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(54) Title: MODIFIED GAS DIFFUSION LAYER IN FUEL CELLS

Figure 1

(57) Abstract: The invention relates to fuel cells such as those used in vehicles. A modification to the gas diffusion layer 2 (GDL) results in an anisotropic diffusion rate for the various diffusion media in the fuel cell, in particular such as water vapor or, for example, oxygen as well. For this purpose, defined areas 3 composed of a material with selective diffusion characteristics are introduced into the GDL 2. Diffusion-controlling materials such as these are preferably arranged in the GDL in the area of the webs 5, that is to say between the channels 4 of the adjacent gas distribution structure. In particular, this makes it possible to influence lateral diffusion via the GDL 2 between the channels 4. This leads to regulation of the water budget and/or to compensation for the gas distribution of the reaction gases.
Modified Gas Diffusion Layer in Fuel Cells

The invention relates to fuel cells, such as those used for traction purposes in modern vehicles. Groups of fuel cells are typically in this case combined to form so-called stacks.

In general, fuel cells comprise two electrically conductive current transmitter plates as an anode and cathode, between which there is an intermediate layer which conducts ions. By way of example, the intermediate layer is in the form of a polymer electrolyte membrane (PEM). This arrangement is referred to as a membrane electrolyte assembly (MEA). On each side (anode or cathode) of the MEA, the reaction gases (anode gas, that is to say hydrogen or a gas containing hydrogen, and cathode gas, that is to say oxygen or a gas containing oxygen, in particular air) are passed via channels in a gas distribution structure to a respective gas diffusion layer (GDL).

In this embodiment of fuel cells, the water balance represents a particular problem: if a membrane is not moisturized or is only partially moisturized, drying-out effects occur on the membrane which can adversely affect the efficiency or completely prevent operation of the MEA. In the worst case, if the electrolyte dries out locally, gas can pass through thus leading to the formation of combustible gas mixtures, which can irreparably damage the fuel cell.

The prior art includes arrangements for feeding some of the cathode gas, which has been moisturized by the reaction process, back to the input of the cathode. A fuel cell with corresponding moisture regulation of the reaction gases is described, for example, in WO 94/03937 A1. In this arrangement, the operating state of the fuel cell is first of all determined from the actual current and voltage output, and the amount of gas to be fed back is then calculated, and set by means of valves, with the aid of control electronics as
a function of these operating parameters. In this case, the operating parameters are always calculated using the same scheme, that is to say any changes in the operating behavior of the cell over time, for example as a result of ageing, partial drying out, etc., are ignored. This can lead to the control electronics calculating operating parameters which do not lead to optimum operating states in the fuel cell, and therefore lead to poorer performance.

Laid-open specification DE 101 49 059 A1 describes a gas distribution structure in which the channels are routed such that, shortly after the inlet for the relatively dry reaction gas, channel sections run in the vicinity of other channel sections which lead to the gas outlet and in which the partially consumed reaction gas has a relatively high moisture content because of the electrolytic reaction which has already taken place. According to the teaching of this document, this adjacent distribution of incoming and outgoing channel sections with a greatly different water vapor partial pressure is associated with water vapor diffusion across the PEM, compensating for the moisture gradient.

Laid-open specification DE 102 29 820 A1 likewise relates to regulation of the moisture content of the reaction gases in fuel cells. This document describes a gas distribution apparatus in which reaction gases are introduced in at least two different directions through adjacent channels over the electrochemically active area. In the simplest case, the reaction gases flow in the opposite direction through channels that run parallel over the electrode. The bidirectional flow path for the reaction gases is intended to homogenize the water budget in the fuel cell, and therefore to compensate for any differences in the flow density distribution. One problem in this case is possible lateral diffusion of the reaction gases in the GDL, leading to gas being exchanged between the channels.

Laid-open specification DE 10 2005 011 853 A1 relates to compensating moisturization in the proton exchange membranes of fuel cells, and therefore relates to the same technical field as the abovementioned documents. This document discloses a fuel cell in which the gas diffusion layer GDL has hydrophilic and hydrophobic layers. Figure 1 (which corresponds to Figure 7 in DE 10 2005 011 853 A1) illustrates the configuration schematically. The hydrophobic layer is arranged with respect to the MEA and distributes moisture over the plane, thus promoting equalized moisturization of the PEM. The hydrophilic layer is arranged at the side of the gas distribution structure and keeps water
available for emission to the reaction gas diffusing into the GDL. The hydrophobic layer is made locally stronger in the areas between the channels of the gas distribution structure. The aim of this is to counteract the moisture gradient between the channel area and the intermediate web. In order to further improve the water budget, the teaching in this document provides additional capillary structures that carry water.

The disadvantages of an apparatus such as this are the amount of production effort to produce the hydrophilic and hydrophobic layers with a locally different strength and the additional capillary structures.

The invention is based on the last-mentioned document as the closest prior art. It is based on the object of developing an alternative apparatus for regulation of the water budget in fuel cells.

For an apparatus having the features of the precharacterizing clause of claim 1, this object is achieved by the characterizing features of claim 1. Further details and advantageous embodiments of the apparatus according to the invention are the subject matter of the dependent claims.

The invention proposes that the GDL be provided with anisotropic diffusion characteristics, by appropriate structuring. This results, for example, in a GDL with a good diffusion capability for water vapor from the gas-carrying channels in the direction of the MEA and, in contrast, a reduced water vapor diffusion rate laterally with respect to this, that is to say from channel to channel in the gas distribution structure.

In the case of gas diffusion layers composed of fiber-like material, for example graphite fabric, this anisotropic diffusion rate is achieved, for example, by means of a specifically designed texture, that is to say the fiber arrangement or fiber mesh is introduced on a direction-oriented basis such that, for example, preferred gas-flow directions are formed parallel to the channels and/or webs in the gas distribution structure. In the case of gas diffusion layers of a different type without fiber structures, a modification according to the invention can be achieved in that defined areas composed of a material with selective diffusion characteristics for the various diffusion media in a fuel cell, in particular such as water vapor or, for example, oxygen as well, are introduced into the GDL. Diffusion-controlling materials such as these are preferably arranged in the GDL in the area of the
webs, that is to say between the channels of the adjacent gas distribution structure. In particular, this makes it possible to influence lateral diffusion via the GDL between the channels. An embodiment such as this is particularly suitable for regulation of the water budget and of the gas distribution of the reaction gases, using the opposing-flow principle according to the document DE 102 29 820 A1 described above.

Combinations of both structuring measures, that is to say additionally incorporated areas composed of material with a selective diffusion character in a GDL, are also part of the teaching according to the invention.

One exemplary embodiment of the invention will be explained in more detail in the following text with reference to Figure 2 and the reference symbols stated therein.

Figure 2 shows a section through the various layers and structures of the reaction area of a fuel cell. The illustration shows the membrane electrode assembly 1 with the adjacent gas diffusion layer 2 and the gas distribution structure resting on it, comprising gas-carrying channels 4 and separating webs 5. In this example, the diffusion processes in the GDL 2 are influenced by arranging areas 3 composed of material with selective diffusion characteristics over the webs 5 of the adjacent gas distribution layer. In order to avoid reducing the reactive area of the MEA 1 by the structuring of the GDL 2 according to the invention, the areas 3 either do not extend as far as the MEA 1 or, as is illustrated in Figure 2, they are preferably designed in such a way that they taper towards the MEA 1. These areas 3 which, for example, are prismatic, are used with an appropriate choice of material to regulate the diffusion of reaction components in the GDL 2 laterally with respect to the channels 4. A corresponding material can be used for this purpose, depending on the desired diffusion rate. If, for example, the aim is to completely suppress diffusion from one channel to another transversely through the areas 3, then, for example, an epoxy adhesive can be used for these structures in the GDL 2. A correspondingly reduced gas exchange then takes place between the channels just via the areas of the GDL 2 which remain free, depending on the shape, position and extent of the areas 3 over the webs 5 and the distance that remains free to the MEA 1.

In the embodiment shown in Figure 2, it is particularly advantageous for the diffusion-controlling structures 3 to be formed from materials through which different media pass
selectively. For example, polyphenylsulfone (PPSU) is suitable for this purpose, in particular with hydrophilic additives such as polyvinyl alcohol, in order on the one hand to allow moisture compensation from one channel to another, while on the other hand preventing uncontrolled mixing of reaction gases. In addition, partial permeability for other gases, for example oxygen, can be selected specifically as well by further additives, therefore making it possible to match the oxygen concentration on the cathode side of the PEM. This is associated with an improvement in the current density distribution.

The structure according to the invention of the GDL in order to produce anisotropic diffusion characteristics offers a multiplicity of design and combination options. Parameters which can be varied over wide ranges are in this case on the one hand the texture characteristics of the GDL layer itself and/or the shape, position, extent and the material of the areas 3 in the GDL. The GDL can therefore be designed for lateral diffusion rates which differ as a function of the media.

The specifically variable exchange of the various gas components between the channels not only allows compensation for moisture but also matching of concentration differences in the reactants, for example the oxygen content. This is associated with an improvement in the current density distribution. Overall, this leads to a performance advantage and to stability of the fuel cell, with a positive effect on the life of the cell.
Patent Claims

1. A fuel cell having a membrane electrolyte assembly 1 (MEA), with the reaction gases being passed through channels 4 in a gas distribution structure to a gas diffusion layer 2 (GDL), characterized in that the gas diffusion layer 2 has locally anisotropic diffusion characteristics for water vapor and/or at least one of the reaction gases.

2. The fuel cell as claimed in claim 1, characterized in that the GDL 2 is composed of fiber-like material, preferably graphite fabric, with anisotropic diffusion characteristics being achieved by alignment of the fiber arrangement (texture), preferably parallel to the channels 4 and/or webs 5 in the gas distribution structure.

3. The fuel cell as claimed in claim 1 or 2, characterized in that the GDL 2 has local areas 3 composed of diffusion-controlling material.

4. The fuel cell as claimed in claim 3, characterized in that the areas 3 are arranged over the webs 5 of the gas distribution structure.

5. The fuel cell as claimed in claim 3 or 4, in that a material which is impermeable to water vapor and reaction gases, preferably an epoxy adhesive, is used for the areas 3.
6. The fuel cell as claimed in claim 3 or 4, characterized in that a material which has selectively different diffusion rates for water vapor and reaction gases, preferably a polyphenylsulfone, is used for the areas 3.

7. The fuel cell as claimed in claim 6, characterized in that selectively different diffusion rates are achieved by additives to the material of the areas 3, preferably hydrophilic additives such as polyvinyl alcohol.

8. The fuel cell as claimed in one of claims 4 to 7, characterized in that the areas 3 have a profile over the webs 5 which tapers from the web 5 over the thickness of the GDL 2 towards the MEA 1.
**Figure 1**

- Target area
- Very highly hydrophobic
- Less hydrophobic but moreso than above the channels
- Least hydrophobic

**Figure 2**

- Hydrophobic
- Hydrophilic
- Hydrophobic/hydrophilic change on the plane/transversely with respect to the plane

- Stages 1, 2, 3, 4, 5
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01M4/86 H01M8/02 H01M8/04

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

B. RELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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& document member of the same patent family

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Name and mailing address of the ISA:

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Martin Fernandez, A
### Documents Considered to Be Relevant

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