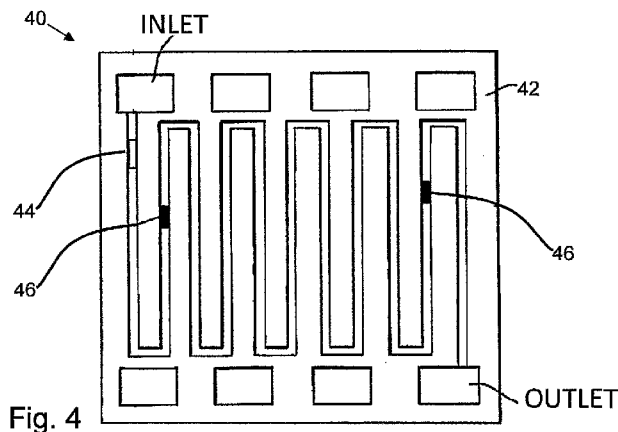




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(54) Title: COMPONENT FOR A FUEL CELL SYSTEM



(57) Abstract: The invention relates to a component for a fuel cell system. The component has a surface region that is reconfigurable between at least a first state and a second state, wherein the first state is more hydrophilic than the second state and wherein the surface is configured to adopt the first state or the second state in accordance with a condition at the surface.

WO 2016/124937 A1

Component for a Fuel Cell System

The invention relates to a component for a fuel cell system and in particular, although not exclusively, to such a component with improved fluid flow properties.

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Conventional electrochemical fuel cells convert fuel and oxidant into electrical energy and a reaction product. One example layout of a conventional fuel cell 10 is shown in figure 1 which, for clarity, illustrates the various layers in exploded form. A solid polymer ion transfer membrane 11 is sandwiched between an anode 12 and a cathode 13. Typically, the anode 12 and the cathode 13 are both formed from an electrically conductive, porous material such as porous carbon, to which small particles of platinum and/or other precious metal catalyst are bonded. The anode 12 and cathode 13 are often bonded directly to the respective adjacent surfaces of the membrane 11. This combination is commonly referred to as the membrane-electrode assembly, or MEA.

15

Sandwiching the polymer membrane and porous electrode layers is an anode fluid flow field plate 14 and a cathode fluid flow field plate 15. Intermediate backing layers 15a and 13a may also be employed between the anode fluid flow field plate 14 and the anode 12 and similarly between the cathode fluid flow field plate 15 and the cathode 13. The backing layers 15a are of a porous nature and fabricated so as to ensure effective diffusion of gas to and from the anode and cathode surfaces as well as assisting in the management of water vapour and liquid water. For this reason, the backing layers 15a are sometimes also referred to as gas diffusion layers (GDLs).

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The fluid flow field plates 14, 15 are formed from an electrically conductive, non-porous material by which electrical contact can be made to the respective anode electrode 12 or cathode electrode 13. At the same time, the fluid flow field plates facilitate the delivery and/or exhaust of fluid fuel, oxidant and/or reaction product to or from the porous electrodes 12, 13. This is conventionally effected by forming fluid flow passages in a surface of the fluid flow field plates, such as grooves or channels 16 in the surface presented to the porous electrodes 12, 13.

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With reference also to figure 2a, one conventional configuration of fluid flow channel provides a serpentine structure 20 in a face of the anode 14 (or cathode 15) having an inlet manifold 21 and an outlet manifold 22 as shown in figure 2a. According to conventional design, it will be understood that the serpentine structure 20 comprises a channel 16 in the surface of the plate 14 (or 15), while the manifolds 21 and 22 each

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comprise an aperture through the plate so that fluid for delivery to, or exhaust from, the channel 20 can be communicated throughout the depth of a stack of plates in a direction orthogonal to the plate as particularly indicated by the arrow in the cross-section on A–A shown in the figure 2b.

5

With reference to figure 3, in an example of a conventional fuel cell assembly 30, stacks of plates are built up. In this arrangement, adjacent anode and cathode fluid flow field plates are combined in conventional manner to form a single bipolar plate 31 having anode channels 32 on one face and cathode channels 33 on the opposite face, each adjacent to a respective membrane-electrode assembly (MEA) 34. The inlet manifold apertures 21 and outlet manifold apertures 22 are all overlaid to provide the inlet and outlet manifolds to the entire stack. The various elements of the stack are shown slightly separated for clarity, although it will be understood for the purposes of the present invention that they will be compressed together using sealing gaskets. Alternatively, the individual fuel cell assemblies 30 can be provided separately, for example in a row.

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Water management is an important consideration in the operation of such fuel cells. During operation of a fuel cell, product water from the reaction between hydrogen and oxygen is formed at catalytic sites of the MEA. This water must be exhausted from the MEA via the cathode diffusion structure at the same time that oxygen is transported to the cathode face of the MEA. However, it is also important that the MEA remains suitably hydrated to ensure that the internal electrical resistance of the cell remains within tolerable limits. Failure to control the MEA humidification leads to hot spots and potential cell failure and/or poor electrical cell performance.

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According to a first aspect of the invention there is provided a component for a fuel cell system, the component having a surface region that is reconfigurable between at least a first state and a second state, wherein the first state is more hydrophilic than the second state and wherein the surface is configured to adopt the first state or the second state in accordance with a condition at the surface.

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The surface region may be dynamically controlled. The surface region may be dynamically reconfigurable during operation of the fuel cell system. The surface region may be reversibly configurable between at least a first state and a second state. The surface region may be reconfigurable in response to time-dependent stimulus.

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The surface region may be configured to adopt the second state in response to a localised increase in a water level at the surface. The surface region may be configured to switch from the first state to the second state in response to an increase in a water level at the surface. The condition may be one or more of a water level, a current density, an electric field, electric potential at the surface, a temperature, temperature gradient at the surface, a pH of a fluid at the surface or a concentration of a ligand or ion at the surface.

The component may be one of: a gas diffusion layer, a fuel cell plate, a fluid flow plate configured to guide reactant over an active area of a fuel cell of the fuel cell system, a water separator, a heat exchanger, a pump or a fluid line.

The surface region may have one or more further states in addition to the first and second states. The surface region may have a continuum of states between the first and second states. Each state may have a different level of hydrophobicity to the other states. Such a surface region may provide a variety of hydrophobic conditions in response to the condition at the surface.

The component may comprise a plurality of independently reconfigurable surface regions.

The plurality of independently reconfigurable surface regions may comprise at least first and second subsets. Each subset may comprise one or more reconfigurable surface regions. The first subset may be configured to adopt one of the first state and the second state in response to the condition at the surface meeting a first trigger. The second subset may be configured to adopt one of the first state and the second state in response to the condition at the surface meeting a second trigger. The first trigger may be different to, or the same as, the second trigger. The first trigger may relate to a different type of condition to the second trigger. The first trigger may relate to the same type of condition as the second trigger. The first trigger may be at a different level to the second trigger.

A layer of molecules may be attached to the surface. Each molecule may have a functional end group. Each molecule may have a chain connecting the surface to the functional end group. The functional end group may be configured to attract or repel water molecules. The chain may be configurable such that in one of the first state and the second state the functional end group is provided distally from the surface for interacting with water molecules. The chain may be configurable such that in the other of the first state and the second state the functional end group is provided proximal to the surface and inhibited from interacting with water molecules.

The functional end group may comprise a benzyl moiety, such as benzyl ammonium, pyridinium or a carboxylate. The chain may comprise an alkyl chain or glycol chain selected to have a different hydrophobicity to the functional end group. The chain may be more or less hydrophobic than the functional end group. The chain may comprise a trans-isomer in one of the first and second states. The chain may comprise a cis-isomer in the other of the first and second states.

According to a further aspect of the invention there is provided a method of operating a fuel cell system comprising a component having a surface region with at least a first state and a second state, wherein the first state is more hydrophilic than the second state, the method comprising reconfiguring the surface to adopt the first state or the second state in accordance with a condition at the surface.

According to a further aspect of the invention there is provided a fuel cell system comprising a component as described above.

Embodiments of the present invention are now described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a schematic cross-sectional view through a part of a conventional fuel cell;

Figures 2a and 2b respectively show a simplified plan and sectional view of a fluid flow field plate of the fuel cell of figure 1;

Figure 3 shows a cross-sectional view through a conventional fuel cell stack with bipolar plates;

Figure 4 illustrates an example of a component with a surface having a reconfigurable hydrophobicity; and

Figures 5a and 5b show schematic views of a first state and a second state of a surface having reconfigurable hydrophobicity.

The invention relates generally to a component for a fuel cell system that has a reconfigurable surface. The reconfigurable, or switchable, surface is able to vary its hydrophobicity between at least a first state and a second state according to its environment. The first state is more hydrophilic than the second state. Expressed in another way, the second state is more hydrophobic than the first state because hydrophobicity can be considered to be the absence of a hydrophilic attraction.

The surface is configured to adopt the first state or the second state in accordance with a condition at the surface, for example a voltage change at a gas diffusion layer or bipolar plate. In this way interfacial properties, such as wetting behaviour, at the surface can be dynamically controlled in accordance with the environment at the surface. The surface
5 may therefore automatically compensate for variations in the environmental condition without the need for any active, or external, control in order to improve the performance of the component.

Figures 4 illustrates an example of a component 40 for a fuel cell system. In this example,
10 the component is a fuel cell plate configured to guide reactant over an active area of a fuel cell, which may be provided in a fuel cell stack of the fuel cell system. The component 40 of figure 4 is generally similar to the component described with reference to 2a and 2b except that the component 40 of figure 4 has a surface 42 with a reconfigurable hydrophobicity. The reconfigurable surface may also be provided in the water manifolds
15 (the inlet and outlet) of the plate.

The surface 42 of the component 40 comprises a plurality of reconfigurable surface regions 44, 46. Each regions is independently reconfigurable between at least a first state and a second state. That is, a state of one region 44 of the surface 42 does not affect a state of
20 another region 46 of the surface 42.

The plurality of surface regions may be provided over the entirety of the surface or over only a portion of the surface (less than the entirety of the surface). In the example shown in figure 4, reconfigurable surface regions 44, 46 are provided along a fluid flow path
25 between the inlet and the outlet. In this example it is not necessary to coat the inlands that separate the regions of the fluid flow path and so the amount of reconfigurable material used may be reduced compared to examples in which the entire surface is coated.

The plurality of surface regions 44, 46 are configured to adopt the first state or the second
30 state in accordance with a condition at the surface. During operation of a fuel cell in which the component 40 is located, localised flooding can occur at one or more regions of the surface 42 due to a build-up of water by-product from electrochemical reactions occurring at the MEA. Localised flooding caused by the water build-up results in a decrease in the efficiency of the cell and can cause premature and localised failure of the cell. Another
35 effect of localised flooding is that an electrical potential in the region of the cell that is flooded may be reduced because of the localised decrease in efficiency. This change in potential provides a trigger for switching the state of the reconfigurable surface. The

reconfigurable surface may change from a hydrophilic, or neutral, first state to a hydrophobic second state in order to clear the flooded water from the affected region and so improve the localised operation of the component 40. An advantage of this technique is that the response of the surface 40 to the environmental conditions is automatic in that
5 no additional control or actuation is required in order to affect the change. In this way, the component automatically compensates for the occurrence of undesirable surface conditions, such as localised flooding.

Three of the plurality of reconfigurable surface regions are labelled in figure 4. A first
10 surface region 44 is in the first state. Second and third surface regions 46 have adopted the second state (more hydrophobic than the first state) in response to a localised increase in water level, or more specifically in response to the localised increase in water level altering the local potential within the second and third regions 46. In this way, the interfacial properties of the regions of the surface are dynamically controlled in accordance with the
15 local environment at the surface 42.

In this example, the condition that acts as a trigger for the switching is a current density, an electric field or electric potential at the surface. Alternatively, the surface may be configured to adopt a particular configuration in response to a temperature or temperature
20 gradient at the surface, or in response to a pH of a fluid at the surface, the relative humidity of the fluid at the surface, the pressure of the fluid at the surface, a compressive force applied to the surface or the chemistry of the fluid at the surface. Each of these conditions may be affected by localised flooding of the surface. As a further alternative, the surface may be configured to adopt a particular configuration directly in response to relative
25 humidity of the fluid at the surface

Although figure 4 is discussed in relation to a fuel cell plate, it will be appreciated that similar surfaces may be advantageous in other fuel cell components. For example, the component may be a different fuel cell stack component such as a gas diffusion layer.
30 Alternatively, the component may be a water separator, a heat exchanger, a pump or a fluid line of a fuel cell system.

An advantage of providing a switchable surface region with a hydrophobicity that varies in accordance with local conditions, as opposed to providing a region that is hydrophobic all
35 of the time, is that a certain level of moisture, or hydration is required in order for efficient cell operation and so providing a permanent hydrophobic layer may cause the cell to dry out.

The surface 42 of the component 40 may comprise a plurality of reconfigurable surface regions in which there are first and second subsets of the plurality of reconfigurable surface regions. Each subset can comprise one or more reconfigurable surface regions. The first subset is configured to adopt the first state or the second state in response to the condition at the surface 42 meeting a first trigger. Similarly, the second subset is configured to adopt the first state or the second state in response to the condition at the surface 42 meeting a second trigger.

All of the surface regions 44, 46 in figure 4 have the same type and level of trigger and so any division of these regions 44, 46 into first and second subsets results in the first subset having a first trigger that is both the same type and same level as a second trigger of the second subset.

Alternatively, the first trigger may be different from the second trigger. The first trigger may be a different type to the second trigger. For example, the first trigger may be related to the ionic conductivity of fluid at the surface and the second trigger may be related to an electric field at the surface (or any other type of condition). If both the first trigger and the second trigger are related to the electric field, for example, then the triggers are of the same type. In the case where the triggers are of the same type, the first trigger may be at a different level than the second trigger. Where the first and second triggers are related to the electric field, the first trigger may have a level of 100 V.m^{-1} and the second trigger may have a level of 200 V.m^{-1} . In this example, the first subset of reconfigurable surface regions may switch from the second state to the first state when the electric field at those regions falls below 100 V.m^{-1} and the second subset of reconfigurable surface regions may switch from the second state to the first state when the electric field at regions falls below 200 V.m^{-1} .

In another example in which the first trigger is of the same type as the second trigger but the first and second triggers are at different trigger levels, the reconfigurable surface regions in the first and second subset may both be sensitive to the temperature at the surface. The state of the first subset may be set in response to the temperature passing 300 K and the state at the second subset may be set in response to the temperature passing 350 K .

Figures 5a and 5b show schematic views of a surface 50 having reconfigurable hydrophobicity. The surface is shown in a first state in figure 5a and in a second, less hydrophilic state in figure 5b.

5 In both figures 5a and 5b the surface 50 comprises a bulk 52 and a layer of molecules 54a, 54b, 56 attached to the bulk 52. The layer of molecules 54a, 54b, 56 may be provided as a self-assembled monolayer. Each molecule 54a, 54b, 56 has a functional end group 56 and a chain 54a, 54b connecting the bulk 52 to the functional end group 56. The functional end group 56 is configured to attract or repel water molecules and also configured to be
10 attracted to, or repelled from, the bulk depending upon a condition. In the example illustrated, the condition is the electric potential of the bulk 52 of the surface 50 and the functional end group 56 is a positively-charged hydrophilic ligand that exhibits an attractive force for water molecules. In other examples, the functional group may be chosen from elements or compounds that are known to exhibit an attraction or repulsion in response to
15 a particular temperature or temperature gradient at the surface, or in response to a pH of a fluid at the surface, the relative humidity of the fluid at the surface, the pressure of the fluid at the surface, a compressive force applied to the surface or the chemistry of the fluid at the surface, including, for example a concentration of a particular ligand or ion at the surface. In this way, the surface 50 may be made to be responsive to a variety of
20 conditions.

Examples of end groups for use in fuel cell applications include a benzyl end group, covalently bound to the substrate using diazonium chemistry; or pyridinium, benzyl ammonium or other positively-charged group attached to an unbound end of the alkyl
25 chain; its positive charge conferring potential-dependent switching behaviour. An alkyl chain may be attached to the end group in a para position.

The presence of an electro-positive end group in a fuel cell environment may provide the additional benefit of absorbing any free anions which are present in the system, such as
30 Cl⁻. Alternatively, the functional end group 56 may be a negative end group such as a hydrophilic carboxylate.

The chain 54a, 54b is resiliently flexible between a first configuration in the first state and a second configuration in the second state to allow the functional end group 56 to move
35 relative to the bulk 52. In some examples, the chain is a molecule that is able to shift between isomer configurations depending upon the applied conditions. For example, the chain may adopt a trans-isomer in the first state and a cis-isomer in the second state.

The chain may itself be hydrophobic, such as a hydrophobic alkyl chain, in order to increase the variation in hydrophobicity between the first and second states.

5 A preferred route for effecting a bond between the functional end group, or ligand, and the substrate of the surface is to form a covalent bond using diazonium chemistry. The layer of molecules 54a, 54b, 56 may also be provided as a self-assembled monolayer, such as a monolayer of (16-Mercapto)hexadecanoic acid (MHA). MHA self assembles on Au(111) and provides the reconfigurable surface properties.

10

Figure 5a illustrates a first state of the surface 50 in which the bulk is electropositive (carries a positive charge 58). In this example the functional end group 56 is also electropositive and so is repelled from the bulk 52. In the first state, the chain 54a is configured such that the functional end group 56 is provided distally from the bulk 52. The chain 54a is therefore orientated to enable interaction between the functional end group 56 and water molecules. The functional end group 56 exerts an attractive force on water molecules in this example and so the first state of the surface is hydrophilic.

20 The absolute sign of the electric field applied at the surface 50 does not necessarily need to change in order to cause a reorientation of the chain molecules between the first and second positions. Instead the sign of the potential may change with respect to a potential of zero charge (pzc) of the surface. The pzc of the surface, including switchable chain molecules, may be tuned so that it is at a trigger level intermediate between, for example, the potential of a flooded cell and a functioning fuel cell.

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Figure 5b illustrates a second state of the surface 50 in which the bulk is less electropositive than the surface 50 in the first state, and so is relatively electronegative (illustrated as carrying a negative charge 60). The electropositive functional end group 56 is attracted to the bulk 52. In the second state, the chain 54b is configured such that the functional end group 56 is provided proximal to the bulk 52. The orientation of the chain 54b therefore inhibits interaction between the functional end group 56 and water molecules. The interaction between the functional end group 56 and water molecules is inhibited by shielding of the functional end group 56 from the water molecules by the chain 54b.

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The surface 50 illustrated in figures 5a and 5b may be provided on a component of a fuel cell such as a fuel cell plate that is positively charged during operation. During normal

operation, a higher positive charge is present on the surface 50 than during impaired operation when the surface 50 is flooded. The surface 50 therefore adopts the first, hydrophilic state (illustrated in figure 5a) during normal operation and the second hydrophobic state (illustrated in figure 5b) during impaired operation. The adoption of a hydrophobic state counteracts the flooding that is impairing operation of the fuel cell. In this way, operational fuel cell may be automatically improved.

In some practical applications, the molecules may move through a range of conformations between the extremes shown in figures 5a and 5b. In such examples, the surface energy of the surface may vary continuously between first state and the second state. This property may be advantageous in fuel cell applications because it enables fine control of the movement of liquid water within the fuel cell system. In such examples a level of hydrophobicity may be provided by the reconfigurable surface in proportion to the level of water at the surface.

15

Claims

1. A component for a fuel cell system, the component having a surface region that is reconfigurable between at least a first state and a second state, wherein the first state is more hydrophilic than the second state and wherein the surface is configured to adopt the first state or the second state in accordance with a condition at the surface.
5
2. The component of claim 1, wherein the condition is a water level at the surface.
- 10 3. The component of claim 2, wherein the surface region is configured to adopt the second state in response to an increase in the water level at the surface.
4. The component of claim 1, wherein the condition is a current density, an electric field or electric potential at the surface.
15
5. The component of claim 1, wherein the condition is a temperature or temperature gradient at the surface.
6. The component of claim 1, wherein the condition is a pH of a fluid at the surface or a concentration of a ligand or ion at the surface.
20
7. The component of any preceding claim, wherein the component is one of: a gas diffusion layer, a fuel cell plate or a fluid flow plate configured to guide reactant over an active area of a fuel cell of the fuel cell system.
25
8. The component of any of claims 1 to 6, wherein the component is one of: a water separator, a heat exchanger, a pump or a fluid line.
9. The component of any preceding claim, wherein the surface region is dynamically reconfigurable during operation of the fuel cell system.
30
10. The component of any preceding claim, wherein the surface region has one or more further states in addition to the first and second states, each state having a different level of hydrophobicity to the other states.
- 35 11. The component of any preceding claim, wherein the surface region has a continuum of states between the first and second states.

12. The component of any preceding claim, comprising a plurality of independently reconfigurable surface regions.
- 5 13. The component of any preceding claim, wherein the plurality of independently reconfigurable surface regions comprises first and second subsets, wherein each subset comprises one or more reconfigurable surface regions, wherein the first subset is configured to adopt the first state or the second state in response to the condition at the surface meeting a first trigger, wherein the second subset is configured to adopt the first state or the second state in response to the condition at the surface meeting a second trigger and wherein the first trigger is different from the second trigger.
- 10 14. The component of claim 13, wherein the first trigger relates to a different type of condition to the second trigger.
- 15 15. The component of claim 13 or claim 14, wherein the first trigger is at a different level to the second trigger.
16. The component of any preceding claim, wherein a layer of molecules is attached to the surface, each molecule having a functional end group and a chain connecting the surface to the functional end group, wherein the functional end group is configured to attract or repel water molecules, wherein the chain is configurable such that:
- 20 in the first state the functional end group is provided distally from the surface for interacting with water molecules; and
- 25 in the second state the functional end group is provided proximal to the surface and inhibited from interacting with water molecules.
17. The component of claim 16, wherein the functional end group comprises a benzyl moiety, pyridinium or a carboxylate.
- 30 18. The component of claim 17, wherein the chain comprises an alkyl chain or glycol chain selected to have a different hydrophobicity to the functional end group.
19. The component of claim 16 or claim 17, wherein the chain comprises a trans-isomer in the first state and a cis-isomer in the second state.
- 35 20. A fuel cell system comprising the component of any preceding claim.

21. A method of operating a fuel cell system comprising a component having a surface region with at least a first state and a second state, wherein the first state is more hydrophilic than the second state, the method comprising reconfiguring the surface to adopt the first state or the second state in accordance with a condition at the surface.

5

22. A component for a fuel cell system as described herein with reference to the accompanying figures.

23. A method of operating a fuel cell system as described herein with reference to the accompanying figures.

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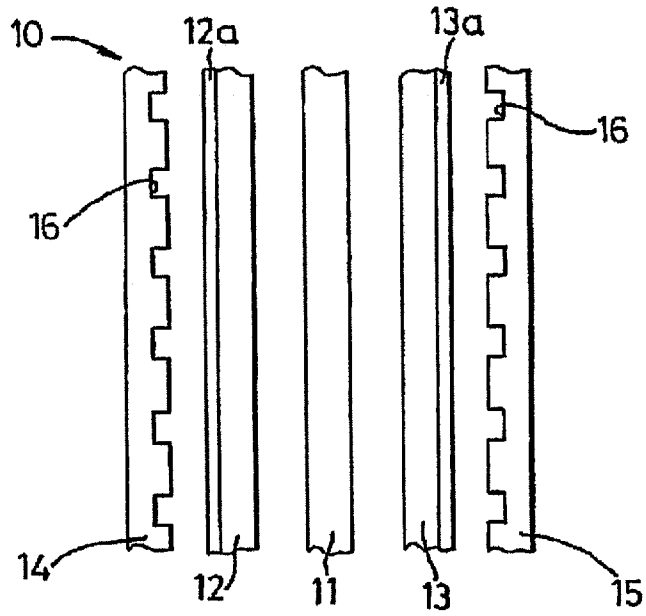


Fig. 1

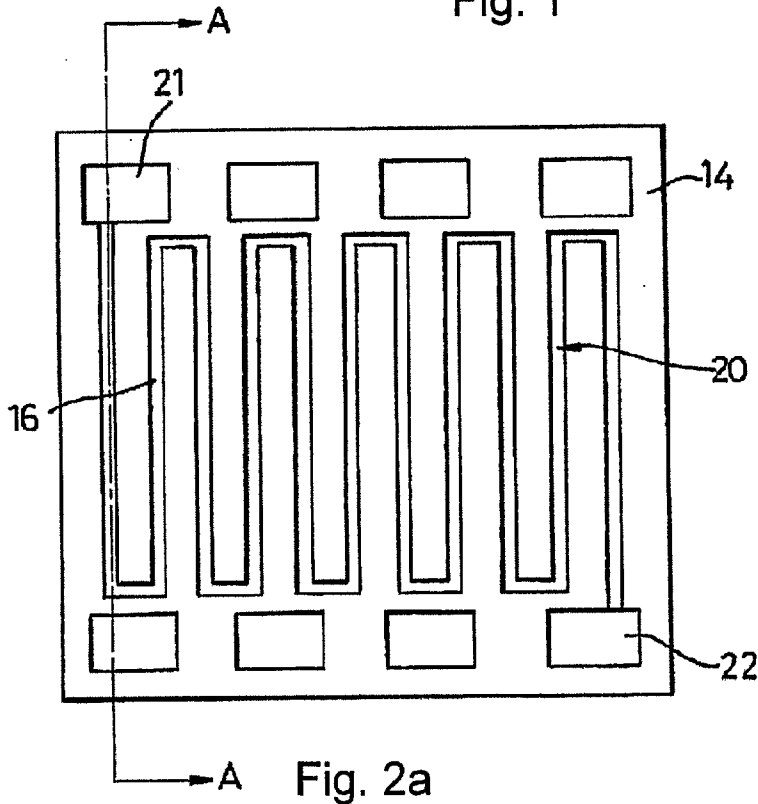


Fig. 2a

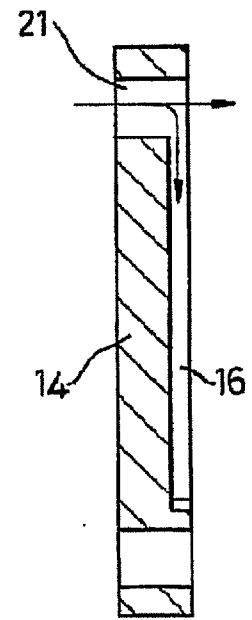


Fig. 2b

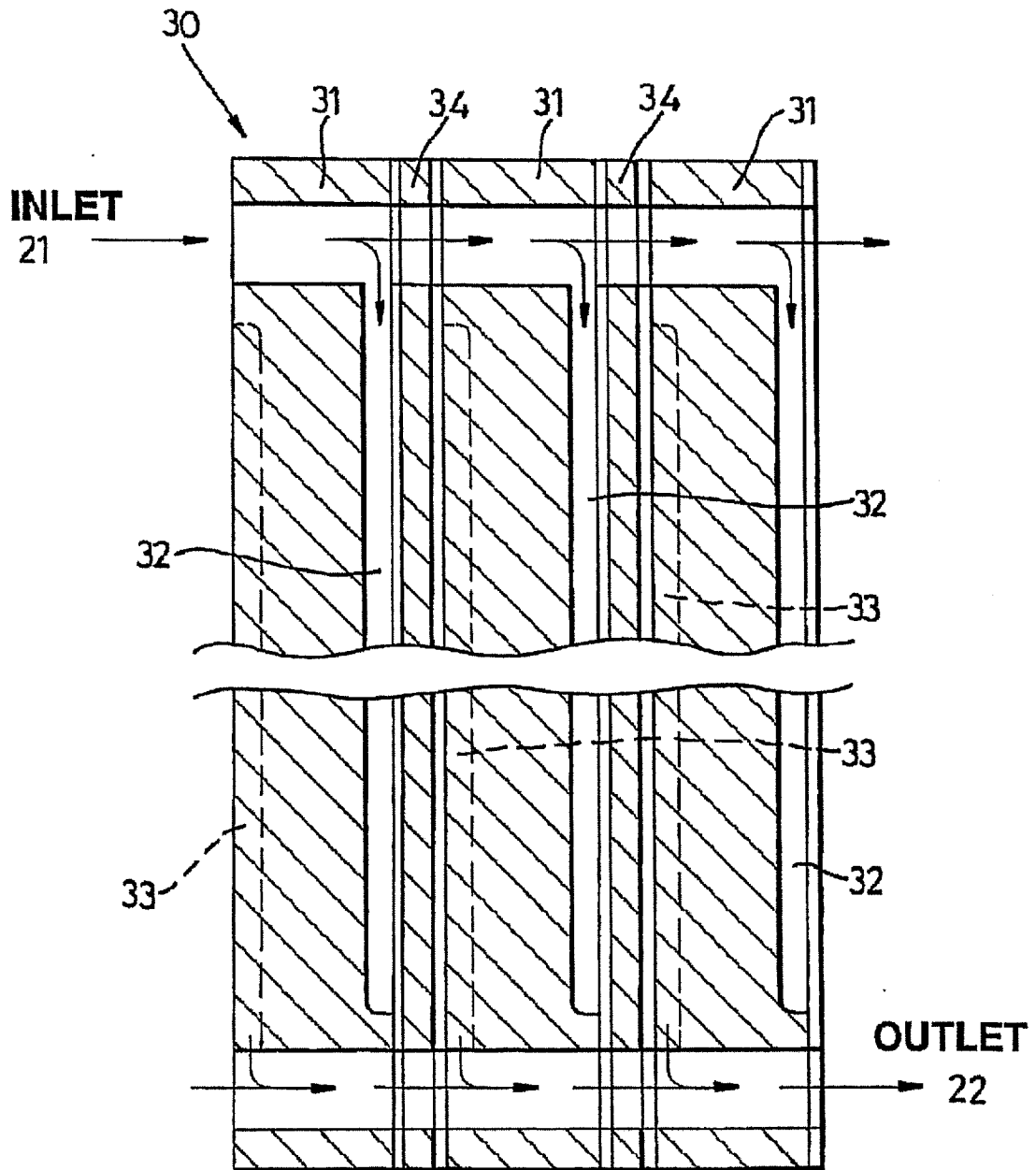


Fig. 3

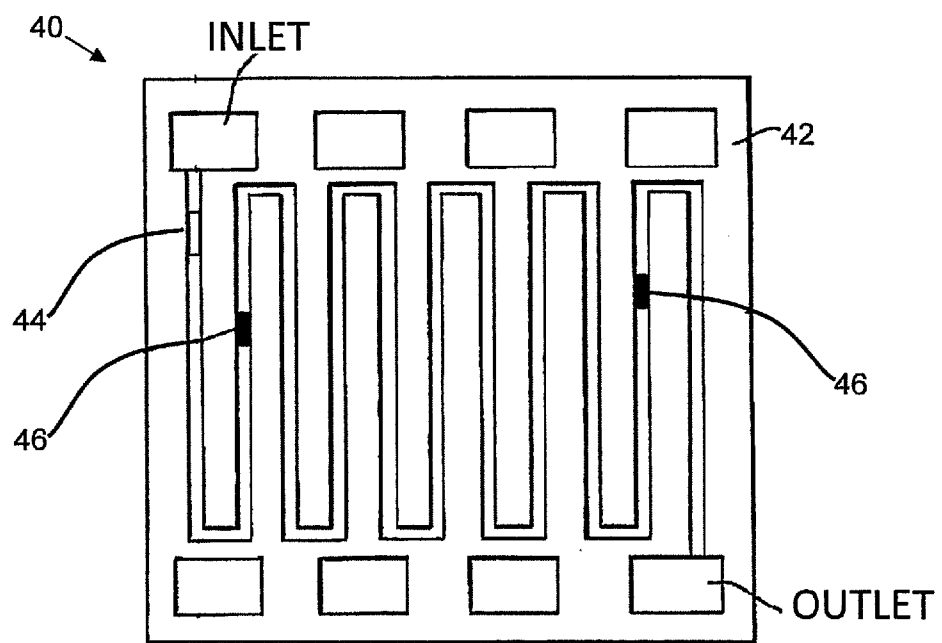


Fig. 4

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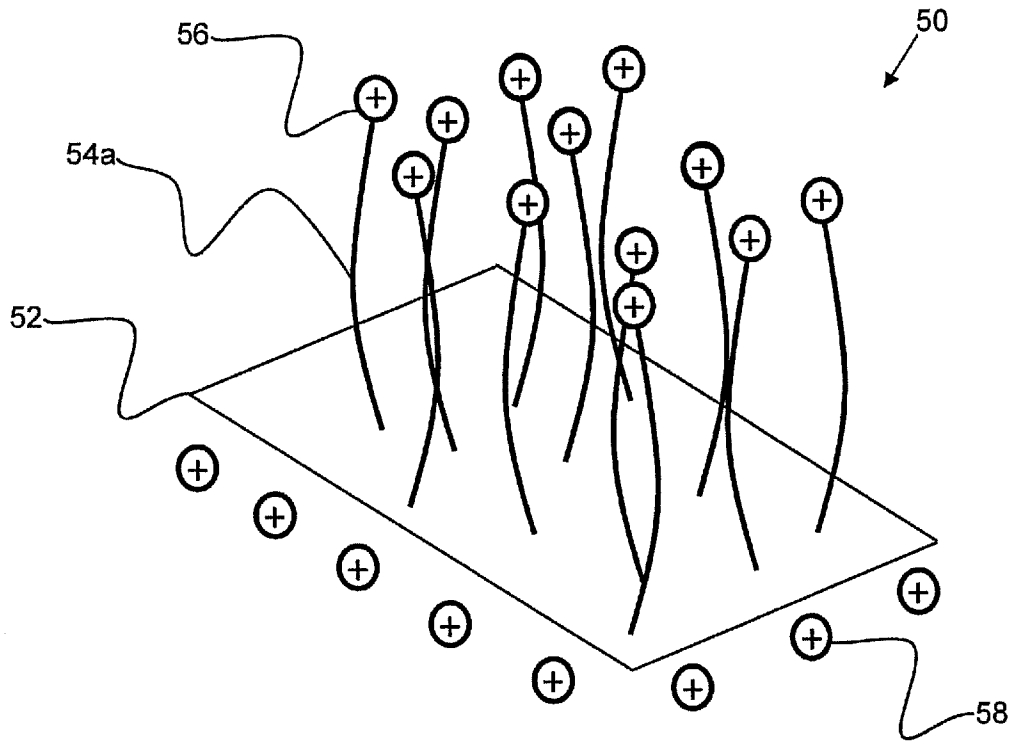


Fig. 5a

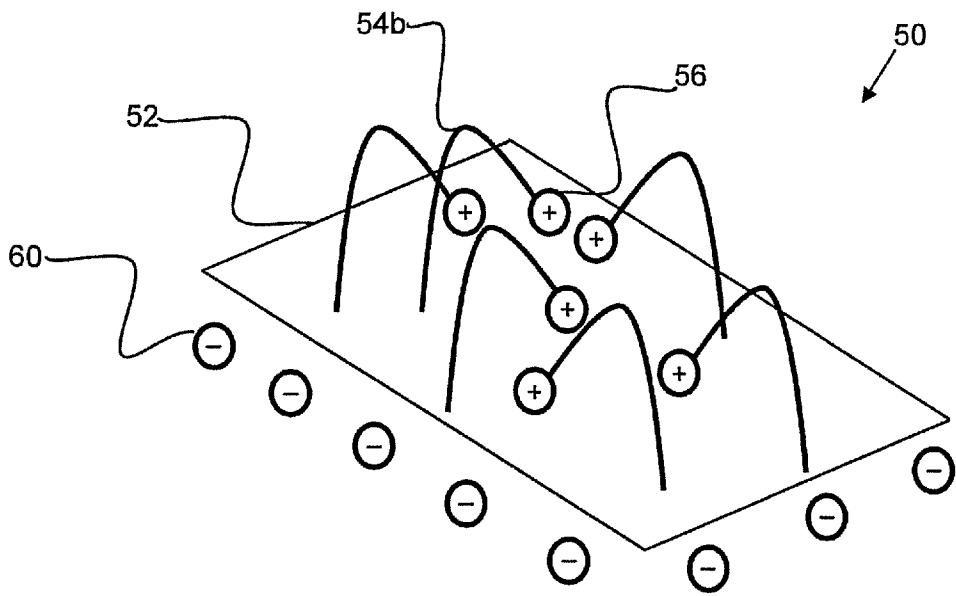


Fig. 5b

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2016/050266

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M8/02
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/142901 A1 (LAHANN JOERG [US] ET AL) 31 July 2003 (2003-07-31) paragraph [0107] - paragraph [0108]; claim 70	16-18
X	----- US 2008/292940 A1 (XIE TAO [US]) 27 November 2008 (2008-11-27) claims 12, 20, 22	16,18
X	----- US 2011/171564 A1 (BLUNK RICHARD H [US] ET AL) 14 July 2011 (2011-07-14) claims 1, 4, 5 -----	16,17

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

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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

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

"&" document member of the same patent family

Date of the actual completion of the international search

25 April 2016

Date of mailing of the international search report

03/05/2016

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Martín Fernández, A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2016/050266

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.: 1-15, 19-23
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 1-15, 19-23

Following claims relate to a product which has a given desired property or effect, namely:

- Claim 1 : "the surface is configured to adopt the first state (the first state being more hydrophilic than the second state) or the second state in accordance with a condition in the surface".

- Claim 2 : "condition is water level at the surface".

-

- Claim 3 : "the surface region is configured to adopt the second state in response to an increase in water level at the surface".

- Claim 4 :

"condition is a current density, an electric field or electric potential at the surface"

- Claim 5 : "condition is a temperature or temperature gradient at the surface".

- Claim 6 : " condition is a pH of a fluid at the surface or concentration of a ligand or ion at the surface".

-

- Claim 9 : "the surface region is dynamically reconfigurable during operation of the fuel cell".

- Claim 10 : "the surface region has one or more further states, each state having different level of hydrophobicity".

- Claim 11 : "the surface region has a continuum of states between the first and the second states".

- Claim 12 :

"plurality of independently reconfigurable surface regions".

- Claim 13

: "first and second subsets, wherein each subset comprises one or more reconfigurable surface regions, wherein the first subset is configured to adopt the first state or the second state in response to the condition at the surface meeting a first trigger, wherein the second subset is configured to adopt the first state or the second state in response to the condition at the surface meeting a second trigger and wherein the first trigger is different from the second trigger".

- Claim 16 : "the functional end group is configured to attract or repel water molecules, wherein the chain is configurable such that: in the first state the functional end group is provided distally from the surface for interacting with water molecules; and in the second state the functional end group is provided proximal to the surface and inhibited from interacting with water molecules".

- Claim 21 : "reconfiguring the surface to adopt the first state or the second state in accordance with a condition at the surface".

The present application does not disclose any specific embodiments or experiments showing how the surface has to be modified in order to change from an hydrophilic condition (first state) to a less hydrophilic condition (second state) and there is no common

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

general knowledge of a product having the said properties or effects available to the person skilled in the art. On that account, the description does not provide support and disclosure in the sense of Article 6 and 5 PCT for the subject-matter of claims 1-6, 9-13, 16 and 21 .

The subject-matter of claim 19 refers to a chain that can change from a:

- first state: the chain comprising a trans-isomer in the first state, to a
- second state: the chain comprising a cis-isomer in the second state.

However, the description of the present application does not show any specific embodiments or experiments explaining how the isomers are modified from a trans- to a cis-isomer configuration and there is no common general knowledge of an isomer having the said properties or effects available to the person skilled in the art. On that account, the description does not provide support and disclosure in the sense of Article 6 and 5 PCT for the subject-matter of claim 19 . Claims 22 and 23 are unclear because they merely refer to the content of the figures and they don't contain any technical feature in order to define the subject-matter for which protection is sought. On that account, the subject-matter of claims 22 and 23 do not meet the requirements of Article 6 and 5 PCT.

This non-compliance with the substantive provisions of the present claims is to such an extent, that the search was performed taking into consideration the non-compliance in determining the extent of the search of the claims 1-23 (PCT Guidelines 9.19 and 9.20).

The search of claims 1-23 was consequently restricted to the following clearly defined technical features:

Claim 16: A component for a fuel cell system having a surface region, wherein a layer of molecules is attached to the surface, each molecule having a functional end group and a chain connecting the surface to the functional end group.

Claim 17: The functional end group comprises a benzyl moiety, pyridinium or a carboxylate.

Claim 18: The chain comprises an alkyl chain or glycol chain selected to have a different hydrophobicity to the functional end group.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2016/050266

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