide region between the oxygen supply layer and the oxygen electrode side diffusion layer, the generated water in the oxygen supply layer is drawn in the oxygen electrode side diffusion layer, and the water in the oxygen supply layer can be discharged efficiently. However, the oxygen electrode side diffusion layer was submerged in water, and as a result, a decrease in voltage caused by the flooding of the oxygen electrode side diffusion layer instead of the oxygen supply layer was observed.

As a result, it is understood that, when the fuel cell is placed, the water-absorbing layer, in which an area of a plane cut along a plane perpendicular to the proton conduction direction is large, needs to be formed between the oxygen supply layer and the collector.

Next, an example will be described, which has a configuration in which the end portion of the collector is present on an opposite side of the fuel cell with a plane including openings being a reference, and the water-absorbing layer and the collector are in contact with each other outside the cell. That is, the example provides a fuel cell in which the end portion of the

collector is present on an opposite side of the cell with a plane including openings being a reference, and at least a part of a region present on an opposite side of the fuel cell is in contact with the water-absorbing layer with a plane including the openings in the collector being a reference. Hereinafter, a state in which the end portion of the collector is present on an opposite side of the fuel cell with a plane including openings being a reference may be referred to as a state in which the collector extends off from the cell, and a portion present on an opposite side of the fuel cell with a plane including the openings in the collector being a reference may be referred to as a portion extending off from the cell.

(Example 4)

In this example, the collector has a comb shape, the comb portion is present on an opposite side of the cell with a plane including openings being a reference, and the collector is in contact with the water-absorbing layer in a portion present on an opposite side of the cell with the openings being a reference, i.e., in the comb portion. The width and length of the comb have the same sizes as those of the portion present on an opposite side of the cell with the openings being a reference, and only the collector in the portion being in contact with the water-absorbing layer outside of the cell extends off from the cell.

Example 4 is the same as Example 1, except that the collector has a comb shape, the end portion thereof is outside the cell, and the collector is in contact with the water-absorbing layer outside the cell. The length of the collector extending off from the cell was set to be 2 mm on the right and left sides.

(Example 5)

In this example, the end portion of the collector has a linear shape, the end portion in a liner shape is present on an opposite side of the cell with a plane including openings being a reference, and a portion present on an opposite side of the cell is in contact with the water-absorbing layer with the openings of the collector being a reference. Example 5 is the same as Example 1, except that the entire collector extends off from the cell, and the water-absorbing layer and the collector are in contact with each other even outside the cell.

The length of the collector extending off from the cell was set to be 1 mm on the right and left sides.

FIGS. 34A to 34D illustrate the water-absorbing layer 11 and the collector 1 in Example 4. FIG. 34A is a cross-sectional view of the collector cut along a plane perpendicular to the proton conduction direction, FIG. 34B is a projected view in which light is irradiated to the water-absorbing layer and the collector from the oxygen supply layer side in a

direction parallel to the proton conduction direction, FIG. 34C is a projected view in which light is irradiated to the water-absorbing layer and the collector from an opposite side of the water-absorbing layer with the collector being a reference in a direction parallel to the proton conduction direction, and FIG. 34D is a cross-sectional view in which the water-absorbing layer and the collector are cut along a plane perpendicular to a plane including the openings.

Further, FIGS. 35A to 35D illustrate the water-absorbing layer 11 and the collector 1 in Example 5. FIG. 35A is a cross-sectional view in which the collector is cut along a plane perpendicular to the proton conduction direction, FIG. 35B is a projected view in which light is irradiated to the water-absorbing layer and the collector from the oxygen supply layer side in a direction parallel to the proton conduction direction, FIG. 35C is a projected view in which light is irradiated to the water-absorbing layer and the collector from an opposite side of the water-absorbing layer with the collector being a reference in a direction parallel to the proton conduction direction, and FIG. 35D is a cross-sectional view in which the water-absorbing layer and the collector are cut along a plane perpendicular to a plane including the openings.

As illustrated in FIGS. 34A to 34D and 35A to 35D, the width of the collector in each of Examples 4 and 5

is larger than that of the cell, and extends off from the cell, and the collector is in contact with the water-absorbing layer not only in the cell but also outside the cell. At this time, as illustrated in FIGS. 34D and 35D, when the water-absorbing layer is placed so as to be wound around the extending portion, the water-absorbing layer can be placed in a twofold amount with the same extending amount, whereby space efficiency is enhanced. Further, in the case where the entire collector in Example 5 illustrated in FIG. 35A extends off, the extending portion is not in a band shape as in Examples 1 to 4, and the water-absorbing layer can be placed in a ladder shape over the entire extending portions of the collector, so that space efficiency can be further enhanced.

In the case where the collector is allowed to extend off from the cell, and the water-absorbing layer and the collector are brought into contact with each other even outside the cell, there is an advantage that the space efficiency is enhanced as described above, and heat generated during power generation can be supplied to the water-absorbing layer. That is, by supplying heat to the water-absorbing material of the water-absorbing layer, the perspiration is enhanced, and the characteristics are expected to be enhanced particularly in a high humidity environment in which the perspiration is degraded. At this time, it is more

preferable to fix the extending portion of the collector and the water-absorbing layer with a heat-conductive double-sided tape, because heat can be supplied more efficiently. In order to confirm the above-mentioned effects, flooding resistance characteristics in a high humidity environment were evaluated by performing measurement at a constant current of 400 mA/cm^2 by natural aspiration without using an auxiliary appliance such as a compressor under the following measurement conditions. The cells in Examples 1, 4, and 5, and Comparative Example 1 were placed in a constant temperature and constant humidity tank at 25°C in a 90% atmosphere. FIG. 36 illustrates the results.

In the fuel cell having no absorbing layer in Comparative Example 1, a voltage was decreased largely due to the flooding, whereas the cells in Examples 1, 4, and 5 did not show a decrease in voltage and exhibited high flooding resistance characteristics. Further, when the amounts of water remaining in the cells were compared with each other based on changes in cell weights before and after the measurement, the water amount was 0.234 g in Comparative Example 1, and the water amount was 0.237 g in Example 1. Further, in Example 1, an initial voltage was 0.635 V, whereas the voltage was 0.537 V at a time of the completion of the measurement. Thus, a decrease in voltage of 0.116 V,

i.e., 18.3% was confirmed.

In contrast, the amounts of water remaining in the cells in Examples 4 and 5 were 0.148 g and 0.144 g, respectively. An initial voltage was 0.648 V in Example 4, whereas the voltage was 0.608 V at a time of the completion of the measurement. Thus, a decrease in voltage was suppressed to 0.04 V, i.e., 6.2%. Further, in Example 5, an initial voltage was 0.621 V, whereas the voltage was 0.561 V at a time of the completion of measurement. Thus, a decrease in voltage was suppressed to 0.06 V, i.e., 9.7%.

From the above-mentioned results, it can be considered to be preferable to form the water-absorbing layers with higher discharge ability as in Examples 4 and 5, although there is an effect even in the cell with a configuration as in Example 1 under a high humidity environment such as an atmosphere of 90% at 25°C. The reason for this is as follows. Since the perspiration of the water-absorbing layer is degraded under a high humidity environment, the collector extends off from the cell, and the water-absorbing layer and the collector are brought into contact with each other even in the extending portion as in Examples 4 and 5, whereby the perspiration of water in the water-absorbing layer can be promoted using the heat generated by power generation.

Example 4 exhibits a higher voltage than that of

Example 5. This is considered to be caused by the effect that the collector has a comb shape. In the case where the entire collector extends off as in Example 5, the collector plays a roll such as a hood, which inhibits the diffusion of gas, and the characteristics may be degraded. In contrast, in the case of Example 4, since the collector has a comb shape, gas is supplied from between the extending portions, i.e., between the tooth portions, whereby the inhibition of the diffusion of gas can be minimized. In the case of Example 5, the entire collector extends off, whereby the area where the water-absorbing layer is placed can be a large size. That is, the extending amount for placing the water-absorbing layer in the same amount may be smaller than that in Example 4. Actually, although Examples 4 and 5 have the same discharge ability, the extending amount of the collector is smaller in Example 4 than in Example 5, whereby a more compact cell can be obtained. That is, the fuel cell with the configuration in Example 4 can be appropriately selected in an application in which an emphasis is placed on the characteristics, and the fuel cell with the configuration in Example 5 can be appropriately selected in the application in which an emphasis is placed on a cell size.

This application claims priority from Japanese Patent Application No. 2006-027793 filed February 3, 2006, which is hereby incorporated by reference herein.

CLAIMS

1. A fuel cell comprising:

a power generation layer member for moving hydrogen ions from one surface to another surface, and causing the hydrogen ions to react with oxygen on the another surface; and

an oxygen supply layer for diffusing oxygen in an atmosphere taken in from a side surface to supply the oxygen to the another surface, wherein:

the fuel cell has a water-absorbing layer; and

the water-absorbing layer whose stability of holding liquid water is higher than that of the oxygen supply layer, is communicated with the oxygen supply layer and is placed opposed to the power generation layer member with at least the oxygen supply layer interposed therebetween.

2. The fuel cell according to claim 1, wherein:

the water-absorbing layer is a sheet-shaped member made of a material different from that of the oxygen supply layer; and

the material for the water-absorbing layer has hydrophilicity higher than that of the material for the oxygen supply layer.

3. The fuel cell according to claim 2, wherein air permeability of the oxygen supply layer in a direction communicating the power generation layer

member with the water-absorbing layer is higher than that in a direction along a surface of the power generation layer member.

4. The fuel cell according to claim 3, comprising:

a diffusion layer placed between the oxygen supply layer and the power generation layer member, whose average opening size of a tissue is smaller than that of the oxygen supply layer and larger than that of the power generation layer member; and

a number of through-holes communicating the oxygen supply layer with the power generation member are formed in the diffusion layer.

5. The fuel cell according to claim 1, wherein at least a part of the water-absorbing layer is directly opened to an atmosphere outside of the oxygen supply layer.

6. The fuel cell according to claim 1, wherein the water-absorbing layer at a plane position close to the side surface from which oxygen is taken in has the stability for holding liquid water higher than that at a plane position away from the side surface from which oxygen is taken in.

7. The fuel cell according to claim 1, wherein supply of oxygen from the side surface from which oxygen is taken in to the power generation layer member depends upon natural diffusion of oxygen through the

oxygen supply layer.

8. A fuel cell comprising an electrolyte film, a catalyst layer, two diffusion layers, a fuel supply layer, an oxygen supply layer, a water-absorbing layer, and a collector, wherein:

the fuel cell has an opening at least in a part of a side surface parallel to a proton conduction direction of the electrolyte film among side surfaces of the fuel cell;

the water-absorbing layer is present between the oxygen supply layer and the collector; and

an end portion of the water-absorbing layer is present on one of a plane including the opening and an opposite side of the fuel cell with the plane including the opening being a reference.

9. The fuel cell according to claim 8, wherein:

the water-absorbing layer includes a plurality of regions each having hydrophilicity different from that of a different region; and

the hydrophilicity is higher in a region closer to the opening among the plurality of regions.

10. The fuel cell according to claim 8, wherein:

the oxygen supply layer has a groove on a surface thereof in the collector side; and

at least a part of the water-absorbing layer is present in the groove.

11. The fuel cell according to claim 8, wherein

the oxygen supply layer has a plurality of holes each of whose depth direction being a direction parallel to the proton conduction direction.

12. The fuel cell according to claim 11, wherein the water-absorbing layer is present in the hole.

13. The fuel cell according to claim 12, wherein the water-absorbing layer present between the oxygen supply layer and the collector is connected to the water-absorbing layer present in the hole.

14. The fuel cell according to claim 8, wherein the water-absorbing layer is not contact with the diffusion layer.

15. The fuel cell according to claim 12, wherein the water-absorbing layer is not contact with the diffusion layer.

16. The fuel cell according to claim 8, wherein:

an end portion of the collector is present on the opposite side of the fuel cell with the plane including the opening being a reference; and

at least a part of a region present on an opposite side of the fuel cell with the plane including the opening in the collector being a reference is in contact with the water-absorbing layer.

17. The fuel cell according to claim 16, wherein the collector has a comb shape.

18. A fuel cell system comprising a fuel cell stack, wherein:

the fuel cell stack comprises a plurality of fuel cells; and

the fuel cell is any one of the fuel cells according to claims 1 to 17.

FIG. 1

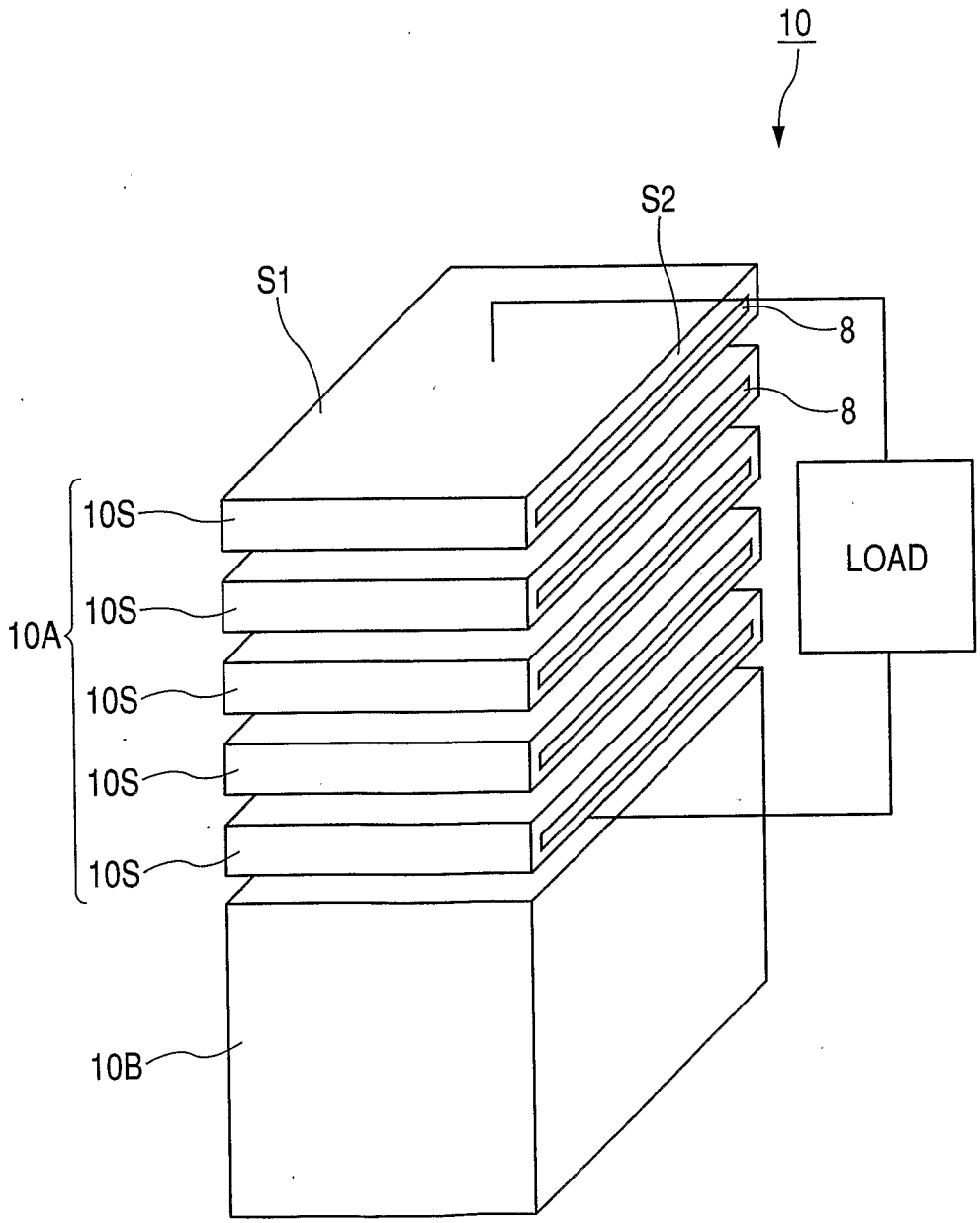


FIG. 4

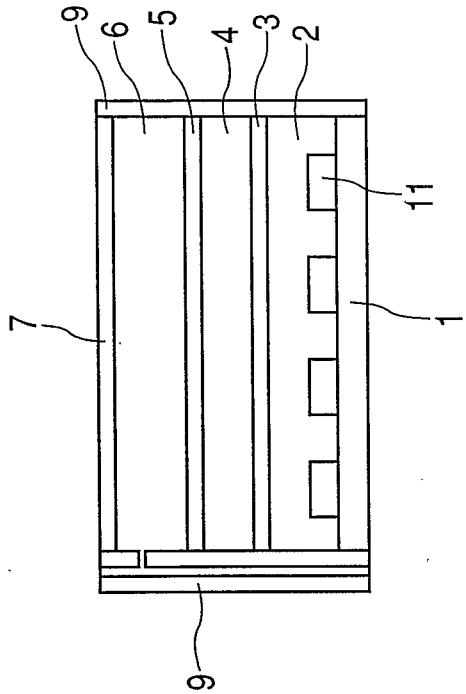


FIG. 5

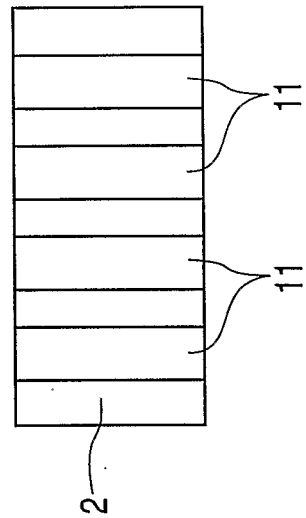


FIG. 2

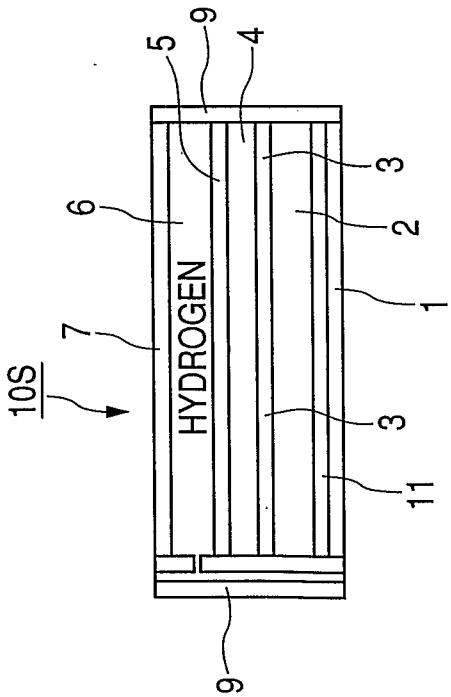


FIG. 3

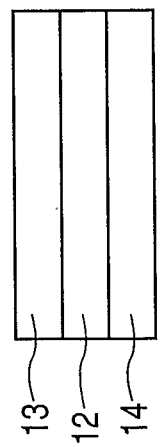


FIG. 8

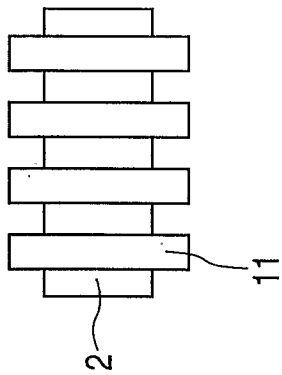


FIG. 9

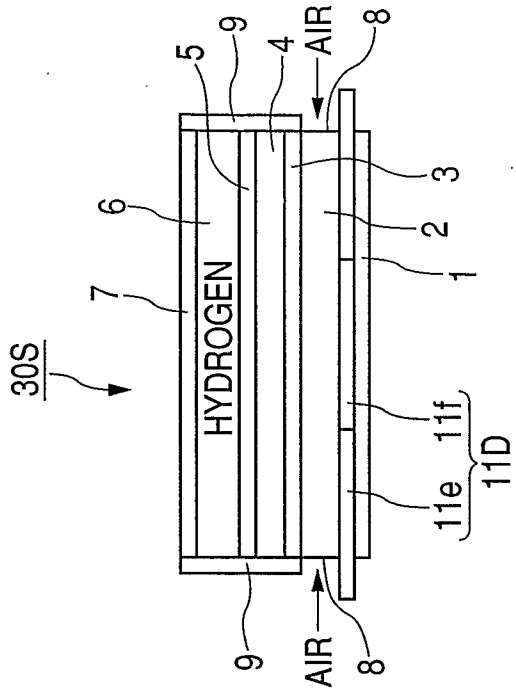


FIG. 6

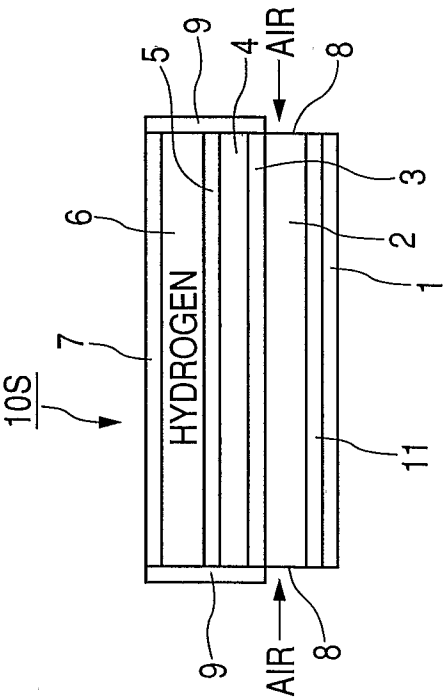


FIG. 7

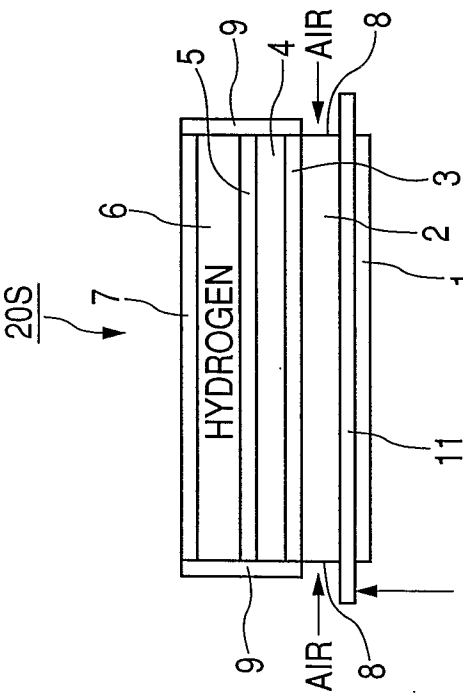


FIG. 12

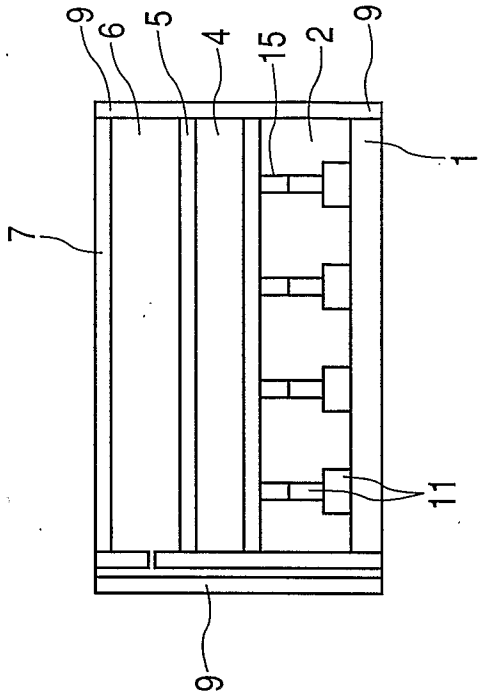


FIG. 13

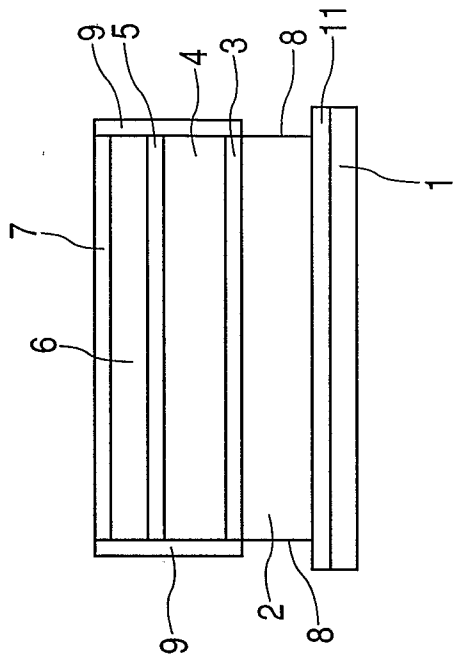


FIG. 10

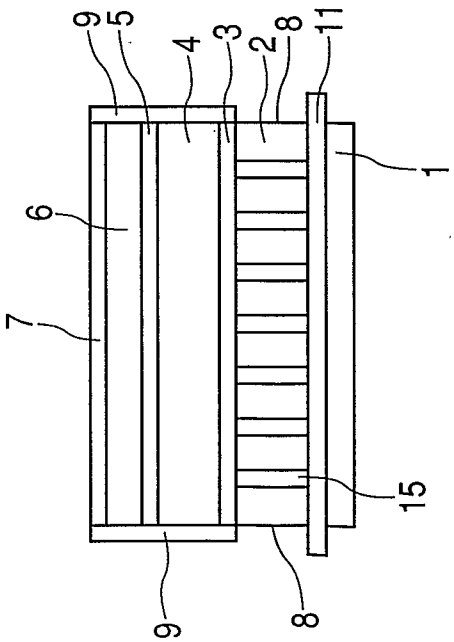


FIG. 11

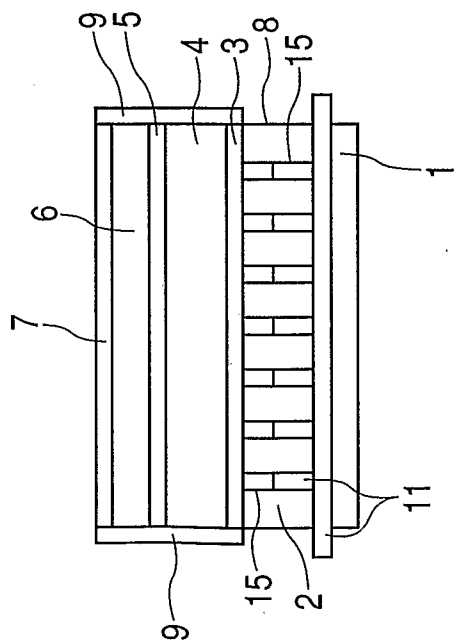


FIG. 14

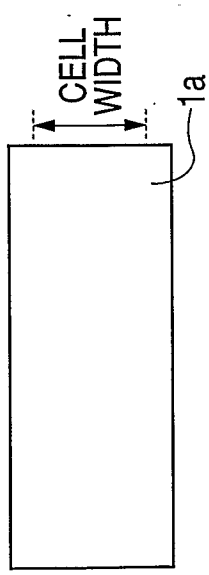


FIG. 15

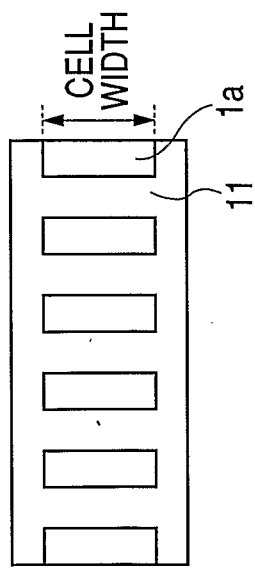


FIG. 16

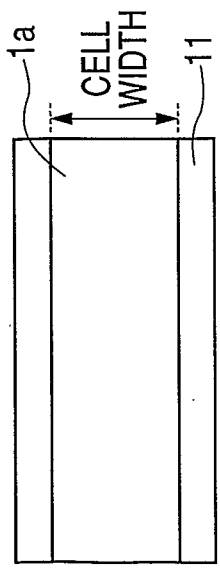


FIG. 17

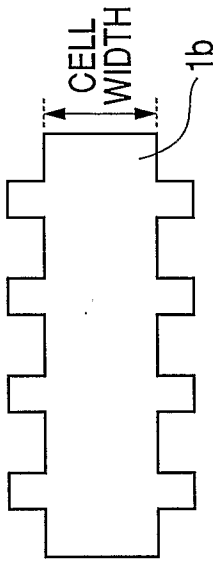


FIG. 18

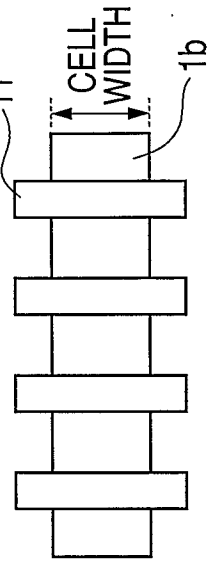


FIG. 19

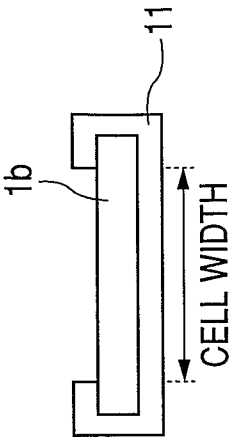


FIG. 22

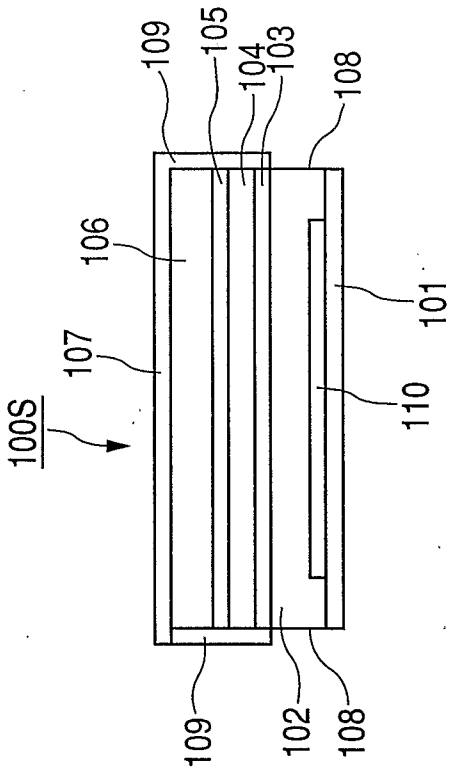


FIG. 23

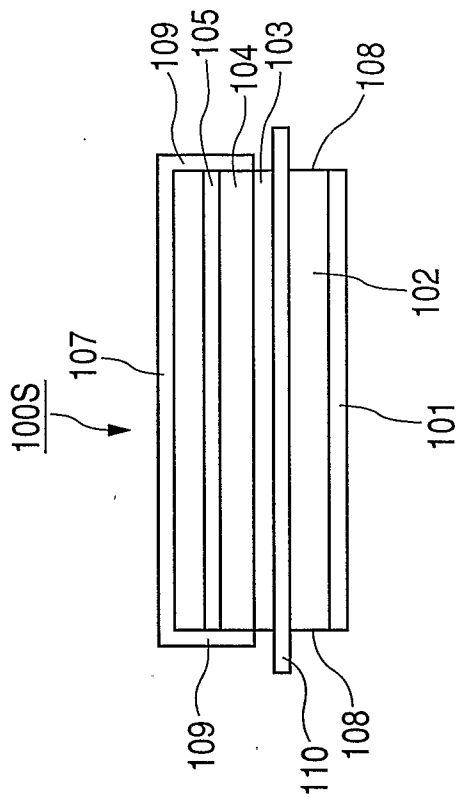


FIG. 20

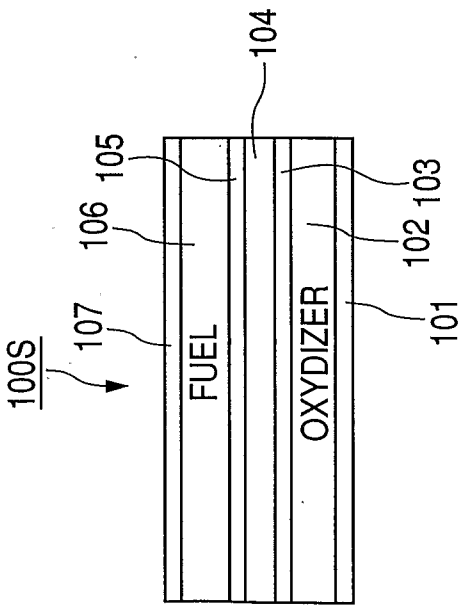


FIG. 21

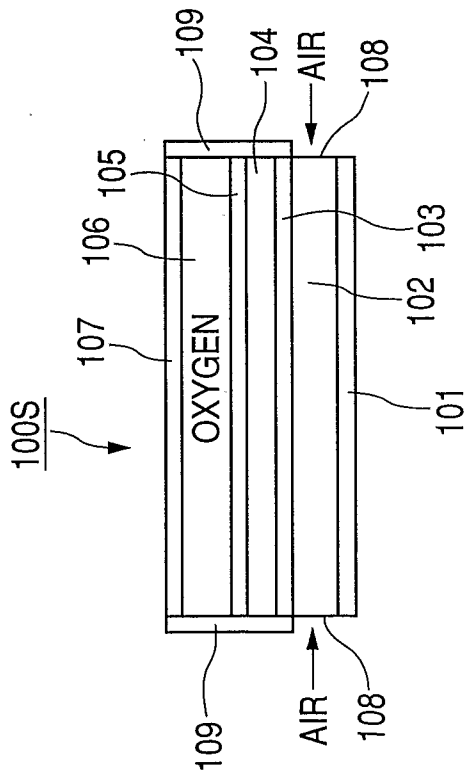


FIG. 25A

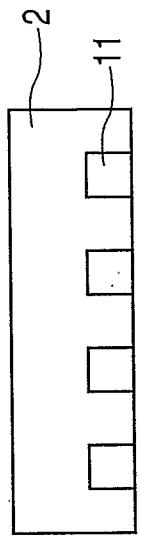


FIG. 25B

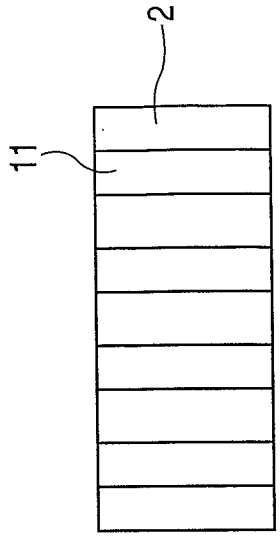


FIG. 25C

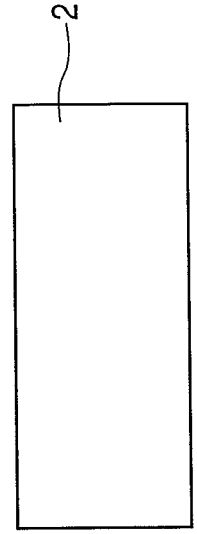


FIG. 24A

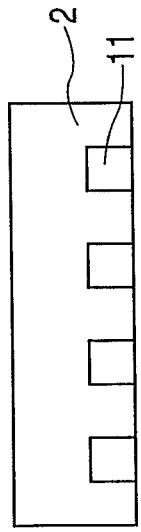


FIG. 24B

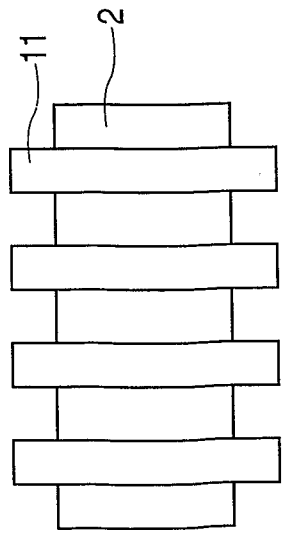


FIG. 24C

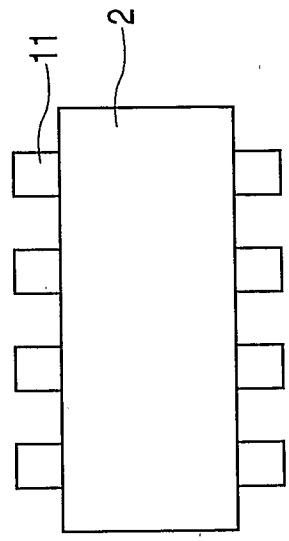


FIG. 26

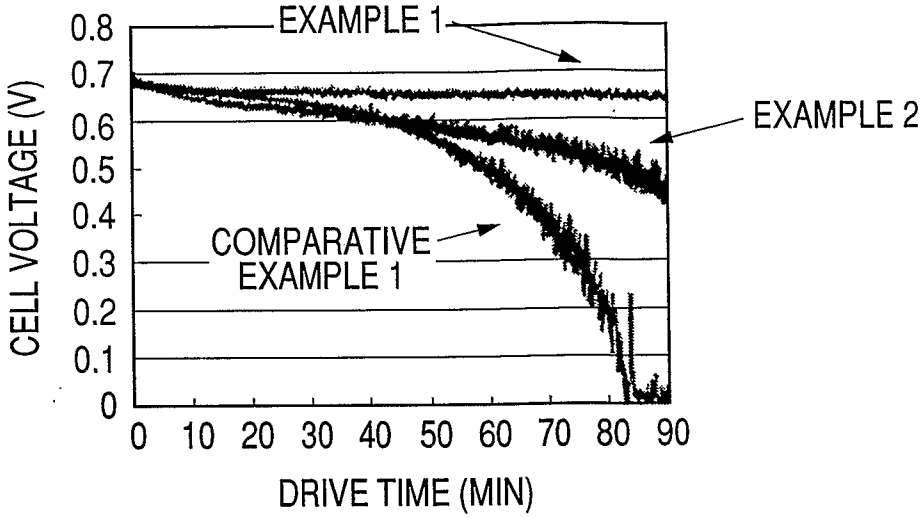


FIG. 27A

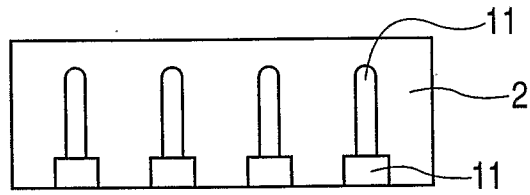


FIG. 27B

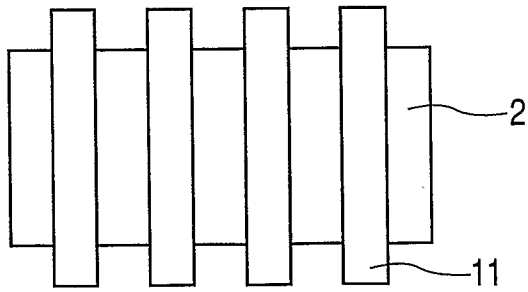


FIG. 27C

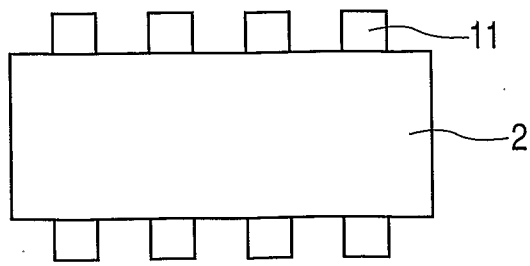


FIG. 27D

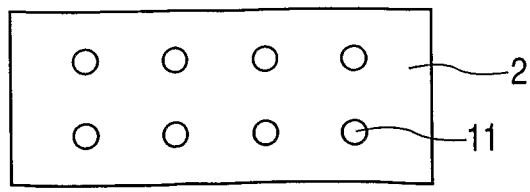


FIG. 28

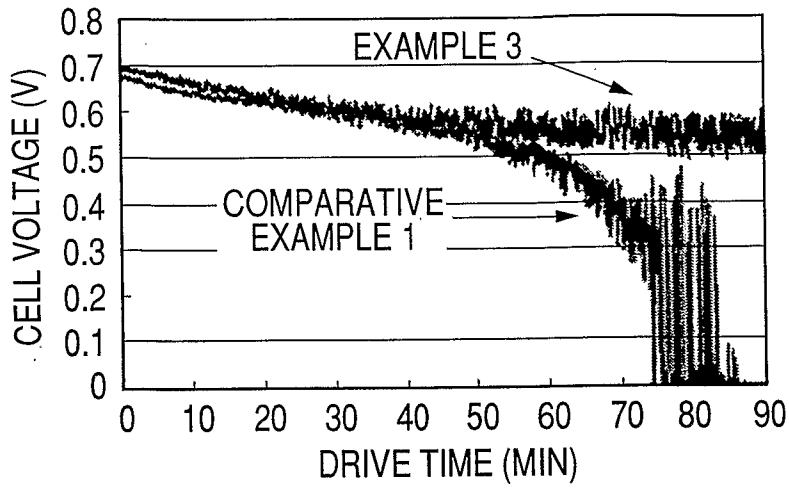


FIG. 29A

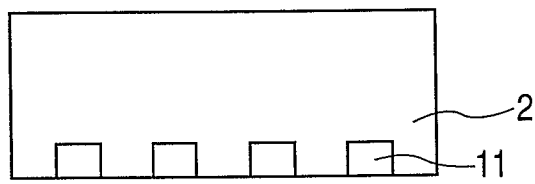


FIG. 29B

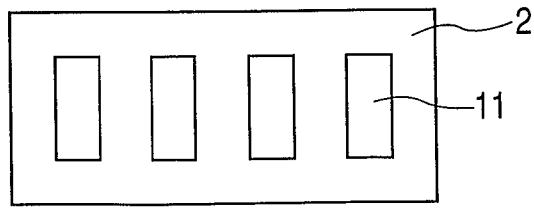


FIG. 29C

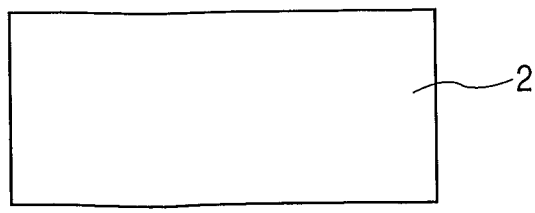


FIG. 30

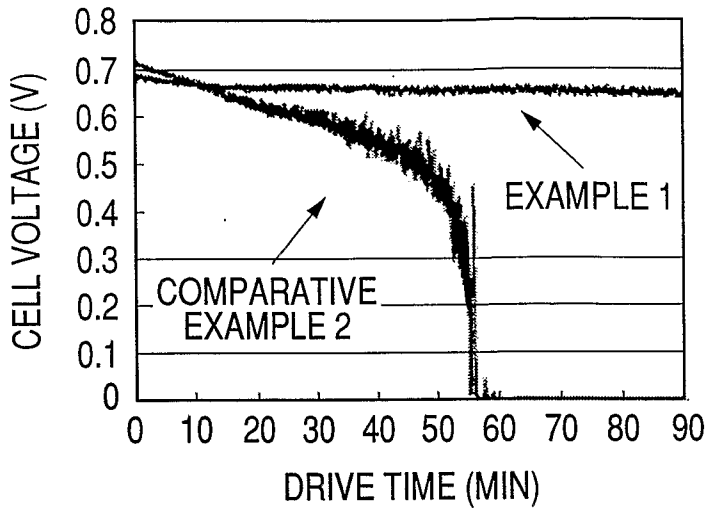


FIG. 31A

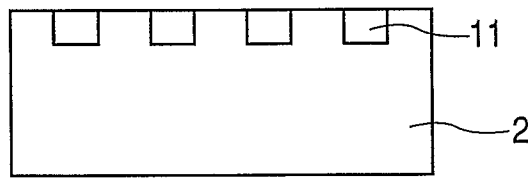


FIG. 31B

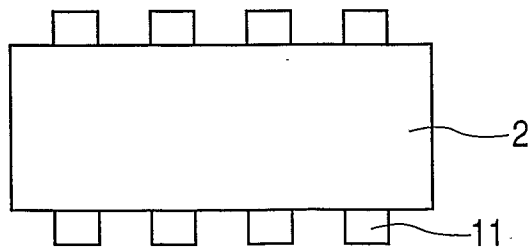


FIG. 31C

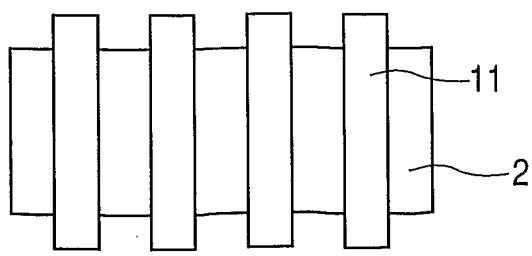


FIG. 32

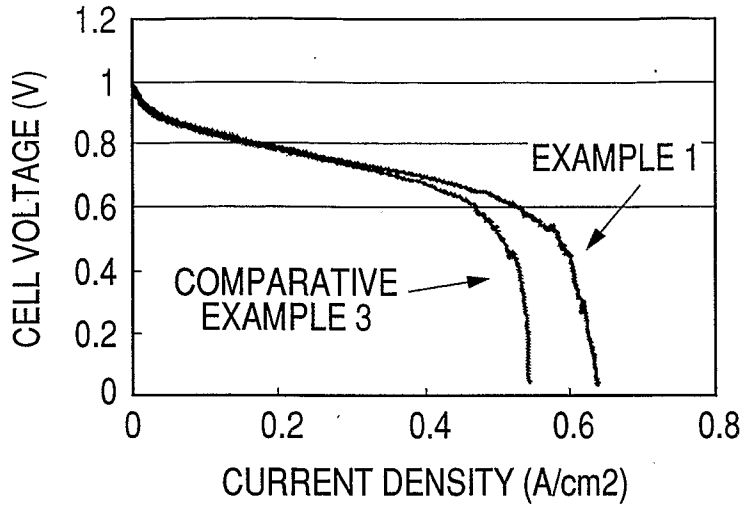

1.2
1
0.8
0.6
0.4
0.2
0
CELL VOLTAGE (V)
EXAMPLE 1
COMPARATIVE EXAMPLE 3
0
0.2
0.4
0.6
0.8
CURRENT DENSITY (A/cm2)

FIG. 33

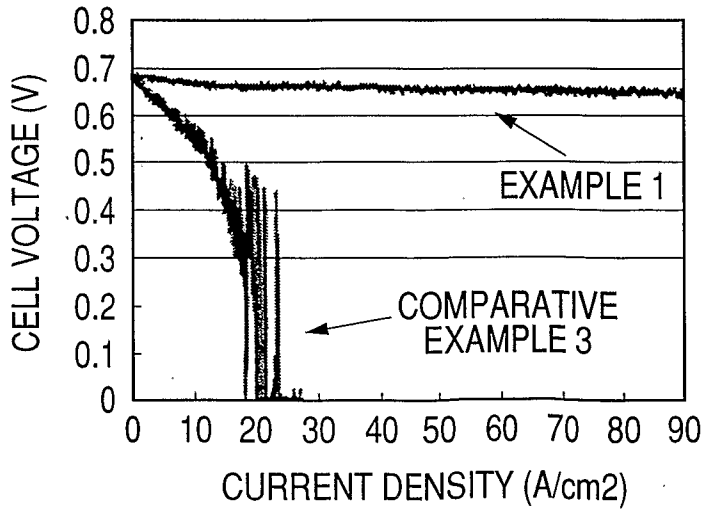

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CELL VOLTAGE (V)
EXAMPLE 1
COMPARATIVE EXAMPLE 3
0
10
20
30
40
50
60
70
80
90
CURRENT DENSITY (A/cm2)

FIG. 34A

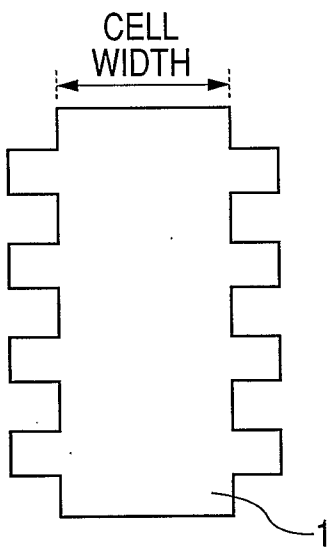


FIG. 34C

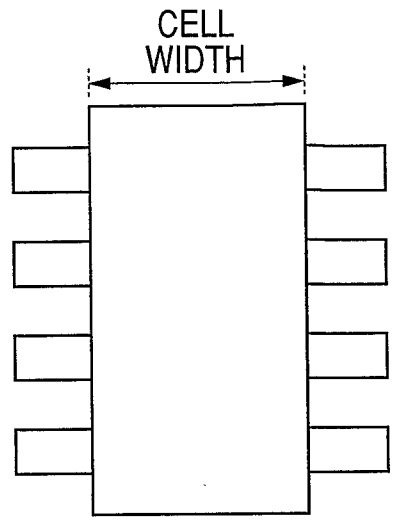


FIG. 34B

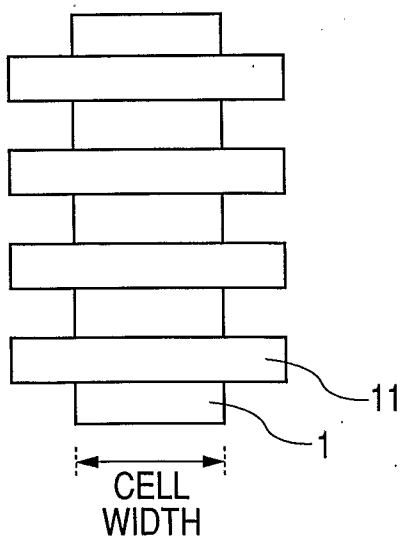


FIG. 34D

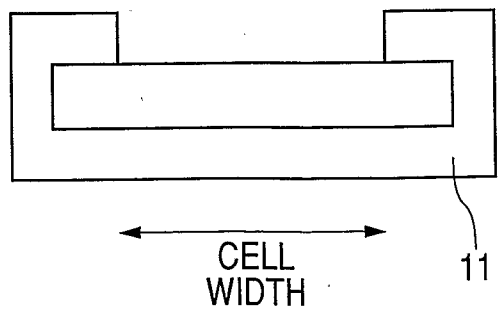


FIG. 35A

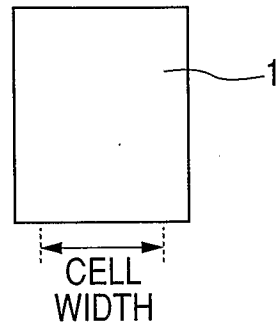


FIG. 35B

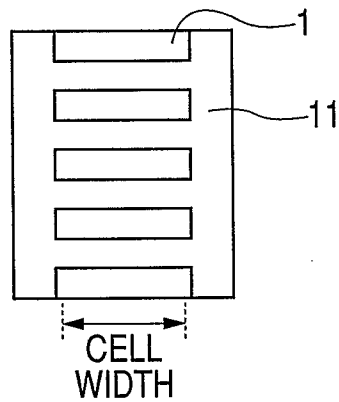


FIG. 35C

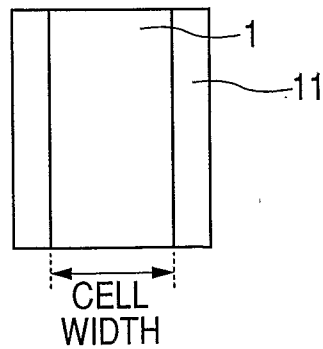


FIG. 35D

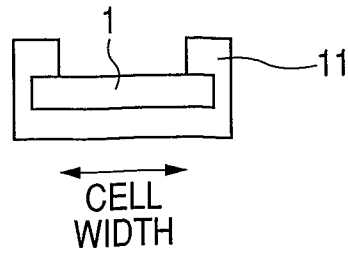
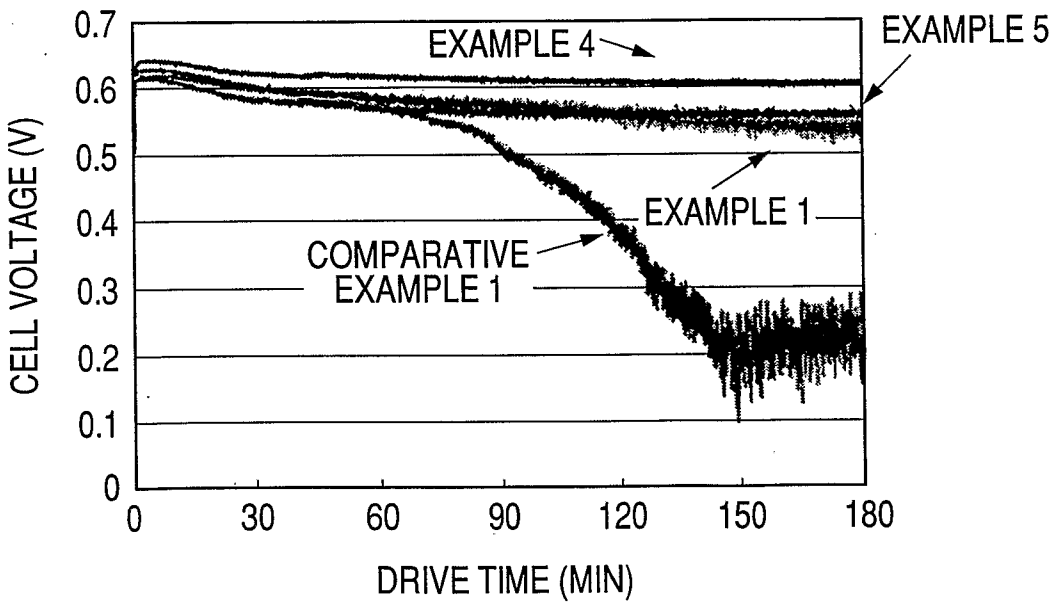


FIG. 36


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CELL VOLTAGE (V)
EXAMPLE 4
EXAMPLE 5
EXAMPLE 1
COMPARATIVE EXAMPLE 1
0
30
60
90
120
150
180
DRIVE TIME (MIN)

INTERNATIONALSEARCHREPORT

International application No.
PCT/JP2007/052156

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H01M8/02(2006.01)i, H01M4/86(2006.01)i, H01M8/06(2006.01)n, H01M8/10(2006.01)n

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. H01M8/02, H01M4/86, H01M8/06, H01M8/10

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2007
Registered utility model specifications of Japan 1996-2007
Published registered utility model applications of Japan 1994-2007

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 11-135132 A (Toshiba Corporation) 1999.05.21, claim 1-12, 【0007】, 【0053】－【0059】, fig. 2,3 (Family None)	1,2,5,7,8,15,16,18 3,11,12 4,6,9,10,13,14,17
X A	JP 2002-313359 A (Mitsubishi Hevy Industries, Ltd.) 2002.10.25, claim 1-13, fig. 1 (Family None)	1,2,7,18 3-6,8-17
X A	JP 2004-39416 A (NEC Corporaition) 2004.02.05, claim 1-28, fig. 1,2 & US 2005/255373 A1 & WO 2004/006364 A1	1,2,7,18 3-6,8-17

☑ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08.05.2007	22.05.2007

Name and mailing address of the ISA/JP	Authorized officer
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INTERNATIONALSEARCHREPORT

International application No.
PCT/JP2007/052156

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 10-189012 A (Toyota Motor Corporaition) 1998.07.21, 【００１１】—【００１３】,【００２９】, fig. 2,3 (family None)	3 1,2,4-17
Y A	JP 59-56362 A (Mitsubishi Electric Corporaition) 1984.03.31, claim 1,2, fig. 1-3 (family None)	11,12 1-10,13-17
A	JP 2005-149846 A (DENSO Corporaition) 2005.06.09 (family None)	1-17
A	JP 6-267562 A (Mitsubishi Hevy Industries, Ltd.) 1994.09.22 (family None)	1-17