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(54) Title: AN ENERGY DEVICE

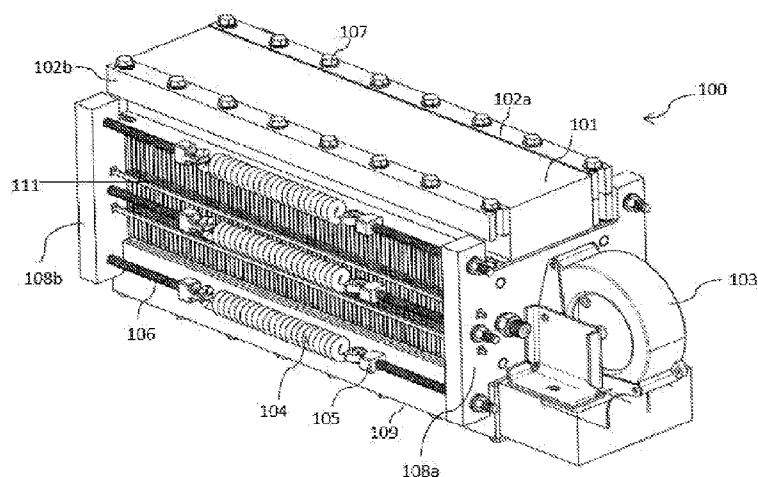


Fig. 1

(57) Abstract: The present invention relates to a power supply source, and more particularly, the present invention relates to a fuel cell stack (100). The present subject matter also provides an energy device which is a fuel cell stack (100) comprising plurality of fuel cells with each having a flow field plate to accommodate heating coil for the fuel cell stack to operate. Each of the heating coil (305) are secured in dedicated heating coil channel (401) which enables direct heating without wasting of the energy and enabling quick operation of the fuel cell stack (100).



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- *as to the identity of the inventor (Rule 4.17(i))*
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AN ENERGY DEVICE

TECHNICAL FIELD

[0001] The present invention relates to a power supply source, and more particularly, the present invention relates to a fuel cell stack.

BACKGROUND

5 [0002] Fuel cells are electrochemical devices that directly convert chemical energy of fuel and oxidant into electrical energy by the redox process with a high efficiency and zero emission. Fuel cell consists of an anode, cathode, electrolyte, gas-diffusion layer and bipolar plates. An anode facilitates the oxidation of the fuel, while a cathode promotes the reduction of oxidant. The electrodes should be both
10 catalytically active and conductive in nature. The electrodes are used to provide the active sites, physical barrier which separates the bulk gas phase and the electrolyte and also to facilitate the ion transport away from or into the three-phase interface. The electrolyte also acts as a physical barrier between the fuel and oxidant.

[0003] Fuel cells are mainly classified based on electrolyte. The choice of the
15 electrolyte medium decides the operating temperature of the fuel cell. The porous gas diffusion layers provide structural support for the electrodes and diffusion path through which the oxidant or fuel gases can reach the catalyst. Gas diffusion layers are made of carbon paper or woven carbon cloth. Bipolar plates can be coated with dispersed carbon to provide corrosion resistance and good electrical conductivity.
20 The bipolar plates used for the distribution of fuel and oxidant; heat and water management; separate the individual cells in the stack and to humidify the gases and also as a current collector.

[0004] Fuel cells can be classified based on fuel (direct or indirect fuel), oxidant, electrolyte and temperature. The proton exchange membrane fuel cell uses a water-
25 based, acidic polymer membrane as its electrolyte, with platinum-based electrodes. Proton exchange membrane fuel cells operate at relatively low temperatures (below 100 degrees Celsius) and can tailor electrical output to meet dynamic power requirements. Due to the relatively low temperatures and the use of precious metal-

based electrodes, these cells must operate on pure hydrogen. Proton exchange membrane fuel cells are currently the leading technology for light duty vehicles and materials handling vehicles, and to a lesser extent for stationary and other applications. The proton exchange membrane fuel cell is also sometimes called a
5 polymer electrolyte membrane fuel cell.

[0005] Hydrogen fuel is processed at the anode where electrons are separated from protons on the surface of a platinum-based catalyst. The protons pass through the membrane to the cathode side of the cell while the electrons travel in an external circuit, generating the electrical output of the cell. On the cathode side, another
10 precious metal electrode combines the protons and electrons with oxygen to produce water, which is expelled as the only waste product; oxygen can be provided in a purified form, or extracted at the electrode directly from the air.

BRIEF DESCRIPTION OF THE DRAWINGS

15 [0006] The detailed description is described with reference to the accompanying figures. The same numbers are used throughout the drawings to reference like features and components.

[0007] **Fig. 1** illustrates a perspective view of the present subject matter.

[0008] **Fig. 2** illustrates an exploded view of the present subject matter.

20 [0009] **Fig. 3** illustrates a front view of the anode flow field plate with a heating coil of the present subject matter.

[00010] **Fig. 4** illustrates an exploded view of the anode flow field plate.

[00011] **Fig. 5** illustrates a front view of the cathode flow field plate.

[00012] **Fig. 6** illustrates a front view of the cathode flow field plate with heating
25 coil terminals.

DETAILED DESCRIPTION

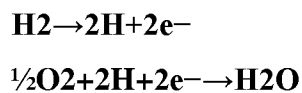
[00013] The demand for clean energy is rising every year because of the environmental adverse impact because of the pollution caused by other available

sources of energy. Fuel cell is a clean, efficient and environmental friendly source to run a machine and can be utilized in several other applications.

[00014] A fuel cell is essentially an electrochemical device which mainly converts the chemical energy into electrical energy. The fuel cell combines oxygen and hydrogen using suitable electrodes and electrolytes to produce water.

[00015] A fuel, like hydrogen is introduced at first electrode, anode, where electrochemical reaction results to produce electrons and cations (positively charged ions). The electron gets conducted from anode to second electrode, cathode, through an electric circuit formed between the cathode and anode. The cations generated from the chemical reaction at the first electrode that is anode move through the electrolyte to the cathode.

[00016] Simultaneously, an oxidant like oxygen is introduced at the cathode where the oxidant reacts electrochemically in the presence of the electrolyte and the catalyst, producing anions and the electrons. The half-cell reaction can be represented by below reaction:



[00017] The electrons generated during the electrochemical reaction are withdrawn by an external load. The byproduct from the electrochemical reaction inside the fuel cell leads to generation of water which can be further utilized for the human consumption and thereby making the fuel cell one of the cleanest sources of electricity when compared with sources of energy. There are several types of fuel cells available but proton exchange membrane (PEM) is replacing the traditional power generation systems. The PEM fuel cell are compact, simple in design but at the same time providing better energy output with pollution free byproduct.

[00018] A PEM fuel cell mainly comprises two flow field plates also called bipolar plates, an anode flow field plate and a cathode flow field plate with a membrane electrode assembly (MEA) disposed therebetween. The MEA includes the proton exchange membrane and catalysts coated onto the membrane. Gas diffusion layer (GDL), made up of carbon, is provided between each flow field plate and PEM. Fuel cells are generally used in bunch by connecting each of the fuel cell

with each other in series to make a fuel cell stack which is enclosed in housing. Only one fuel cell can be used but using plurality of fuel cells provides high voltage.

[00019] A variant of the proton exchange membrane fuel cell which operates at elevated temperatures is known as the high temperature proton exchange membrane fuel cell. By changing the electrolyte from being water-based to a mineral acid-based system, high temperature proton exchange membrane fuel can operate up to 200 degrees Celsius. This overcomes some of the current limitations with regard to fuel purity with high temperature proton exchange membrane fuel cells able to process reformat (high-octane liquid products) containing small quantities of Carbon Monoxide.

[00020] The high temperature proton exchange membrane fuel cell stack is heated to the operating temperature of around 80-150°C with pad heaters. It takes much longer time to heat proton exchange membrane fuel cell stack to the minimum operating temperature of 80°C and hence the start-up time of the fuel cell stack is very high. Also the slow heating and high time to heat the fuel cell stack is due to large losses at the ends of the stack, and poor thermal conductivity axially throughout the stack, especially the gasket materials used, which has a poor thermal conductivity. The membrane electrode assembly which is having conducting medium has to be heated to the operating temperature for the high temperature proton exchange membrane fuel cell stack to function. But, pad heaters heat the complete fuel cell stack structure instead of membrane electrode assembly alone. A proton exchange membrane is placed between said cathode flow field plate (600) and said anode flow field plate (300).

[00021] Hence, it is the object of the present subject matter to provide an energy device overcoming all the problems in known art. As per an aspect of the present invention, the energy device is a fuel cell stack comprising plurality of fuel cells with each having a flow field plate to accommodate heating coil for the fuel cell stack to operate.

[00022] In accordance with the first embodiment of the present subject matter a fuel cell stack is provided which comprises of plurality of individual fuel cells connected in series. Each of the fuel cell in the fuel cell stack comprises a

bipolar plate which is acting as anode flow field plate on one side and cathode flow field plate on other side, a membrane electrode assembly disposed between the anode and cathode flow field plates, where the anode flow field plate includes a plurality of anode channels and a plurality of ribs separating the anode channels. A
5 cathode flow field plate includes a plurality of cathode channels and a plurality of ribs separating the cathode channels.

[00023] In yet another embodiment the present subject matter provides a unipolar anode flow field plate and a unipolar cathode flow field plate. The unipolar anode flow field plate and a unipolar cathode flow field plate is provided with
10 channels for fuel or oxidant flow only on one side of the flow field plate.

[00024] In yet another embodiment the present subject matter provides a bipolar plate. The bipolar flow field plate is provided with channels for fuel flow on one side of the plate and channels for oxidant flow on other side of the plate.

[00025] In yet another embodiment the present subject matter provides a fuel
15 cell stack where at least one portion of the anode channels and the cathode channels are disposed directly opposite to one another with member exchange assembly (MEA) therebetween.

[00026] In another embodiment the present invention provides an anode channel and cathode channel where the ribs of the anode channel and the ribs of the
20 cathode channel are matching.

[00027] In yet another embodiment the present invention each of the anode flow field plates and cathode flow field plates includes an inlet for fuel, outlet to release byproduct.

[00028] In another embodiment of the present invention a coolant duct is
25 configured to carry the oxidant to each of the fuel cell for the electro-chemical reaction to take place in order to generate electricity and also allowing to keep the fuel cell from excessive heating.

[00029] In another embodiment of the present invention the anode flow field plate of each fuel cell includes at least one fuel inlet distribution channel connecting
30 the fuel inlet to the anode channels and at least one fuel outlet collection channel connecting the anode channels to the fuel outlet. Similarly, the cathode flow field

plate of each fuel cell can include at least one oxidant inlet distribution channel connecting the oxidant inlet to the cathode channels, and at least one oxidant outlet collection channel connecting the cathode channels to the oxidant outlet

[00030] In another embodiment the present invention provides a plurality of heating coils to improve the heating of fuel cells in the fuel cell stack by directly heating each of the membrane electrode assembly of plurality of fuel cells in a fuel cell stack. The dedicated heating coil for each of the membrane electrode assembly in the fuel cell allows focused heating and allows the operating temperature to reach required value in less time.

10 [00031] In yet another embodiment of the present invention the heating coil for each of the membrane electrode assembly in plurality of fuel cells avoids the heating of the entire fuel cell thereby saving energy and prevents unnecessary heat buildup.

[00032] In another embodiment of the present invention the heating coil is provided inside the fuel cell to enable quick heating by keeping the heating coil in close proximity of the channels provided in the anode flow field plate and cathode flow field plate.

[00033] In yet another embodiment the present invention provides plurality of the heating coils in the heating channels etched on the anode flow field plate with dedicated channels for affixing the plurality of the heating coils.

[00034] In another embodiment the present invention provides plurality of heating coils in the heating channels etched on the cathode flow field plate with dedicated channels for affixing the plurality of the heating coils.

[00035] **Fig. 1** illustrates the perspective view of the fuel cell stack assembly (100). The fuel cell stack (100) comprises a pair of duct, a top duct (101) and a bottom duct (109). The bottom duct (109) provides an inlet to allow the inflow of air as air works both as coolant and oxidant for the fuel cell stack. Whereas the top duct (101) also called the oxidant outlet duct, helps in releasing the hot air and water vapor generated from the fuel cell stack (100) while generating power and thereby regulating the temperature. The top duct (101) allows the fuel cell stack to release the heat. But in another embodiment the top duct can be removed if the fuel cell

stack (100) is operating at a low temperature (less than 80 degrees Celsius). The top duct (101) also prevents the unnecessary entry of oxidants and moisture in the fuel cell stack which may erode the membrane. The top duct (101) is acting as both oxidant outlet duct and at the same time functioning as a cover for the fuel cell stack (100). The top duct (101) is removably attached to a metal frame (not shown) by taking support of a pair of linear bars (102a, 102b). The linear bars (102a, 102b) are attached with the help of plurality of fasteners (107) at plurality of fastening holes located periodically along the length of the linear bars (102a, 102b).

[00036] Further to allow air from the bottom duct (109), a blower (103) is provided to blow air into the bottom duct (109) and reaches the fuel cell stack (100). The fuel cell stack (100) further comprises an outermost pair of end plate (108a, 108b). The end plate provided on two opposite side of the fuel cell stack (100) is heatable and compresses the fuel cell stacks therebetween. The end plates are compressed with a predetermined torsion compression of about 3Nm. In order to maintain an optimum torsion compression, the end plates are compressed by means of plurality of studs (201a, 201b and 201c) (shown in fig. 2). Further the studs are provided with pair of connector (105) connecting a spring (104) which holds the endplates with optimum force as per the manufacturer's requirement.

[00037] The top duct (101) and the bottom duct (109) allow the flow of air through the fuel cell stack (100). The bottom duct (109) intakes the air from the atmosphere and the air gets used up as an oxidant whereas the top duct (101) releases the hot air and water vapour after the chemical reaction takes place in the fuel cell stack (100) releasing the water as a residue in the form of vapours.

[00038] **Fig. 2** illustrates the exploded view of the fuel cell stack (100). The bottom duct (109) is provided with oxidant /coolant inlet (109a). The oxidant /coolant inlet (109a) is wider compared to the bottom duct (109) so more air can go into the fuel cell stack (100) with ease for effectively cooling. The top duct (101) is provided with residue outlet (202) for hot air and water vapour.

[00039] **Fig. 3** illustrates a front face of the anode flow field plate (300) of the fuel cell stack (100) according to the present subject matter. The anode flow field plate (300) is provided with a fuel inlet orifice (304) for fuel transfer into the

fuel flow field channel (301) and an outlet orifice (303) for removing the unreacted fuel. Further, a fuel inlet distribution channel (308) is connecting the fuel inlet orifice (304) to the fuel flow field channel (301) (or anode channel) and a fuel outlet collection channel (309) connecting the fuel flow field channel (301) to the end plate (108b) through outlet orifice (303). The fuel inlet distribution channel (308) helps in routing the fuel to the fuel flow field channel (301). Similarly, the fuel outlet collection channel (309) takes out the unreacted fuel and routes them towards the end plate (108b) with the help of the fuel outlet orifice (303).

[00040] The anode flow field plate (300) engraved with channels for the flow of fuel. The sub channels are separated by plurality of ribs (302). The ribs (302) separate the sub channels and allow proper flow of fuel in a particular direction.

[00041] Further the anode flow field plate (300) has a heating coil channel (401) (shown in Fig 4) to accommodate a heating coil (305). The heating coil (305) has two supply ends, heating coil terminals (306,307), to connect with the power supply. All the heating coil terminals (306,307) of the fuel cell stack (100) are connected to a metal strip (111) (Shown in fig.1) for conducting electricity and the same metal strip (111) (Shown in Fig. 1) is made up of copper material. The heating coil (305) is disposed in such a manner such that channel carrying the fuel is in proximity with the heating coil channel. Due to close proximity of the heating coil to the fuel channel, when the current supply is provided to the heating coil, it heats up the fuel faster as compared to a heating pad used to heat the fuel. The heating coil surrounds the fuel channel to provide uniform heat to the fuel.

[00042] **Fig. 4** illustrates an exploded structure of the flow field plate of the fuel cell stack (100) according to the present subject matter. The flow field plate is bipolar plate with channels provided on both sides of the flow field plate. The channels provided are symmetric and rectangular in shape. The depth of the channel provided in the flow field plate is in the range 0.9 mm to 1mm depth and 1.2 mm to 1.4 mm is the range of the width of the channel. The heating coil (305) is securely disposed in the heating coil channel (401) surrounding the fuel flow field channel (301) to provide uniform heating from all direction in order to operate the fuel cell stack (100). The heating coil (305) is that the gap between the heating coil (305)

and the fuel cell stack (100) allows uniform heating of entire fuel flow field channel (301) carrying the fuel on an anode flow field plate. The heating coil terminals (306,307) terminates near the fuel outlet orifice (303). All the heating coil terminals (306,307) of each of the flow field plate in the fuel cell stack (100) are connected with a metal strip (111) (shown in fig. 1) for convenient supply of the current in order to start heating process of the fuel cell stack (100). The heating coil (305) surrounds the fuel inlet orifice (304) and the fuel inlet distribution channel (308) such that the heating coil makes an arc (402). The portion of the heating coil (305) in the arc (402) starts heating of the fuel from the fuel inlet orifice (304) itself which, in turn, reduces the heating time by the heating coil (305) in order to heat up the fuel up to a desired temperature and as a result the operation time of the fuel cells gets reduced.

[00043] **Fig.5** illustrates flow field plate (cathode flow field plate) with heating coil channels (501) are in parallel fashion to accommodate the heating coils. The channels carrying oxidants are provided in parallel formation on the flow field plate. The heating coil is placed equidistant with each between the parallel channels. The presence of the heating coil in between the channel allows the heating of the flow field plate more quickly and uniformly. The heating coil channel (501) is similar to heating coil channel (401), with the only difference being that the layout for heating coil channel (401) is open loop structure covering the four sides of the flow field plate whereas the heating coil channel (501) are parallel and placed equidistant from each other on the flow field plate to provide uniform heating.

[00044] **Fig.6** provides the heating coils (601) in the heating coil channels configured in parallel fashion on the oxidant flow field side of the cathode flow field plate (600) with the heating coil (305) and terminals to connect with the current supply to start the heating operation of the fuel cell stack (100).

[00045] Many modifications and variations of the present subject matter are possible in the light of above disclosure. Therefore, within the scope of claims of the present subject matter, the present disclosure may be practiced other than as specifically described.

We claim:

1. An energy device comprising:
a plurality of fuel cell stacks (100), each of said plurality of fuel cell stacks (100) comprising one or more flow field plate, said flow field plate
5 comprises an anode flow field plate (300) to channel a fuel and a cathode flow field plate (600) to channel an oxidant; and
a membrane electrode disposed therebetween said anode flow field plate (300) and said cathode flow field plate (600); said anode flow field plate (300) of said plurality of fuel cell stacks (100) comprising one or more
10 heating coil channel (401,501) to accommodate one or more heating coil (305,601).
2. The energy device according to claim 1, wherein said one or more heating coil (305,601) is attached to a plurality of heating coil terminals (306,307) to connect with a power supply.
- 15 3. The energy device according to claim 1, wherein said one or more heating coil channel (401,501) for accommodating said one or more heating coil (305,601) has a depth in the range of 0.9mm to 1mm.
4. The energy device according to claim 1, wherein said one or more heating coil channel (401,501) for accommodating said one or more heating coil
20 (305,601) has a width in the range of 1.2 mm to 1.4 mm.
5. The energy device according to claim 1, wherein said one or more heating coil channel (401,501) is provided in an open loop configuration on said anode flow field plate (300).
6. The energy device according to claim 1, wherein said heating coil channel
25 (401) is provided in a parallel configuration on said cathode flow field plate (600).
7. The energy device according to claim 1, wherein a plurality of heating coil terminals (306,307) of said one or more heating coil (305,601) are electrically connected to a metal strip (111) preferably made of copper.
- 30 8. A method of assembly of a fuel cell stack (100) comprising the steps of:

- inserting a cathode flow field plate (600) and an anode flow field plate (300) between two end plates (108a,108b);
placing a proton exchange membrane between said cathode flow field plate (600) and said anode flow field plate (300);
5 providing said cathode flow field plate and said anode flow field plate (300) with one or more heating coil channel (401,501);
accommodating one or more heating coil (305,601) in said one or more heating coil channel (401,501);
connecting power supply leads to plurality of heating coil terminals
10 (306,307) of said one or more heating coil (305,601);
and
attaching said plurality of heating coil terminals (306,307) to a metal strip (111) to conduct electricity.
9. A flow field plate of a fuel cell stack (100) comprising:
15 a fuel flow field channel (301) to carry fuel; an outlet orifice (303) and a fuel inlet orifice (304) on said flow field plate; and one or more heating coil channel (401,501) provided on said flow field plate to accommodate one or more heating coil (305,601).
10. The flow field plate of a fuel cell stack (100) as claimed in claim 9, wherein
20 said one or more heating coil channel (401,501) is open loop.
11. The flow field plate of a fuel cell stack (100) as claimed in claim 9, wherein said one or more heating coil channel (401,501) is parallel.

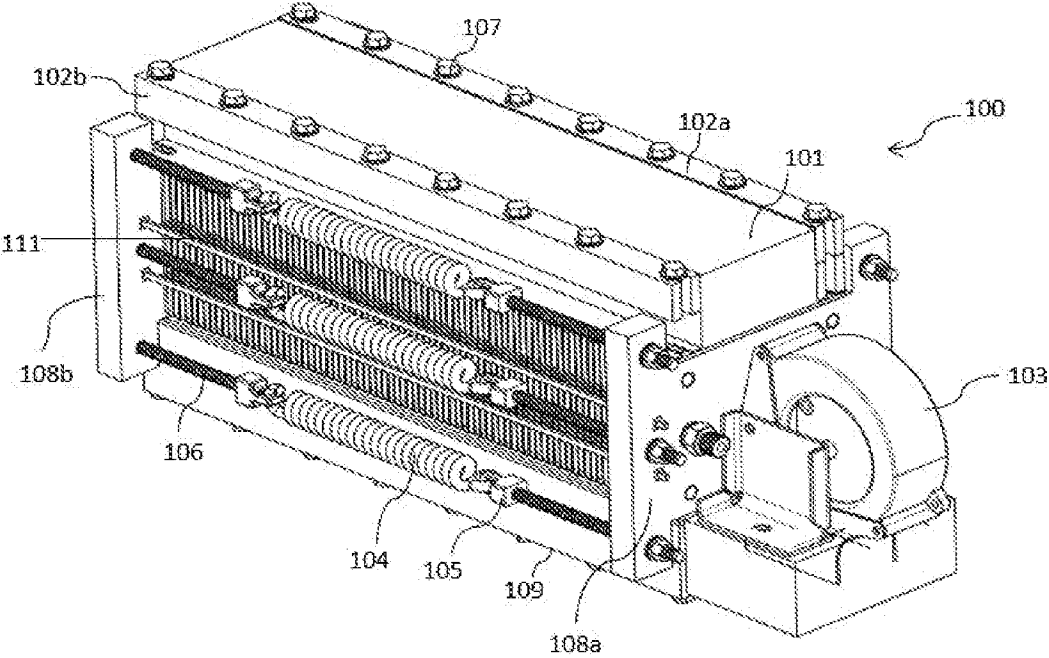


Fig. 1

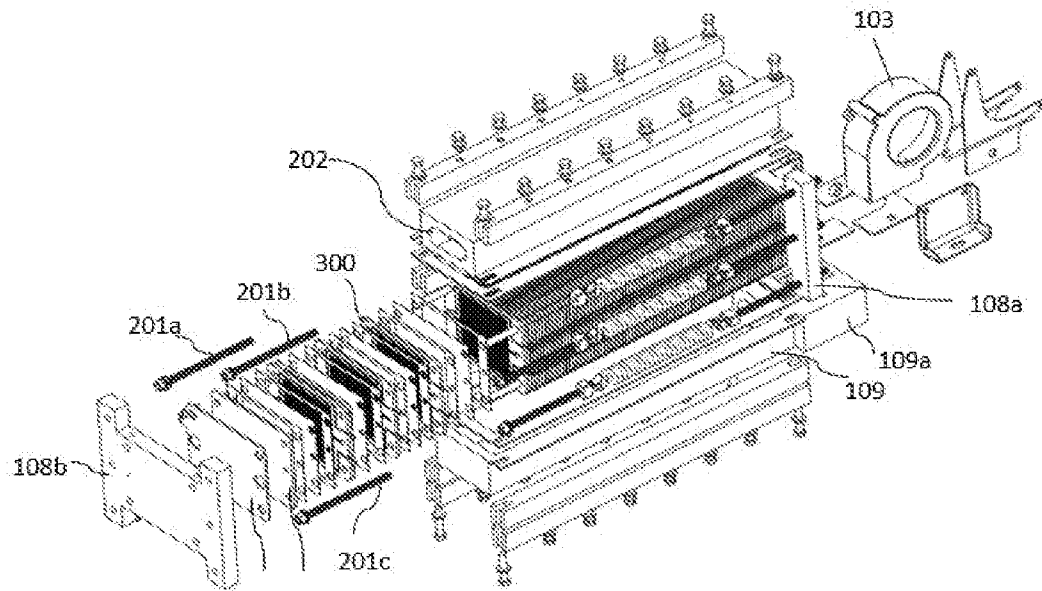


Fig. 2

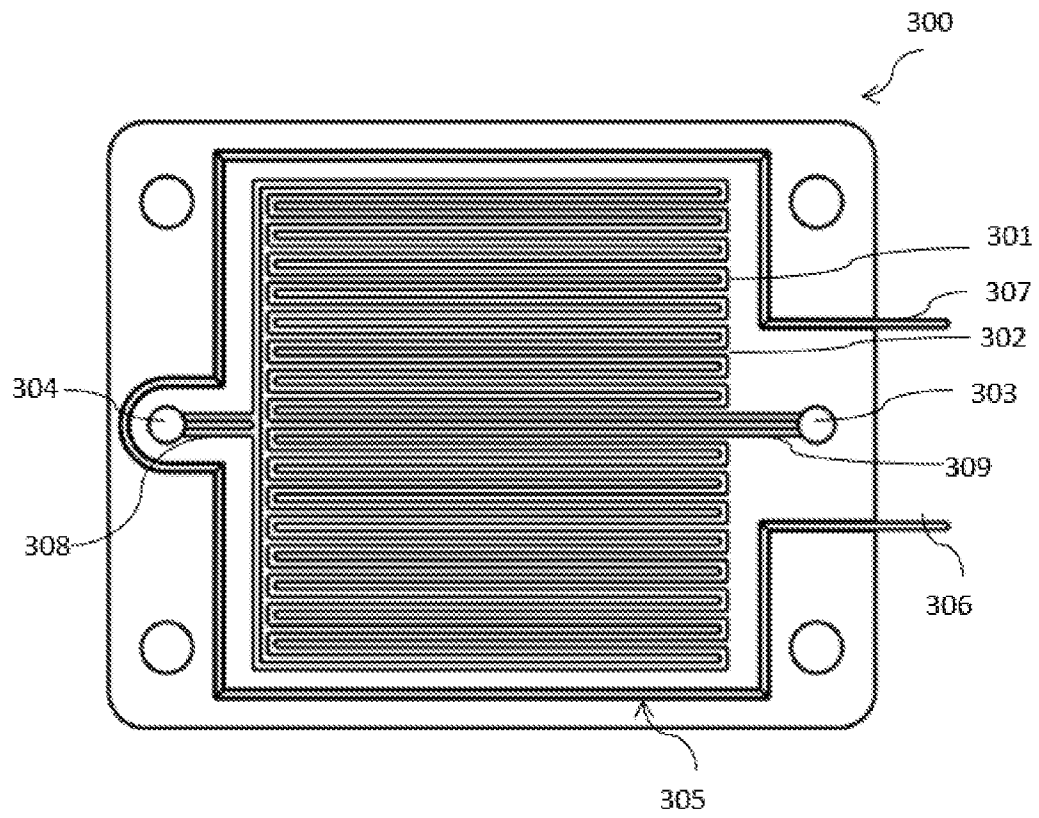


Fig. 3

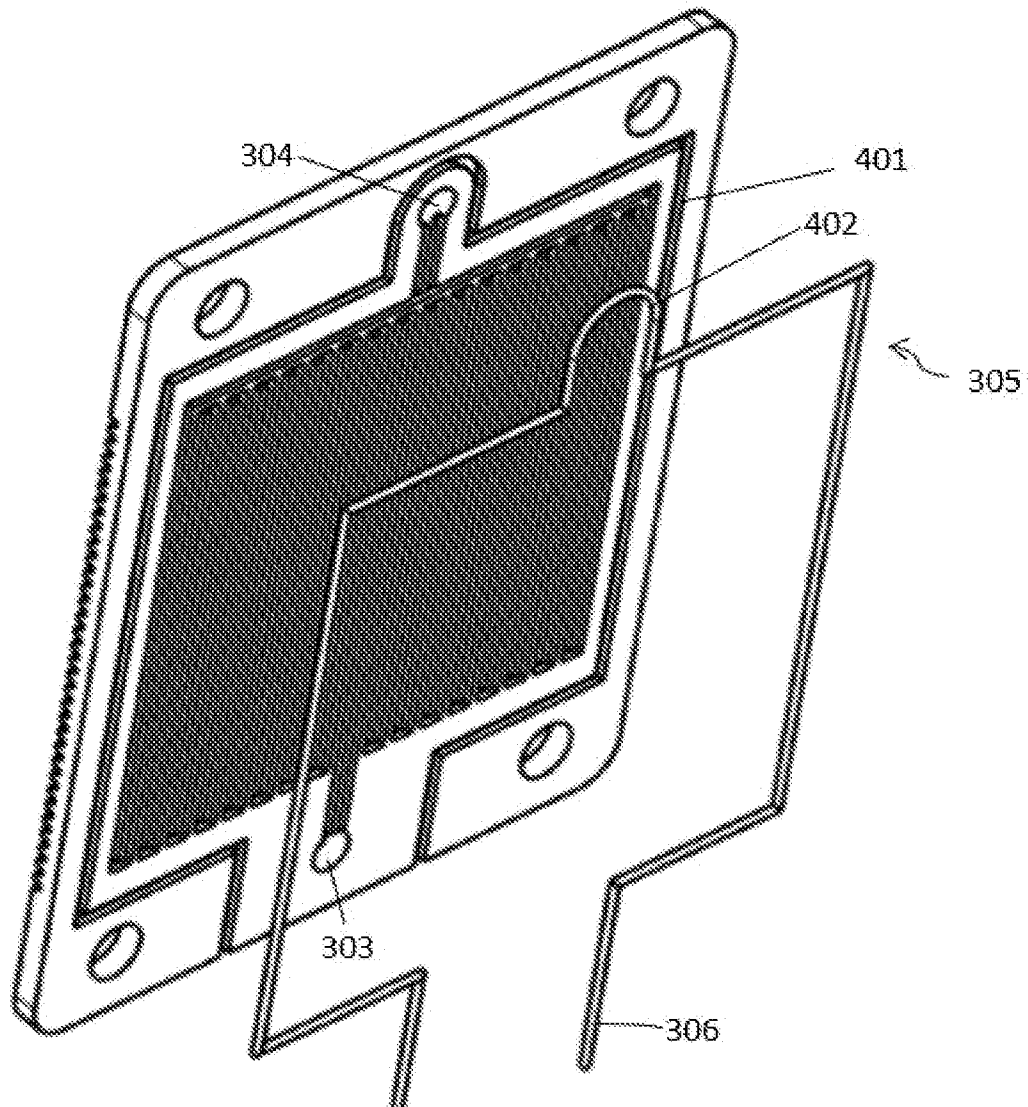


Fig. 4

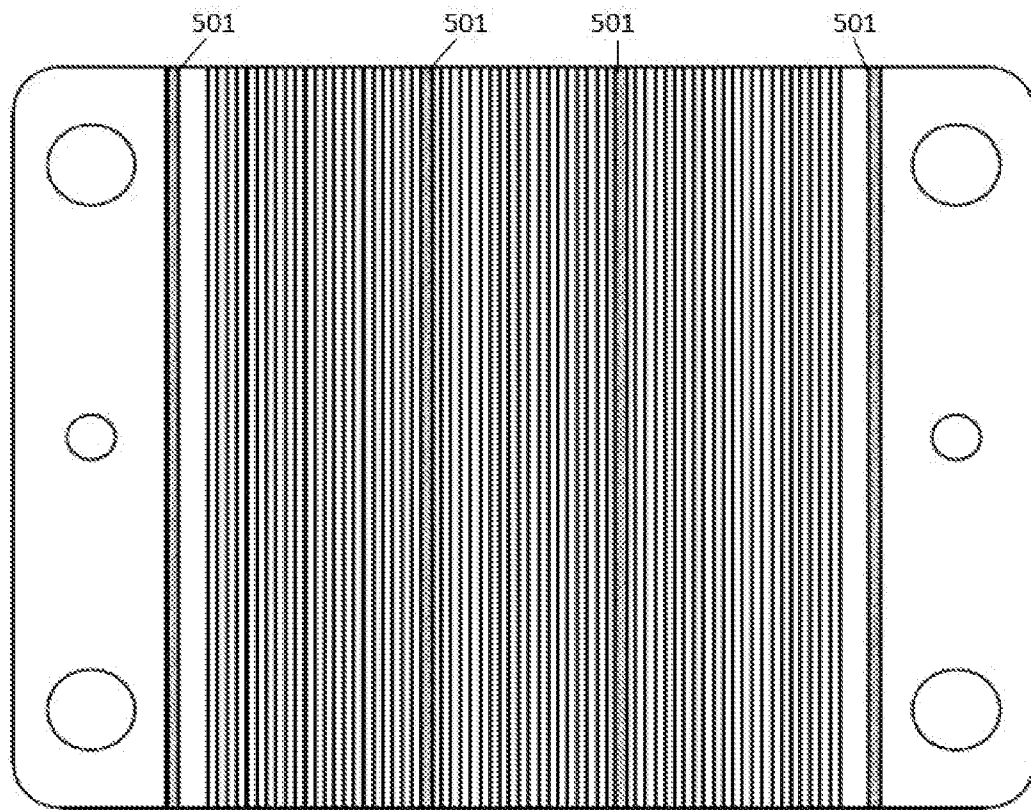


Fig. 5

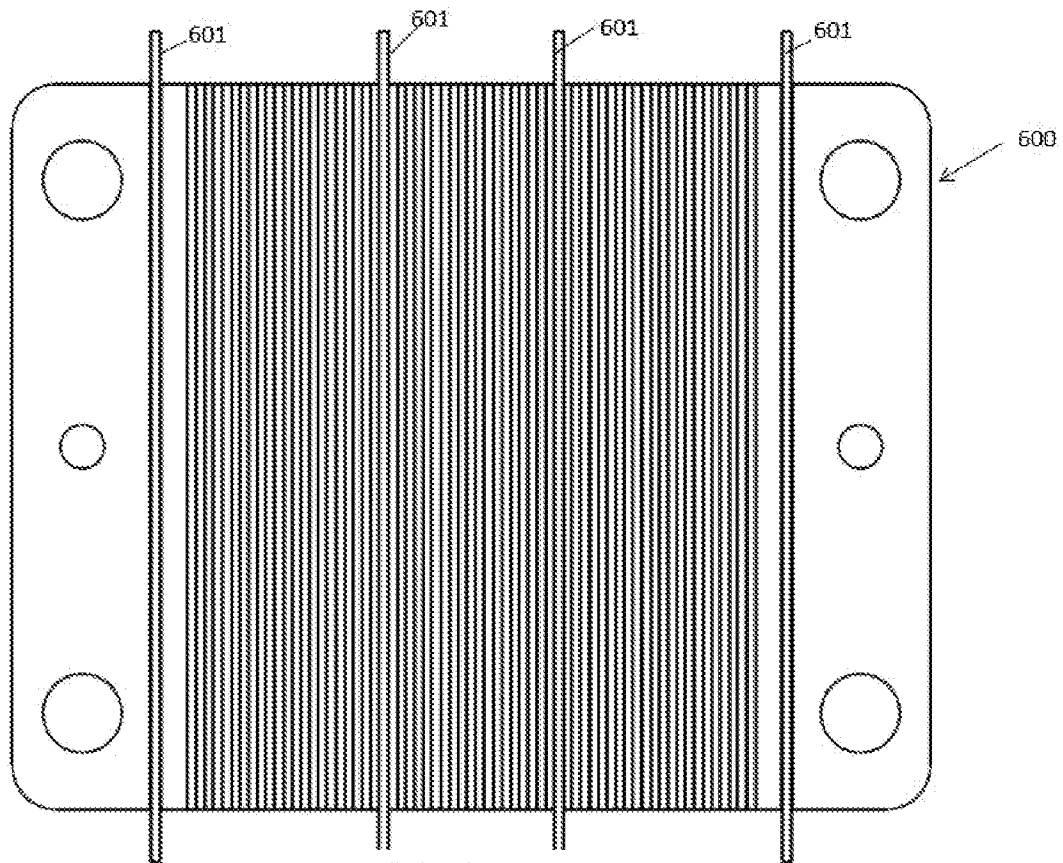


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2020/050216

A. CLASSIFICATION OF SUBJECT MATTER

H01M8/24, H01M8/0267, H01M8/04007 Version=2020.01

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)

DATABASES: TotalPatent One, IPO Internal Database, WIPO PATENTSCOPE

KEYWORDS: fuel cell stack, flow field plate, membrane, heating coil

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US20010036568A1 (PLUG POWER INC) 1st November 2001 (01-11-2001) [Abstract, paragraphs [0004]-[0007], [0025]-[0048], [0066]-[0099], claims 1-44, figures 1-15]	1-11
Y	US8263259B2 (INTELLIGENT ENERGY LTD) 11th September 2012 (11-09-2012) [Abstract, description, claims 1-16, figures 1-13]	1-11



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

01-07-2020

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2020/050216

Citation	Pub.Date	Family	Pub.Date
US 8263259 B2	11-09-2012	CA 2389128 A1	27-01-2003
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