(12)Indian Patent Application

(21) Application Number: 202441010829

(22) Filing Date: 15/02/2024 (43) Publication Date: 22/08/2025

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(51) International Classifications: H01M 8/0258 H01M 8/1004 H01M 8/0267 H01M 8/241 H01M 8/10

(54) Title: A DUAL CELL ASSEMBLY OF A FUEL CELL STACK

(57) Abstract: Present disclosure relates to a dual cell assembly (100) comprising a first cell (100A) having a first and second bipolar plate (BP) (102, 104) having a first and second flow field side. A first membrane electrode assembly (MEA) interposed between the first and the second flow field sides. A second cell (100B), is coupled to the first cell (100A), having a third and fourth BP (106, 108) having a third and fourth flow field side and a second MEA (107) interposed between the third and the fourth flow field sides. Each flow field side includes an inlet port, an outlet port and a flow field zone (20). The flow field zone has a plurality of pathways (22) formed by an array of scales disposed in a spaced apart configuration. The array of scales (30) is an elliptical projection (32) encompassed between a pair of guide vanes (34) converging towards each other.

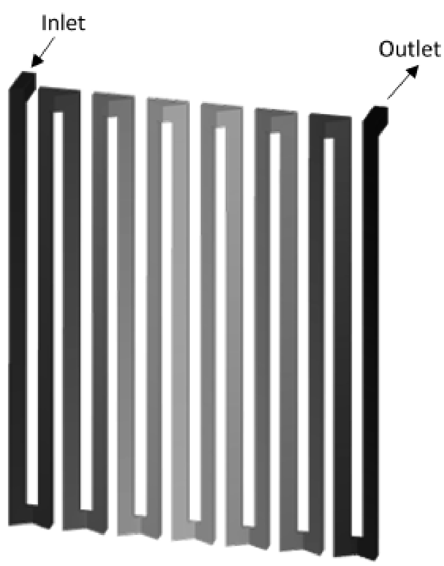

Fig. 1. Prior Art

<u>FORM 2</u>

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

A DUAL CELL ASSEMBLY OF A FUEL CELL STACK

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is to be performed

TECHNICAL FIELD

[0001] Present disclosure relates to a field of an electrochemical reaction cells. More particularly, aspects of the present disclosure relate to fuel cells, electrolysers and one or more bipolar plates defined with an array of scales.

BACKGROUND

[0002] Fuel cells convert chemical energy of fuel and oxidant into electrical energy. Typically, fuel cells are used in space, transportation, material handling, power backup systems and many other applications to generate continuous electric power. An electrolyser converts electric energy and water into hydrogen and oxygen. The electrolysers are used to produce hydrogen and oxygen by water electrolysis process. Fuel cells and electrolysers include at least two electrodes designated as an anode and a cathode which are separated by an electrolyte media.

[0003] Fuel cells are classified based on the type of electrolyte media used. These include Alkaline fuel cells, molten carbonate fuel cells, direct methanol fuel cells, solid oxide fuel cells, phosphoric acid fuel cells, and polymer electrolyte membrane (PEM) fuel cells. Usually, an anode electrode layer and a cathode electrode layer have a catalyst material coating to promote electrochemical reaction. The polymer electrolyte membrane, an anode electrode layer and a cathode electrode layer are jointly called a membrane electrode assembly (MEA). For the operation of the fuel cell, a solid, gas impermeable plates generally known as bipolar plates are employed. The bipolar plates comprise a plurality of flow field channels that facilitates to supply fuel and oxidant to anode and cathode, respectively. Further, a porous layer i.e., a gas diffusion layer (GDL) is disposed between bipolar plate and electrode to facilitate rapid diffusion and transport of reactants to catalyst layer.

[0004] In operation, the fuel such as hydrogen and oxidant such as air or oxygen is supplied through the flow field channels of the bipolar plates to gas diffusion layers. Hydrogen diffuses rapidly through an anode gas diffusion layer and gets oxidized at the anode catalyst layer to release electrons and hydrogen ions. These electrons pass from the anode electrode to the cathode electrode through an external circuit. The polymer electrolyte membrane (PEM) restricts electrons from passing through but allows hydrogen ions to pass from anode electrode to cathode electrode. Further, the oxidant such as oxygen diffuses rapidly through a cathode gas diffusion layer and combines with the hydrogen ions and electrons at the cathode catalyst layer to form water.

[0005] Conventionally, the fuel cell employs bipolar plates which comprise the plurality of flow field channels designed to supply reactants (fuel and oxidant) through an inlet to the membrane electrode assembly (MEA). The bipolar plate performs several functions such as allowing the fuel and the oxidant to pass through the flow field channels on the anode and the cathode, respectively. The bipolar plates also collect current from electrodes and provide series connection between multiple cells at stack level and provides a structural support to the MEA. These conventional bipolar plates are defined with different configuration of the flow field channels such as serpentine, spiral, radial, parallel, interdigitated and straight formed between an inlet and an outlet. However, such configuration of flow field channels defined on the bipolar plates have several disadvantages such as considerable pressure drop and water flooding. As shown in Figure 1, the pressure mapping image of conventional serpentine flow field channels, where from the inlet to the outlet there is a large pressure drop. It is pertinent to maintain a uniform pressure throughout the flow field channels for efficient performance of the fuel cell. Thus, in a conventional configuration of the flow field channels, the gas entering from inlet and exiting from the outlet, there is a difference in the pressure as observed the pressure changes from red zone (high) to blue zone (low) when referred to pressure mapping image of the conventional configuration. Thus, this results in limiting efficient functioning of the fuel cell and eventually may lead to high parasitic power requirements. Additionally, due to nonuniform pressure distribution across the flow filed channels, there is another concern related to water flooding as there are limited flow paths available for water to drain away from flow field zone. This is primarily the issue on the cathode side due to chemical reaction, water is generated, hence if the water content is too much within this flow field channels due to the conventional configuration of the flow field channels, the bipolar plate will be flooded with water and block the flow of oxygen or air on a cathode side of the fuel cell. This affects the operational efficiency and durability of the fuel cell stack. Furthermore, conventional fuel cell includes one or more unit cell in a stacked configuration, however, dissipation of heat generated in these conventional fuel cell stack is challenging. Thus, there is limitation to provide a sufficient cooling arrangement for such conventional fuel cell stack assembly. Therefore, these conventional assembly of a fuel cell stack cannot be used for high capacity power output due to higher amount of heat generation and corresponding need to effectively remove the heat from stack to maintain uniform temperature distribution.

[0006] The present disclosure is directed to overcome one or more limitations stated above or any other limitations associated with the prior art. The information disclosed in this background of the disclosure section is only for enhancement of understanding of the general background of the invention and should not be taken as an acknowledgement or any form of suggestion that this information forms the prior art already known to a person skilled in the art.

SUMMARY OF THE INVENTION

[0007] One or more shortcomings of conventional bipolar plates in a fuel cell stack assembly have been overcome, and additional advantages are provided through a dual cell assembly as claimed in the present disclosure. Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered a part of the claimed disclosure.

[0008] The limitations of the prior arts are addressed by a dual cell assembly of a fuel cell stack as disclosed in the present disclosure. The dual cell assembly comprises a first cell having a first bipolar plate with a first flow field side and a second bipolar plate having a second flow field side. A first membrane electrode assembly (MEA) is interposed between the first and the second flow field sides. The dual cell assembly also comprises a second cell coupled to the first cell, wherein the second cell comprises a third bipolar plate having a third flow field side and a fourth bipolar plate having a fourth flow field side. A second membrane electrode assembly (MEA) is interposed between the third and the fourth flow field sides. Each of the first, second, third and fourth flow field sides is defined with an inlet port to receive a reactant gas, a flow field zone, fluidly connected to the inlet port for a flow of the reactant gas. The flow field zone is defined with a plurality of pathways formed by an array of scales disposed in a spaced apart configuration. Further, each scale of the array of scales is formed by an elliptical projection encompassed between a pair of guide vanes converging towards each other. An outlet port is fluidly connected to the flow field zone for dispensing the reactant gas.

[0009] In an embodiment of the present disclosure, the first bipolar plate comprises a first cooling side, opposite to the first flow field side and the first cooling side is defined with a plurality cooling channels for a coolant flow.

[0010] In an embodiment of the present disclosure, the second bipolar plate is having a second cooling side, opposite to the second flow field side and the second cooling side is defined with a plurality cooling channels for the coolant flow.

[0011] In an embodiment of the present disclosure, wherein the third bipolar plate and the fourth bipolar plate comprises a flushed side opposite to the third flow field side and the fourth flow field side, respectively.

[0012] In an embodiment of the present disclosure, each of guide vane of the pair of guide vanes comprises a leading edge, a trailing edge, and an upper surface formed by an inclined portion at the trailing edge and a flat portion at the leading edge.

[0013] In an embodiment, each of guide vane of the pair of guide vanes comprises a leading edge, a trailing edge, and an upper surface formed by an inclined portion at the trailing edge and a flat portion at the leading edge.

[0014] In an embodiment, a fluid path is provided at an outer perimeter of the flow field zone for collection of fluid released by the fuel cell and passage of the fluid towards the outlet port.

[0015] In an embodiment a seal is disposed around the inlet port, the flow field zone and the outlet port.

[0016] In an embodiment, each of the first bipolar plate, the second, third and fourth bipolar plate comprises a plurality of cutouts for passage of at least one of the reactant gas, a cooling medium, and a fluid released by the fuel cell.

[0017] In an embodiment, an inlet header is interposed between the inlet port and the flow field zone.

[0018] In an embodiment, an outlet header is interposed between the flow field zone and the outlet port. In an embodiment, the first and second membrane electrode assembly (MEA) includes a first electrode, a second electrode, and an electrolyte membrane disposed therebetween.

[0019] In another non-limiting embodiment of the present disclosure, a fuel cell is disclosed. The fuel cell assembly comprises one or more dual cell assemblies arranged in a stacked configuration. Each dual cell assembly comprises a first cell having a first bipolar plate with a first flow field side and a second bipolar plate having a second flow field side. A first membrane electrode assembly (MEA) is interposed between the first and the second flow field sides. The dual cell assembly also comprises a second cell coupled to the first cell, wherein the second cell comprises a third bipolar plate having a third flow field side and a fourth bipolar plate having a fourth flow field side. A second membrane electrode assembly (MEA) is interposed between the third and the fourth flow field sides. Each of the first, second, third and fourth flow field sides is defined with an inlet port to receive a reactant gas, a flow field zone, fluidly connected to the inlet port for a flow of the reactant gas. The flow field zone is defined with a plurality of pathways formed by an array of scales disposed in a spaced apart configuration. Further, each scale of the array of scales is formed by an elliptical projection encompassed between a pair of guide vanes converging towards each other. An outlet port is fluidly connected to the flow field zone for dispensing the reactant gas. The fuel cell assembly further comprises at least one end plate configured to enclose the stack of the one or more dual cell assemblies. The at least one end plate is fastened by a fastening means at either ends of the one or more dual cell assemblies.

[0020] In an embodiment, the fuel cell comprises at least one terminal plate at either ends of the one or more dual cell assemblies enclosed in the stacked configuration. Further, at least one insulation plate is disposed between at least one terminal plate and the at least one end plate in the stacked configuration.

[0021] It is to be understood that the aspects and embodiments of the disclosure described above may be used in any combination with each other. Several of the aspects and embodiments may be combined to form a further embodiment of the disclosure.

[0022] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects and features described above, further aspects and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF ACCOMPANYING DRAWINGS

[0023] The novel features and characteristic of the disclosure are set forth in the appended claims. The disclosure itself, however, as well as a mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an embodiment when read in conjunction with reference to the accompanying drawings wherein like reference numerals represent like elements and in which:

Fig.1 illustrates a pressure mapping of a conventional serpentine flow field configuration having a plurality of flow filed channels;

Fig. 2 illustrates an exploded view of a dual cell assembly of a fuel cell stack, in accordance with an embodiment of the present disclosure;

Fig.3 illustrates a perspective view of a first bipolar plate having a first cooling side of a first cell;

Fig. 4 illustrates a front view of the first bipolar plate having a first field side of the first cell, in accordance with an embodiment of the present disclosure;

Fig.5 illustrates a front view a second bipolar plate having a second cooling side of the first cell;

Fig. 6 illustrates a perspective view of the second bipolar plate having a second flow field side of the first cell, in accordance with an embodiment of the present disclosure;

Fig.7 illustrates a detailed view of flow filed channels defined on flow field side of first, second, third and fourth bipolar plate of the dual cell assembly;

Fig. 8 illustrates a perspective view of a third bipolar plate and the fourth bipolar plate having a flushed side, in accordance with an embodiment of the present disclosure;

Fig. 9 illustrates a front view of the third bipolar plate having a third flow field side of a second cell in accordance with an embodiment of the present disclosure;

Fig. 10 illustrates a front view of a fourth bipolar plate having a fourth flow field side of the second cell, in accordance with an embodiment of the present disclosure.

Fig. 11 illustrates a perspective view of the fuel cell stack assembly having one or more dual cell assembly in a stacked configuration, in accordance with an embodiment of the present disclosure.

The figures depict embodiments of the disclosure for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the system and methods illustrated herein may be employed without departing from the objective of the disclosure described herein. It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative systems embodying the principles of the present subject matter.

DETAILED DESCRIPTION OF THE DRAWINGS

[0024] The foregoing has broadly outlined the features and technical advantages of the present disclosure in order that the detailed description of the disclosure that follows may be better understood. Additional features and advantages of the disclosure will be described hereinafter which forms the subject of the claims of the disclosure. It should be appreciated by those skilled in the art that, the conception and specific embodiments disclosed may be readily utilized as a basis for modifying other devices, systems, assemblies, and mechanisms for carrying out the same purposes of the present disclosure. It should also be realized by those skilled in the art that, such equivalent constructions do not depart from the scope of the disclosure as set forth in the appended claims. The novel features which are believed to be characteristics of the disclosure, to its system, together with further objects and advantages will be better understood from the following description when considered in connection with the accompanying figures. It is to be expressly understood, however, that each of the figures is provided for the purpose of illustration and description only and is not intended as a definition of the limits of the present disclosure.

[0025] In accordance with various embodiments of the present disclosure, a dual cell assembly of a fuel cell stack may be described. The dual cell assembly comprises a first cell and second cell coupled to the first cell. The first cell comprises a first bipolar plate having a first flow field side and a second bipolar plate having a second flow field side. A first membrane electrode assembly (MEA) is interposed between first and the second flow field side of the first bipolar plate and the second bipolar plate. The second cell comprises a third bipolar plate having a third flow field side and a fourth bipolar plate having a fourth flow field side. A second membrane electrode assembly (MEA) is interposed between third and the fourth flow field side of the third bipolar plate and the fourth bipolar plate. Each of the first, second, third and fourth flow field sides comprises an inlet port to receive a reactant gas. A flow field zone is fluidly connected to the inlet port for a flow of the reactant gas, wherein the flow field zone is defined with a plurality of pathways formed by an array of scales disposed in a spaced apart configuration. Each scale of the array of scales is formed by an elliptical projection encompassed between a pair of guide vanes converging towards each other. Further, an outlet port is fluidly connected to the flow field zone for dispensing the reactant gas.

The forthcoming paragraphs will elucidate the configuration of the dual cell assembly. Forthcoming embodiments elucidate the dual cell assembly and its working in detail in conjunction to Figs, 1 to 11.

[0026] The dual cell assembly described above includes a specific configuration of the plurality of pathways on the flow field side of bipolar plates. This enables maintaining uniform pressure distribution across the flow field zone for an improved electrochemical reaction between a fuel and an oxidant. Advantageously, this increases an output and the operational efficiency of the dual cell assembly. Also, the at least one of the first bipolar plate, the second bipolar plate, third and fourth bipolar plate having the flow filed zone of the present disclosure prevents flooding of water across the flow field zone, wherein water is formed as a resultant of the electrochemical reaction. This results in eliminating blocking of the flow of the reactant or fuel within the plurality of the pathways.

[0027] While the embodiments in the disclosure are subject to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the figures and will be described below. It should be understood, however, that it is not intended to limit the disclosure to the particular forms disclosed, but on the contrary, the disclosure is to cover all modifications, equivalents, and alternative falling within the scope of the disclosure.

[0028] It is to be noted that a person skilled in the art would be motivated from the present disclosure and modify construction of the dual cell assembly. However, such modifications should be construed within the scope of the present disclosure. Accordingly, the drawings show only those specific details that are pertinent to understand the embodiments of the present disclosure, so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having benefit of the description herein.

[0029] The terms "comprise," "comprising," or any other variations thereof used in the disclosure, are intended to cover a non-exclusive inclusion, such that a system and method that comprises a list of components does not include only those components but may include other components not expressly listed or inherent to such system, method, or assembly, or device. In other words, one or more elements in a system or device proceeded by "comprises… a" does not, without more constraints, preclude the existence of other elements or additional elements in the system or device.

[0030] The following paragraphs describe the present disclosure with reference to FIG(s) 1 to 11. In the figures, the same element or elements which have similar functions are indicated by the same reference signs. With general reference to the drawings, a dual cell assembly of a fuel cell stack in accordance with the teachings of a preferred embodiment of the present disclosure is illustrated and generally identified with reference numeral 100. The dual cell assembly (100) may be used in the fuel cell /stack to produce electricity. The dual cell assembly (100) may also be used in an electrolyser assembly/stack to produce hydrogen and oxygen by means of water electrolysis. It will be understood that the teachings of the present disclosure are not limited to any particular electrochemical reaction cell.

[0031] The following detailed description is merely exemplary in nature and is not intended to limit application and uses. Furthermore, there is no intention to be bound by any theory presented in the preceding background or summary or the following detailed description. It is to be understood that the disclosure may assume various alternative orientations and step sequences, except where expressly specified to the contrary. It is also to be understood that the specific devices or components illustrated in the attached drawings and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions or other physical characteristics relating to the embodiments that may be disclosed are not to be considered as limiting, unless the claims expressly state otherwise. Hereinafter, preferred embodiments of the present disclosure will be described referring to the accompanying drawings. While some specific terms of "upper," "lower," "below," "above," "right," "left," "rear" or "front" and other terms containing these specific terms and directed to a specific direction will be used, the purpose of usage of these terms or words is merely to facilitate understanding of the present invention referring to the drawings. Accordingly, it should be noted that the meanings of these terms or words should not improperly limit the technical scope of the present invention.

[0032] Also, it is to be understood that the phraseology and terminology used herein is for description and should not be regarded as limiting. Unless specified or limited otherwise, the terms "mounted," "connected," "supported," and "coupled" and variations thereof are used broadly and encompass both direct and indirect mountings, connections, supports, and couplings. Further, "connected" and "coupled" are not restricted to physical or mechanical connections or couplings. It is to be understood that this disclosure is not limited to the specific devices, methods, applications, conditions, or parameters described and/or shown herein and that the terminology used herein is to describe particular embodiments by way of example and is not intended to be limiting of the claimed invention. Hereinafter in the following description, various embodiments will be described. For purposes of explanation, specific configurations and details are outlined to provide a thorough understanding of the embodiments. However, it will also be apparent to one skilled in the art that the embodiments may be practiced without the specific details. Furthermore, well-known features may be omitted or simplified in order not to obscure the embodiment being described.

[0033] Referring to FIGs 2 to 10 in conjunction, which illustrates various views of a dual cell assembly (100) of a fuel cell stack (200) and various components associated with the dual cell assembly (100). The dual cell assembly (100) of the present disclosure may be used in passenger vehicles, heavy commercial vehicles, off-highway vehicles, maritime, aviation, unmanned aerial vehicles (UAVs), drones, backup power, space stations etc. for electric power generation by an electrochemical reaction. The dual cell assembly (100) of the present disclosure may also be used to produce hydrogen and oxygen by means of water electrolysis process. Also, application of the dual cell assembly (100) elucidated going forward should not be construed as a limitation of the present disclosure. Figs. 2 to 10 schematically illustrates an embodiment of one or more dual cell assemblies (100) used in the fuel cell stack (200). Hereinafter, features of the fuel cell assembly (200) having the dual cell assembly (100) along with its working may be elucidated.

[0034] The fuel cell assembly (200) comprises one or more dual cell assemblies (100) stacked together. The dual cell assembly (100) of the present disclosure comprises a first cell (100A) and a second cell (100B) coupled to the first cell (100A). The first cell (100A) comprises a first bipolar plate (102) and second bipolar plate (104). The first bipolar plate (102) and the second bipolar plate (104) comprises a first flow field side (102a) and second flow filed side (104a), respectively. Also, the first bipolar plate (102) comprises a first cooling side (102b) opposite to the first flow field side (102a), likewise the second bipolar plate (104) comprises a second cooling side (104b) opposite to the second flow field side (104a). More specifically, each of the first bipolar plate (102) and the second bipolar plate (104) comprises flow field side and a cooling side opposite to the flow field side. The flow field side of the first bipolar is namely a first flow field side (102a) and for the second bipolar plate (104) is a second flow side (104a), respectively. Accordingly, the cooling side of the first bipolar plate (102) is namely the first cooling side (102b), opposite to the first flow field side (102a). Similarly, the cooling side of the second bipolar plate (104) is namely the second cooling side (104b), opposite to the second flow field side (104a). The first cell (100A) of the dual cell assembly (100) comprises a first membrane electrode assembly (MEA) (103) interposed between the first and the second flow field sides (102a, 104a) of the first bipolar plate (102) and the second bipolar plate (104). More particularly, the first MEA (103) is interposed between the first bipolar plate (102) and the second bipolar plate (104) such that the first and the second flow field sides (102a, 104a) are facing towards each other and the first MEA (103). Referring to Figures 2- Figure 4, the first bipolar plate (102) is defined with inlet port (10a, 10b) to receive the reactant gas. In an embodiment, the cooling side (102b) of the first bipolar plate (102) as seen in Figure 2 is defined with a plurality cooling channels (102c) for a coolant flow. The coolant enters from the inlet port (10c) provided at an upstream of the plurality of cooling channels (102c) and exists through an outlet port (40c) provided downstream of the plurality of channels (102c). An inlet header (70c) of the flow field side (102b) provides guide paths to the coolant towards the plurality of cooling channels (102c). Similarly, an outlet header (80c) of the flow field side (102b) provides a guide path to the coolant leaving the plurality of cooling channels (102c). In an embodiment , the inlet port (10a, 10b) are configured specifically for the receiving the reactant gas and the inlet port (10c) is configured of coolant flow. In a further embodiment, the first flow field side (102a) of the first bipolar plate (102) is defined with a flow field zone (20) and the inlet port (10a) for receiving the reactant gas may be defined downstream of the first flow field side (102a) and the outlet port (40a) may be configured at upstream of the flow field zone (20) as shown in Figure 4. In an embodiment, the first flow field side (102a) of the first bipolar plate (102) is an anode face. Similarly, referring to Fig 5 to Fig 7, the second bipolar plate (104) defined with the second flow field side (104a) faces the first MEA (103), wherein the second flow field side (104a) of the second bipolar plate (104) is defined with the flow field zone (20) and the inlet port (10b) for receiving the reactant gas may be defined upstream of the second flow field side (104a) and the outlet port (40b) may be configured at downstream of the flow field zone (20) as shown in Figure 6. An inlet header (70b) of the flow field side (104a) provides guide paths to the reactant gas towards the flow field zone (20). Similarly, an outlet header (80b) of the flow field side (104b) provides a guide path to the reactant gas leaving the flow field zone (20). Therefore, the cooling side (104b) opposite to the second flow filed side (104a) of the second bipolar plate (104) as seen in Figure 5 is defined with a plurality cooling channels (104c) for the coolant flow. The coolant enters from the inlet port (10c) provided at the upstream of the plurality of cooling channels (104c) and exists through the outlet port (40c) provided downstream of the plurality of channels (104c). An inlet header (70c) of the flow field side (104b) provides guide paths to the coolant towards the cooling channels (104c). Similarly, an outlet header (80c) of the flow field side (104b) provides a guide path to the coolant leaving the cooling channels (104c). In an embodiment, the second flow field side (102a) of the second bipolar plate (102) is a cathode face. In an embodiment, the reactant gas may be a fuel such as hydrogen on anode face and an oxidant such as oxygen or air on a cathode face.

[0035] Further, the flow field zone (20) of each first flow field side (102a) and the second flow field side (104a) is defined at a central portion of the first and second bipolar plate

(102, 104). The flow field zone (20) is configured for a flow of the reactant gas. The flow field zone (20) is defined with a plurality of pathways (22) formed by an array of scales (30) disposed in a spaced apart configuration as seen in Figure 7. The plurality of pathways (22) formed by the array of scales (30) in the flow field zone (20) allows the reactants to flow through the flow field zone (20).

[0036] More particularly, each scale of the array of scales (30) is interposed between the inlet port (10) and the outlet port (40). Each scale of the array of scales (30) is formed by an elliptical projection (32) encompassed between a pair of guide vanes (34) converging towards each other. The elliptical projection (32) extends away upwardly from a substrate surface of the first and the second bipolar plate (102, 104). Further, pair of guide vanes (34) may comprise a left guide vane and a right guide vane, wherein the elliptical portion (32) is disposed between the left guide vane and the right guide vane. Additionally, the left and right guide vanes are configured at a predefined distance from a periphery of the elliptical portion (32). This configuration allows forming plurality of the pathways (22) for the reactant to flow. In an embodiment, each of guide vane of the pair of guide vanes (34) comprises a leading edge (34b), a trailing edge (34a), and an upper surface (34c) formed by an inclined portion at the trailing edge (34a) and a flat portion at the leading edge (34b). More specifically, the left guide vane and the right guide vane are curved from the leading edge (34b) to converge towards the trailing edge (34a) as seen in Figure 7. In an embodiment, this configuration of array of scales (30) forms a three dimensional flow pathway for the reactant to flow across the flow field zone (20) by means of plurality of pathways (22) formed between the elliptical portion (32) and the pair of guide vanes (34). Furthermore, the reactant gas may also flow over an upper surface (34c) of the pair of guide vanes (34) due the inclined portion of the pair of guide vanes (34). In an embodiment, as shown in Figure 4, at the anode face, the reactant gas enters from the inlet port (10a), passes through the inlet header (70a) and flows through the flow field zone (20) having array of scales (30), passes through the outlet header (80a) and eventually exits from the outlet port (40a) provided at the upstream. Correspondingly, referring to Fig 6, at the cathode face, the reactant gas enters from the inlet ports (10b), passes through the inlet header (70b), flows through the flow field zone (20) having array of scales (30), passes through the outlet header (80b) and eventually exits from the outlet port (40b) provided at the downstream. However, this arrangement of the outlet ports (40a, 40b) and the inlet ports (10a,10b) of the first and second bipolar plate (102, 104) shall not be construed as limitation.

[0037] In an example, the three dimensional flow path is explained by considering a first scale and a second scale of the array of scales (30). Each of the first and the second scale comprise the elliptical portion (32) encompassed by the pair of the guide vanes (34) (left and right guide vanes). The second scale is configured below the first scale. During the operation, the reactant gas may flow through the path formed between the left vane with the elliptical portion of the first scale. More specifically, the reactant gas flows from the leading edge (34b) of the left guide vane and converges at the trailing edge (34a) of the left guide vane and later passes through the path formed between the right guide vane of the second scale disposed below the right guide vane of the first scale. Similarly, the reactant gas may flow through the path formed between the right guide vane with the elliptical portion (32) of the first scale. Further, the reactant gas flows from the leading edge (34b) of the right guide vane and converges at the trailing edge (34a) of the right guide vane and later passes through the path formed between the left guide vane of the second scale disposed below the left guide vane of the first scale. Furthermore, the reactant gas may also flow over an upper surface (34c) of the pair of guide vanes (34) due the inclined portion of the pair of guide vanes (34). Thus, this results in the three dimensional cross flow path across the array of the scales defined on the flow field zone (20). This three dimensional cross flow path continues until the reactant gas reaches at the outlet header (80a,80b). This configuration aids in uniform pressure distribution and prevents pressure drop to improve efficiency of the electrochemical reaction. Additionally, this configuration of three dimensional flow path aids in effective water removal from the flow field zone (20). In another embodiment, the array of scales (30) may also be disposed at a predetermined inclination with respect to a horizontal axis (X-X’) of the dual cell assembly (100). The array of scales (30) may be arranged along plurality of columns and rows. In an embodiment, each row of the array of scales (30) may also be arranged in the predetermined inclination with respect to the horizontal axis (X-X’) of the unit cell assembly (100). This configuration facilitates the flow of the byproduct i.e., water to flow in the path formed between each row of plurality of the rows in the array of scales (30). Additionally, the upper surface of pair of guide vanes (34) having the inclined portion aids in effective byproduct water removal thereby preventing flooding of water in the flow field zone (20). The pair of guide vanes (30) also extends upwardly from a surface of the first and the second bipolar plate (102, 104). The first and the second bipolar plate (102, 104) comprises a fluid path (50) provided at an outer perimeter of the flow field zone (20) for collection of fluid released by the fuel cell stack (200) and passage of the fluid towards the outlet ports (40a,40b). In an embodiment, the fluid path (50) is provided on at least one edge of the outer perimeter of the flow field zone (20).

[0038] The second cell (100B) of the dual cell assembly (100) comprises a third bipolar (106) and the fourth bipolar plate (108). The third bipolar plate (106) and the fourth plate (108) comprise a third flow field side (106a) and a fourth flow filed side (108a), respectively. Also, the third bipolar plate (106) comprises a flushed side (106b) opposite to the third flow field side (106a), likewise the fourth bipolar plate (108) comprises a flushed side (108b) opposite to the fourth flow field side (108a). More specifically, each of the third bipolar plate (106) and the fourth bipolar plate (108) comprises flow field side and the flushed side opposite to the flow field side. The flow field side of the third bipolar plate (106) is namely a third flow field side (106a) and for the fourth bipolar plate (108) is a fourth flow field side (108a), respectively. Accordingly, the flushed side (106b) may aid as a cooling side of the third bipolar plate (106), opposite to the third flow field side (106a). Similarly, the flushed side (108b) may aid as cooling side of the fourth bipolar plate (108), opposite to the fourth flow field side (108a). In an embodiment, the flushed side (106b, 108b) of third and fourth bipolar plate (106, 108) may be defined as flat surface with no flow channels as seen in Fig. 8. The second cell (100B) of the dual cell assembly (100) comprises a second membrane electrode assembly (MEA) (107) interposed between the third and the fourth flow field sides (106a, 108a) of the third bipolar plate (106) and the fourth bipolar plate (108) as illustrated in Fig. 2. More particularly, the second MEA (107) is interposed between the third bipolar plate (106) and the fourth bipolar plate (108) such that the third and the fourth flow field sides (106a, 108a) are facing towards each other, specifically towards the second MEA (107). Referring to Fig. 9, the third flow field side (106a) of the third bipolar plate (106) is defined with the flow field zone (20), an inlet port (10a), an inlet header (70a), an outlet header (80a) and an outlet port (40a) in such a way that reactant gas enters from an inlet port (10a), passes through an inlet header (70a), flows through the flow field zone (20), passes through an outlet header (80a) and exits from an outlet port (40a). In an embodiment, the third flow field side (106a) of the third bipolar plate (106) is an anode face. Similarly, referring to Fig 10, the fourth bipolar plate (108) is defined with the fourth flow field side (108a) faces the second MEA (107), wherein the fourth flow field side (108a) of the fourth bipolar plate (108) is defined with the flow field zone (20), inlet ports (10b), an inlet header (70b), an outlet header (80b) and outlet ports (40b) in such a way that reactant gas enters from inlet ports (10b), passes through an inlet header (70b), flows through the flow field zone (20), passes through an outlet header (80b) and exits from outlet ports (40b). In an embodiment, the fourth flow field side (108a) of the fourth bipolar plate (108) is a cathode face.

[0039] Further, the flow field zone (20) of each third flow field side (106a) and the fourth flow field side (108a) is defined at a central portion of the third and fourth bipolar plate (106, 108). The configuration of the flow field zone (20) in the third bipolar plate (106) is similar to the flow field zone (20) configured in first bipolar plate (102), likewise a configuration of the flow field zone (20) in the fourth bipolar plate (108) is similar to the flow field zone (20) configured in second bipolar plate (104) for the flow of the reactant gas. Correspondingly, referring to Fig.9 and Fig 10, arrangement of the outlet port (40a,40b), the inlet port (10a,10b), outlet header (80a,80b) and inlet header (70a,70b) of the third and fourth bipolar plate (106, 108) shall not be construed as limitation. Further, the third and the fourth bipolar plate (106, 108) comprises the fluid path (50) provided at an outer perimeter of the flow field zone (20) for collection of fluid released by the fuel cell (200) and passage of the fluid towards the outlet header (80a,80b). In an embodiment, the fluid path (50) is provided on at least one edge of the outer perimeter of the flow field zone (20).

[0040] In an embodiment, the inlet port (10a,10b,10c) and the outlet port (40a,40b,40c) are defined as an openings. In an embodiment, the inlet port (10a) may be at least one first anode inlet, and third anode inlet defined at one end portion of the first and third bipolar plate (102, 106) for an entry of the fuel at the anode face i.e., the first and third flow field side (102a, 106a). The outlet port (40a) is also defined as the first and third anode outlet provided diagonally opposite to the first and third anode inlet (10a) at the other end portion. The outlet port (40a) also referred as the first anode outlet and third anode outlet is configured for an exit of the fuel from the anode face i.e., the flow field side (102a, 106a) of the first and third bipolar plate (102, 106). Similarly, on the second bipolar plate (104) and the fourth bipolar plate (108), the inlet port (10b) is at least one second cathode inlet and fourth cathode inlet for an entry of the oxidant at the cathode face i.e., the second and fourth flow field side (104a, 108a). Also, the outlet port (40b) is at least one second cathode outlet and fourth cathode outlet arranged diagonally opposite to at least one second and fourth inlet port (10b) for exit of the oxidant, respectively. The oxidant is configured to flow on the cathode face i.e., the second and fourth flow field side (104a, 108a) of the second and fourth bipolar plate (104, 108).

[0041] Each of the first, the second, third and the fourth bipolar plate (102, 104, 106 and 108) comprises an inlet header (70a,70b,70c) interposed between the inlet port

(10a,10b,10c) and the flow field zone (20). Similarly, each of the first, the second, third and the fourth bipolar plate (102, 104, 106 and 108) comprises an outlet header (80a,80b,80c) interposed between the outlet port (40a,40b,40c) and the flow field zone (20). The inlet header (70a,70b,70c) are configured to guide the reactants and coolant entering from inlet port (10a,10b,10c) towards the flow field zone (20) and cooling channels (120c). Similarly, the outlet header (80a,80b,80c) are configured to guide the reactants and coolant leaving from flow field zone (20) and cooling channels (120c) towards outlet port (40a,40b,40c). Further, the at least one first, the second, third and the fourth bipolar plate (102, 104, 106 and 108) comprises a seal (60) disposed around the at least one inlet port (10a,10b,10c), the flow field zone (20), plurality of cooling channels (120c) and at least one outlet port (40a,40b,40c) to restrict leakage of the fuel, the oxidant, and the coolant during the electro-chemical reaction.

[0042] Referring to Fig. 3 and Fig.5 , the first cooling side (102b) of the first bipolar plate (102) and the second cooling side (104b) of the second bipolar plate (104) are defined with the cooling channels (102c,104c), an inlet port (10c), an inlet header (70c), an outlet header (80c) and an outlet port (40c) in such a way that coolant enters from an inlet port (10c), passes through an inlet header (70c), flows through the cooling channels (102c,104c), passes through an outlet header (80c) and exits from an outlet port (40c). In an embodiment, the coolant may be water or any other fluid capable of maintaining the desired temperature of the dual cell assembly (100).

[0043] The dual cell assembly (100) comprising the first membrane electrode assembly (MEA) (103) and the second MEA (107) includes a first electrode, a second electrode, and an electrolyte membrane disposed therebetween. In an embodiment, a plurality of gas diffusion layers (not shown in figures) may be disposed between the first bipolar plate (102) and the first MEA (103) and similarly between the second bipolar plate (104) and the first MEA (103) in the first cell (100A) and likewise in the second cell (100B) the plurality of gas diffusion layers (not shown in figures) may be configured between the third bipolar plate (106) and the second MEA (107) and similarly between the fourth bipolar plate (108) and the second MEA (107). In an embodiment, the plurality of gas diffusion layers facilitates rapid diffusion and transport of reactants to catalyst layers of the at least one first and second membrane electrode assembly (103, 107).

[0044] The fuel cell (200) of the present disclosure may include a plurality of dual cell assembly (100) or a stack of the dual cell assemblies having the first cell (100A) and the second cell (100B). In an embodiment, the dual cell assemblies (100) are stacked in the fuel cell stack (200) in such a way that, the first, second, third and fourth flow field side (102a, 104a, 106a, 108a) of each first, second, third and fourth bipolar plate (102,104,106,108) is in contact with the at least one first and second membrane electrode assembly (103, 107). Further, in an example the electrically conductive materials may be configured to contact the first membrane electrode assembly (103) for electrical conductivity between the first bipolar plate (102) and the second bipolar plate (104) thereby providing a series connection between first cell (100A). Additionally, the electrically conductive materials may be configured to contact the second membrane electrode assembly (107) for electrical conductivity between the third bipolar plate (106) and the fourth bipolar plate (108) to provide a series connection between the second cell (100B). Thus, this configuration of the first and second cell (100A, 100B) forms the dual cell assembly, thereby forming an electrical connection between successive dual cell assemblies of the fuel cell stack/assembly (200). Also, the at least one end plate (202) may be configured to enclose the dual cell assembly (100). Further, one or more openings [not shown in Figures] may be defined on each corner of the at least one end plates (202) being concentric to the at least one anode and one cathode manifolds (both inlets and outlets port) of all the bipolar plates. The one or more openings allows a provision for the gas carrying manifolds to pass through in normal direction. In an embodiment, the end plate (202) may comprise a plurality of cooling channels on the periphery of the at least one end plate (202) to receive the coolant for the coolant flow. A plurality of fastening holes [not shown in Figures] is defined on corners of the at least one end plate (202) to fasten the at least one end plate (202) at either ends of the dual cell assembly (100). The at least one end plate (202) is fastened by passing a plurality of fasteners through the plurality of fastening holes. The fuel cell stack (200) also comprises at least one terminal plate (204) provided at either end of the one or more dual cell assemblies (100) enclosed in the stacked configuration. The terminal plate (204) aids in collection of a current generated by the fuel cell stack (200) through electrochemical reaction. Further, at least one insulation plate (206) is disposed between at least one terminal plate (204) and the at least one end plate (202) when assembled in the stacked configuration. The insulation plate (206) prevents short circuit during operation of the fuel cell stack (200).

[0045] A working operation of the fuel cell (200) in accordance with the embodiments of the present disclosure as elucidated below are now explained. A fuel such as hydrogen enters from inlet port (10a) on the first flow field side (102a) of first bipolar plate (102) and third flow field side (106a) of third bipolar plate (106). The fuel entered from inlet port (10a) is guided by inlet header (70a) towards flow field zone (20). Simultaneously, the oxidant such as oxygen or air enters from inlet ports (10b) on the second flow field side (104a) of second bipolar plate (104) and fourth flow field side (108a) of fourth bipolar plate (108). The oxidant entered from inlet port (10b) is guided by inlet header (70b) towards flow field zone (20). The coolant enters from inlet port (10c) on the first cooling side (102b) of first bipolar plate (102) and second flow cooling side (104b) of second bipolar plate (104). Simultaneously, the coolant enters from inlet port (10c) is guided by inlet header (70c) towards cooling channels (102c,104c). The fuel such as hydrogen while flowing through the plurality of pathways formed by the array of scales (30) of flow field zone (20) diffuses rapidly through gas diffusion layer and reaches at the anode electrode surface of membrane electrode assembly (103,107). The oxidant such as oxygen or air while flowing through the plurality of pathways formed by the array of scales (30) of flow field zone (20) diffuses rapidly through gas diffusion layer and reaches at the cathode electrode surface of membrane electrode assembly (103,107). At anode electrode surface, hydrogen is oxidized to release electrons and hydrogen ions. The electrons passes from anode electrode surface to cathode electrode surface by an external circuit. The hydrogen ions passes through electrolyte and reaches at cathode electrode surface where it combines with electrons and oxygen to form a byproduct water and heat under an exothermic electrochemical reaction. The unused fuel on anode side flow field zone (20) of first flow field side (102a) of first bipolar plate (102) and third flow field side (106a) of third bipolar plate (106) is guided by an outlet header (80a) towards an outlet port (40a). Similarly, the unused air/oxygen on cathode side flow field zone (20) of second flow field side (104a) of second bipolar plate (104) and fourth flow field side (108a) of fourth bipolar plate (108) is guided by an outlet header (80b) towards an outlet port (40b). The coolant flowing through cooling channels (102c, 104c) collects the heat generated during exothermic electrochemical reaction in first cell (100A) and second cell (100B) and passes through an outlet header (80c) and eventually exits from an outlet port (40c). The same process is repeated in each of the first cell (100A) and the second cell (100B) of a dual cell assembly (100) to generate required electric power which is collected at the terminal plates (204).

[0046] In an embodiment, the first, second, third and fourth bipolar plate (102, 104, 106, 108) may be manufactured by CNC machining, metal injection molding, additive manufacturing, chemical etching, selective laser sintering or any other suitable process. In an embodiment, the first, second, third and fourth bipolar plate (102, 104, 106, 108) may be made of metal, alloy, graphite, carbon composites or any other electrically conductive material.

However, this cannot be construed as a limitation and the bipolar plates (102, 104, 106, 108) may be manufactured by processes other than mentioned and materials other than mentioned. In an embodiment, the array of scales (30) of a flow field zone (20) may be a placoid configuration.

WE CLAIM:

1. A dual cell assembly (100) of fuel cell stack (200), the dual cell assembly (100) comprising:

a first cell (100A) comprises:

a first bipolar plate (102) having a first flow field side (102a);

a second bipolar plate (104) having a second flow field side (104a); and

a first membrane electrode assembly (MEA) (103) interposed between the first and the second flow field sides (102a, 104a);

a second cell (100B), coupled to the first cell (100A), wherein the second cell (100B) comprises:

a third bipolar plate (106) having a third flow field side (106a);

a fourth bipolar plate (108) having a fourth flow field side (108a); and

a second membrane electrode assembly (MEA) (107) interposed between the third and the fourth flow field sides (106a, 108a);

wherein, each of the first, second, third and fourth flow field sides (102a, 104a, 106a, 108a) is defined with:

at least one inlet port (10a, 10b) to receive a reactant gas;

a flow field zone (20), fluidly connected to the at least one of the inlet port (10a,10b), for a flow of the reactant gas, wherein the flow field zone (20) is defined with a plurality of pathways (22) formed by an array of scales (30) disposed in a spaced apart configuration, wherein each scale of the array of scales (30) is formed by an elliptical projection (32) encompassed between a pair of guide vanes (34) converging towards each other; and

at least one of the outlet port (40a,40b), fluidly connected to the flow field zone (20), for dispensing the reactant gas.

2. The dual cell assembly (100) as claimed in claim 1, wherein the first bipolar plate (102) comprises a first cooling side (102b), opposite to the first flow field side (102a), wherein the first cooling side (102b) is defined with a plurality cooling channels (102c) for a coolant flow.

3. The dual cell assembly (100) as claimed in claim 2, wherein the plurality of cooling channels (102c) of the first cooling side (102b) is fluidly connected to at least one inlet port (10c) and at least one outlet port (40c) of the first bipolar plate (102).

4. The dual cell assembly (100) as claimed in claim 1, wherein the second bipolar plate (104) is having a second cooling side (104b), opposite to the second flow field side (104a), wherein the second cooling side (104b) is defined with a plurality cooling channels (104c) for a coolant flow.

5. The dual cell assembly (100) as claimed in claim 4, wherein the plurality of cooling channels (104c) of the second cooling side (104b) is fluidly connected to at least one inlet port (10c) and at least one outlet port (40c) of the second bipolar plate (104).

6. The dual cell assembly (100) as claimed in claim 1, wherein the third bipolar plate (106) and the fourth bipolar plate (108) comprises a flushed side (106b, 108b) opposite to the third flow field side (106a) and the fourth flow field side (108a), respectively.

7. The dual cell assembly (100) as claimed in claim 1, wherein each of guide vane of the pair of guide vanes (34) comprises a leading edge (34b), a trailing edge (34a), and an upper surface (34c) formed by an inclined portion at the trailing edge (34a) and a flat portion at the leading edge (34b).

8. The dual cell assembly (100) as claimed in claim 1, wherein the array of scales (30) is disposed at a predetermined inclination with respect to a horizontal axis (X-X') of the dual cell assembly (100).

9. The dual cell assembly (100) as claimed in claim 1, comprises a fluid path (50) provided at an outer perimeter of the flow field zone (20) and the plurality of cooling channels (102c,104c) for collection of fluid released by the fuel cell stack (200) and passage of the fluid towards the at least one of the outlet port (40a,40b,40c).

10. The dual cell assembly (100) as claimed in claim 1, comprises a seal (60) disposed around the at least one of the inlet port (10a,10b,10c), the flow field zone (20), cooling channels (102c,104c) and at least one of the outlet port (40a,40b,40c).

11. The dual cell assembly (100) as claimed in claim 1, wherein each of the first bipolar plate (102), the second bipolar plate (104), the third and fourth the bipolar plate (106, 108) comprises at least one inlet ports (10a,10b,10c) and outlet ports (40a,40b,40c) for

inlet and exit of at least one of the reactant gases, a cooling medium, and a fluid released by the fuel cell stack (200).

12. The dual cell assembly (100) as claimed in claim 1, wherein each of the first bipolar plate (102), the second bipolar plate (104), the third and fourth the bipolar plate (106, 108), comprises at least one of the inlet header (70a,70b) interposed between the at least one of the inlet ports (10a,10b) and the flow field zone (20).

13. The dual cell assembly (100) as claimed in claim 1, wherein each of the first bipolar plate (102), and the second bipolar plate (104) comprises at least one of the inlet headers (70c) interposed between the at least one of the inlet port (10c) and the cooling channels (102c,104c).

14. The dual cell assembly (100) as claimed in claim 1, wherein each of the first bipolar plate (102), the second bipolar plate (104), the third and fourth bipolar plates (106, 108), comprises at least one of the outlet headers (80a,80b) interposed between the flow field zone (20) and the at least one of the outlet port (40a,40b).

15. The dual cell assembly (100) as claimed in claim 1, wherein each of the first bipolar plate (102), and the second bipolar plate (104) comprises at least one of the outlet headers (80c) interposed between the at least one of the outlet ports (40c) and the cooling channels (102c,104c).

16. The dual cell assembly (100) as claimed in claim 1, wherein each of the first and second membrane electrode assembly (MEA) (103, 107) includes a first electrode, a second electrode, and an electrolyte membrane disposed therebetween.

17. A fuel cell stack (200) comprising:

one or more dual cell assemblies (100) arranged in a stacked configuration, wherein each dual cell assembly (100) comprises:

a first cell (100A) having:

a first bipolar plate (102) having a first flow field side (102a);

a second bipolar plate (104) having a second flow field side (104a); and

a first membrane electrode assembly (MEA) (103) interposed between the first and the second flow field sides (102a, 104a);

a second cell (100B), coupled to the first cell (100A), wherein the second cell (100B) comprises:

a third bipolar plate (106) having a third flow field side (106a);

a fourth bipolar plate (108) having a fourth flow field side (108a); and

a second membrane electrode assembly (MEA) (107) interposed between the third and the fourth flow field sides (106a, 108a);

wherein, each of the first, second, third and fourth flow field sides (102a, 104a, 106a, 108a) is defined with:

at least one inlet port (10a, 10b) to receive a reactant gas;

a flow field zone (20), fluidly connected to at least one of the inlet ports (10a,10b), for a flow of the reactant gas, wherein the flow field zone (20) is defined with a plurality of pathways (22) formed by an array of scales (30) disposed in a spaced apart configuration, wherein each scale of the array of scales (30) is formed by an elliptical projection (32) encompassed between a pair of guide vanes (34) converging towards each other; and

at least one of the outlet port (40a,40b), fluidly connected to the flow field zone (20), for dispensing the reactant gas;

wherein a first cooling side (102b) and second cooling side (104b) is defined with;

a plurality of cooling channels (102c,104c) is fluidly connected to at least one inlet port (10c) and at least one outlet port (40c) of at least one first, second, third and fourth bipolar plate; and;

at least one end plate (202) configured to enclose one or more dual cell assemblies (100) in a stacked configuration, wherein the at least one end plate is fastened by a fastening means at either ends of the one or more dual cell assemblies (100).

18. The fuel cell stack (200) as claimed in claim 13, comprises at least one terminal plate (204) at either ends of the one or more dual cell assemblies (100) enclosed in the stacked configuration.

19. The fuel cell stack (200) as claimed in claim 14, comprises at least one insulation plate (206) disposed between at least one terminal plate (204) and the at least one end plate (202) in the stacked configuration.

Dated this 15th day of February 2024

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ABSTRACT

A DUAL CELL ASSEMBLY OF A FUEL CELL STACK

Present disclosure relates to a dual cell assembly (100) comprising a first cell (100A) having a first and second bipolar plate (BP) (102, 104) having a first and second flow field side. A first membrane electrode assembly (MEA) interposed between the first and the second flow field sides. A second cell (100B), is coupled to the first cell (100A), having a third and fourth BP (106, 108) having a third and fourth flow field side and a second MEA (107) interposed between the third and the fourth flow field sides. Each flow field side includes an inlet port, an outlet port and a flow field zone (20). The flow field zone has a plurality of pathways (22) formed by an array of scales disposed in a spaced apart configuration. The array of scales (30) is an elliptical projection (32) encompassed between a pair of guide vanes (34) converging towards each other.

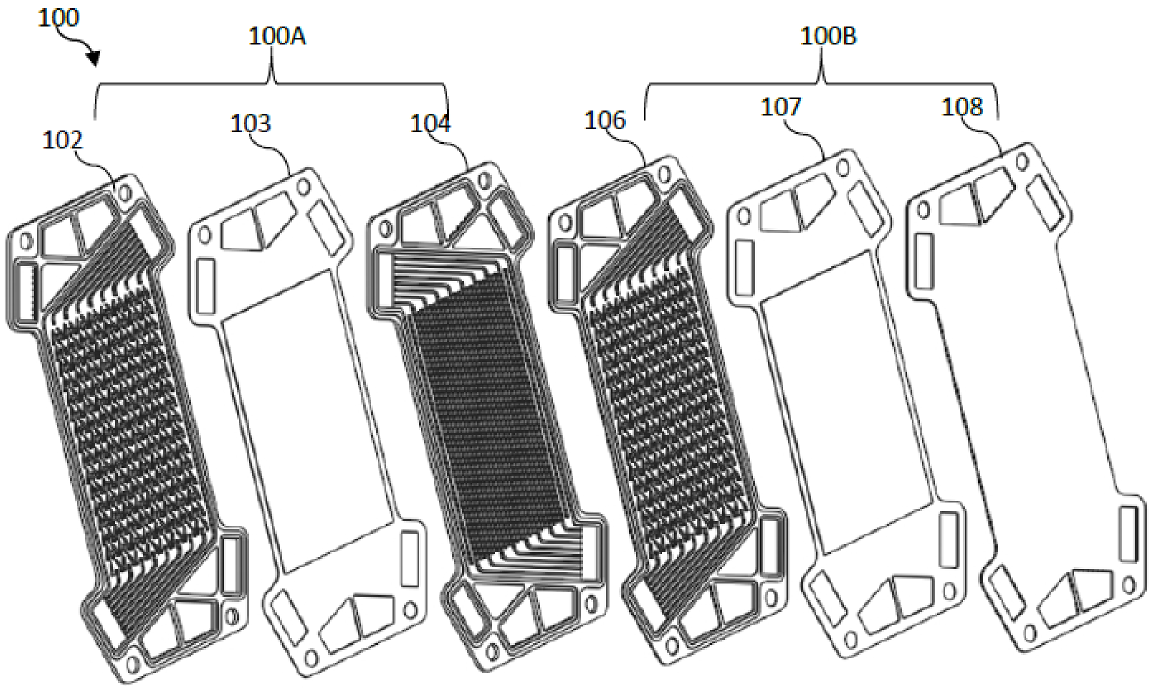

Fig.2

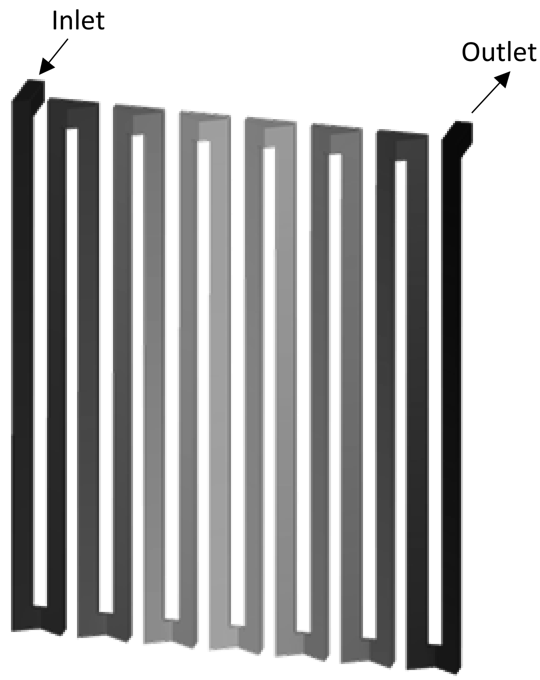

Fig. 1. Prior Art

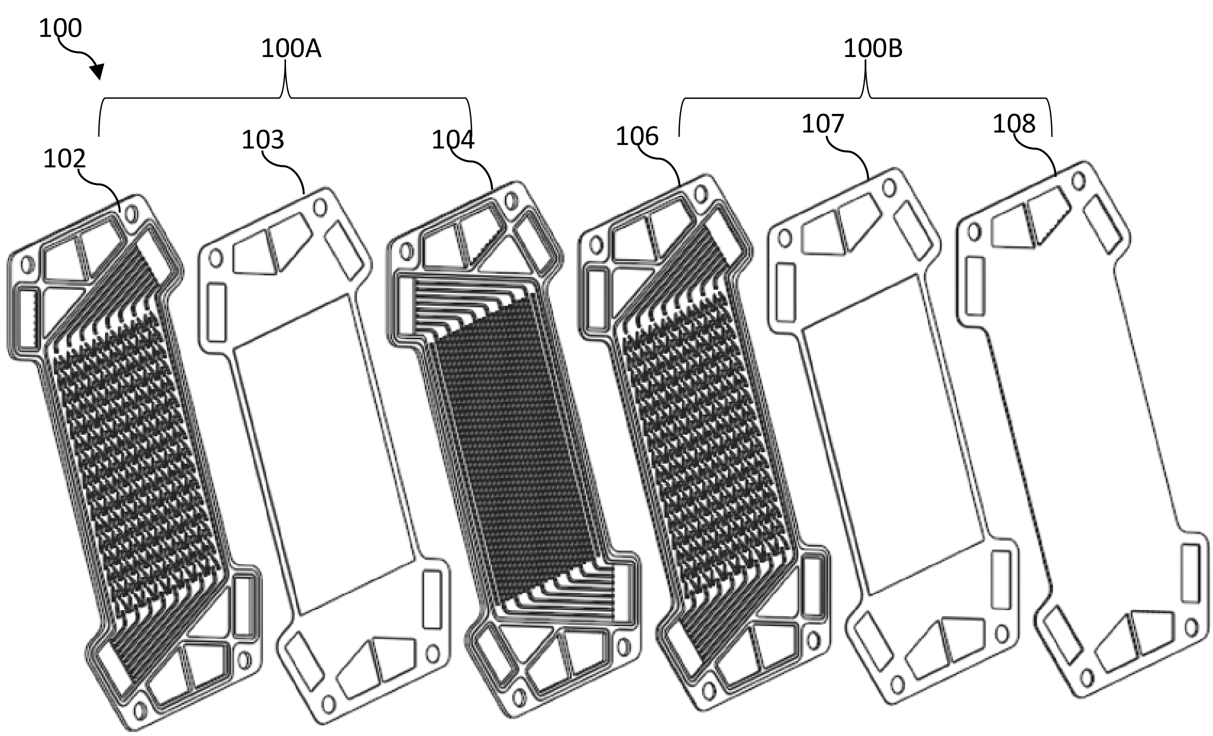

Fig.2

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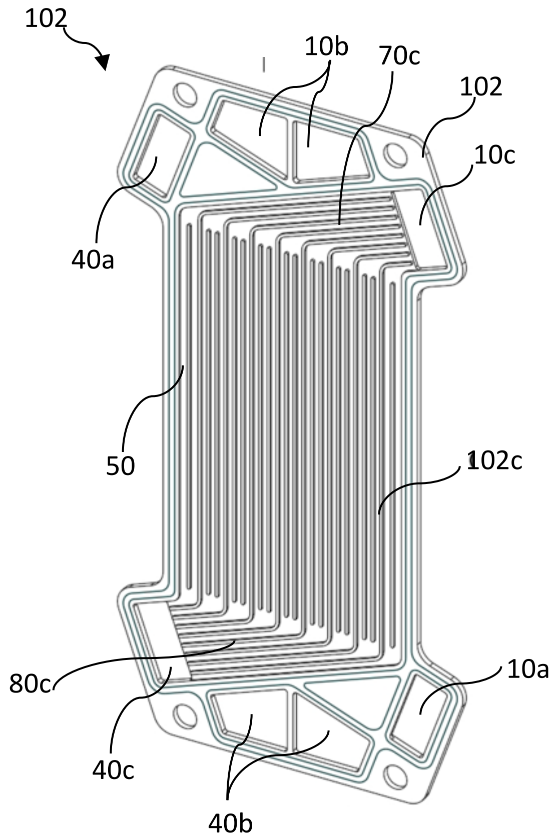

Fig.3

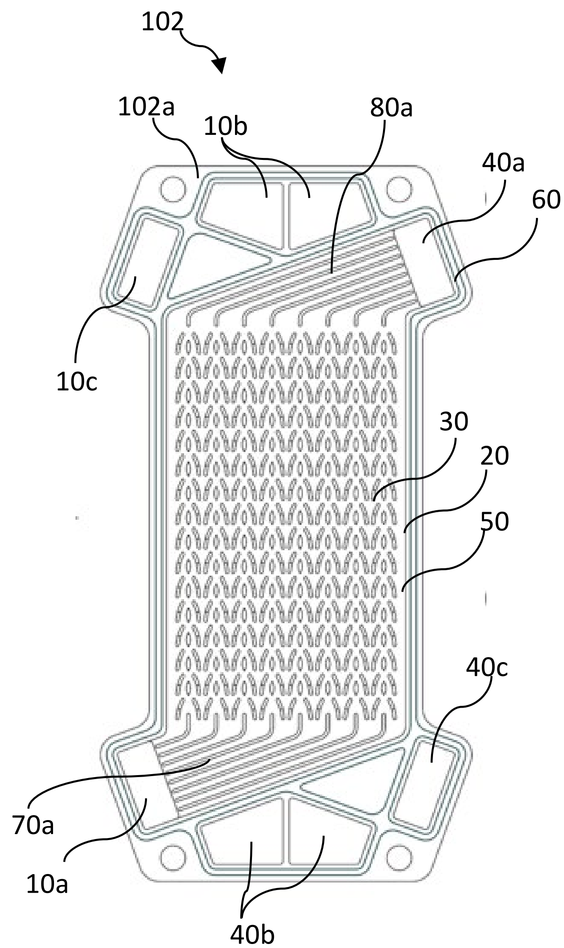

Fig.4

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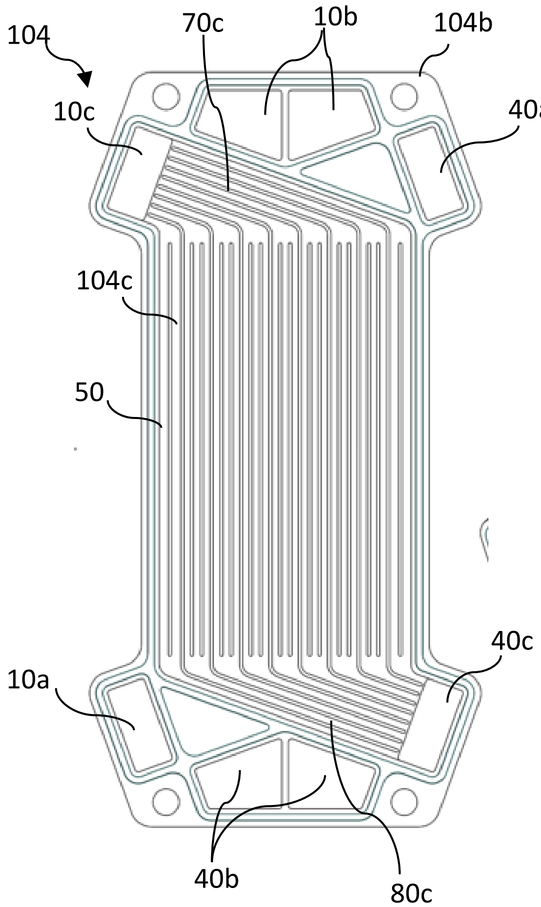

Fig.5

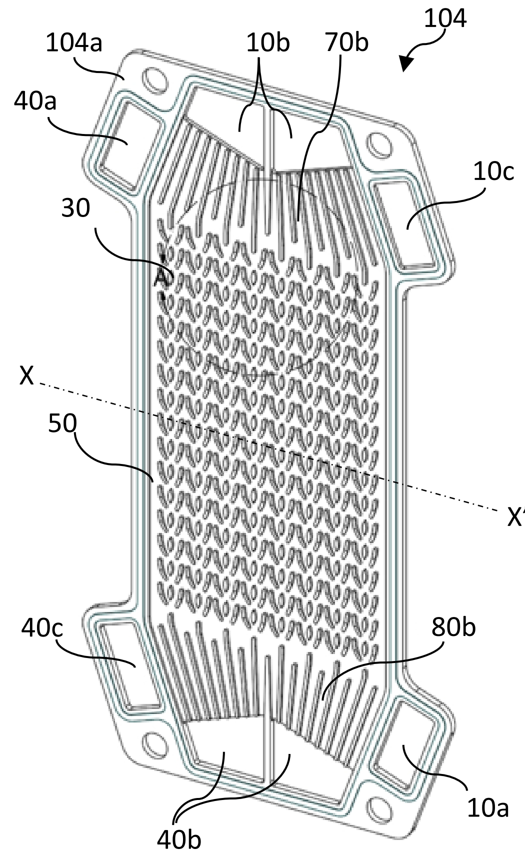

Fig.6

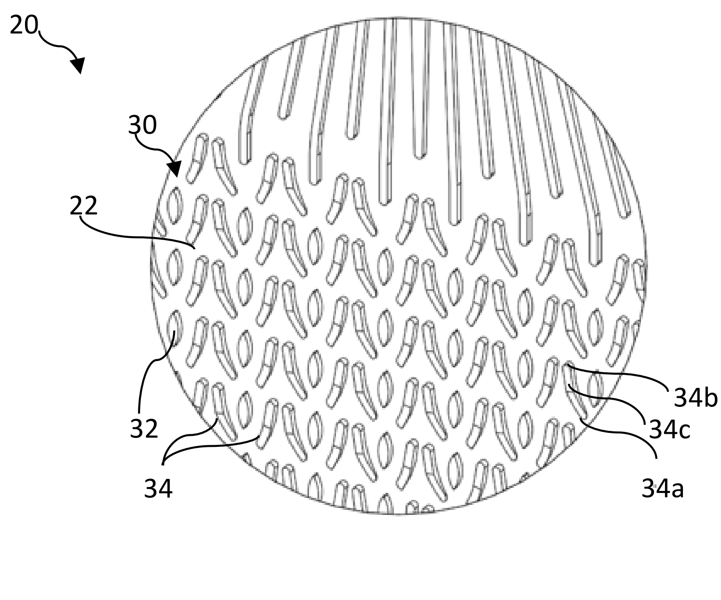

Fig.7

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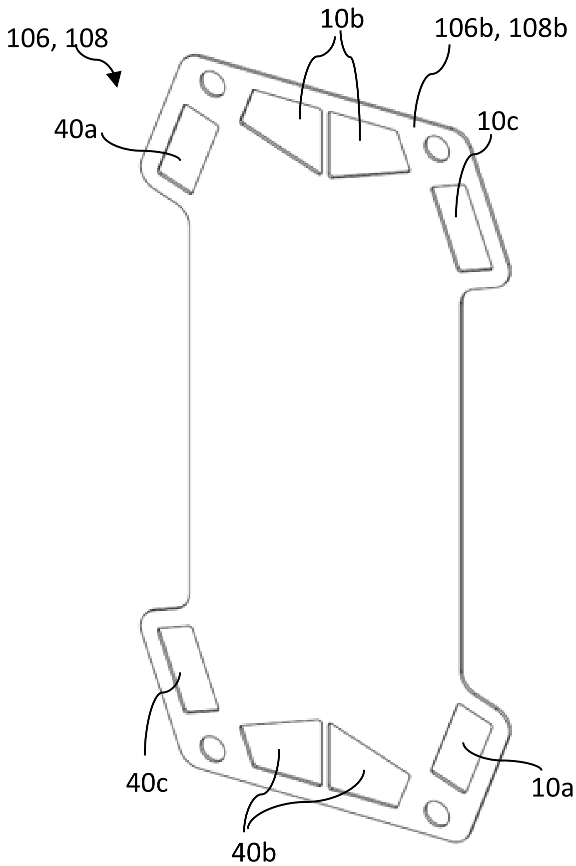

Fig.8

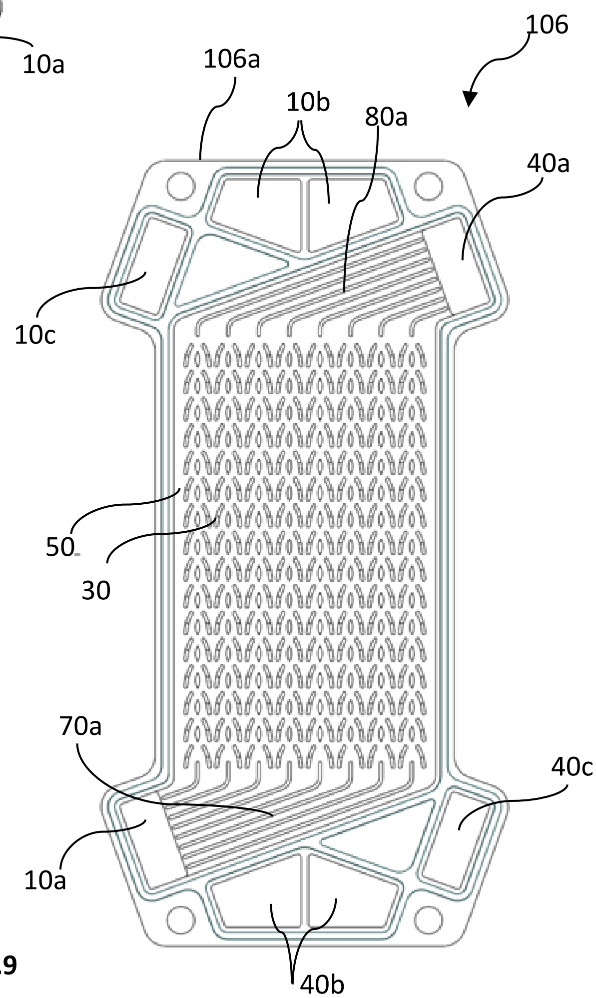

Fig.9

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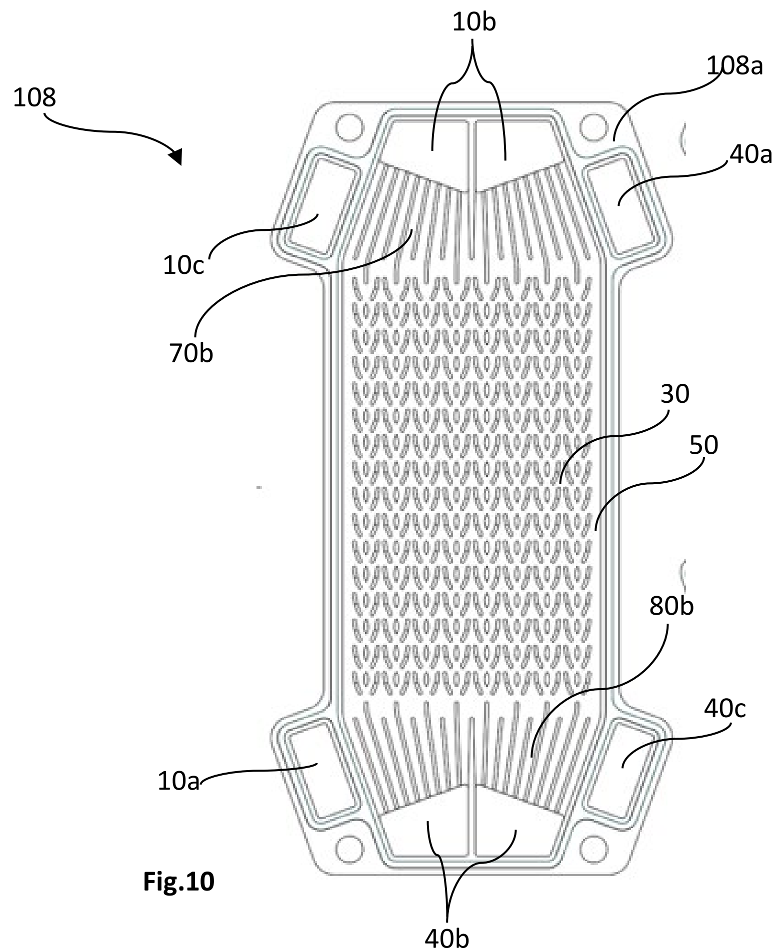

Fig.10

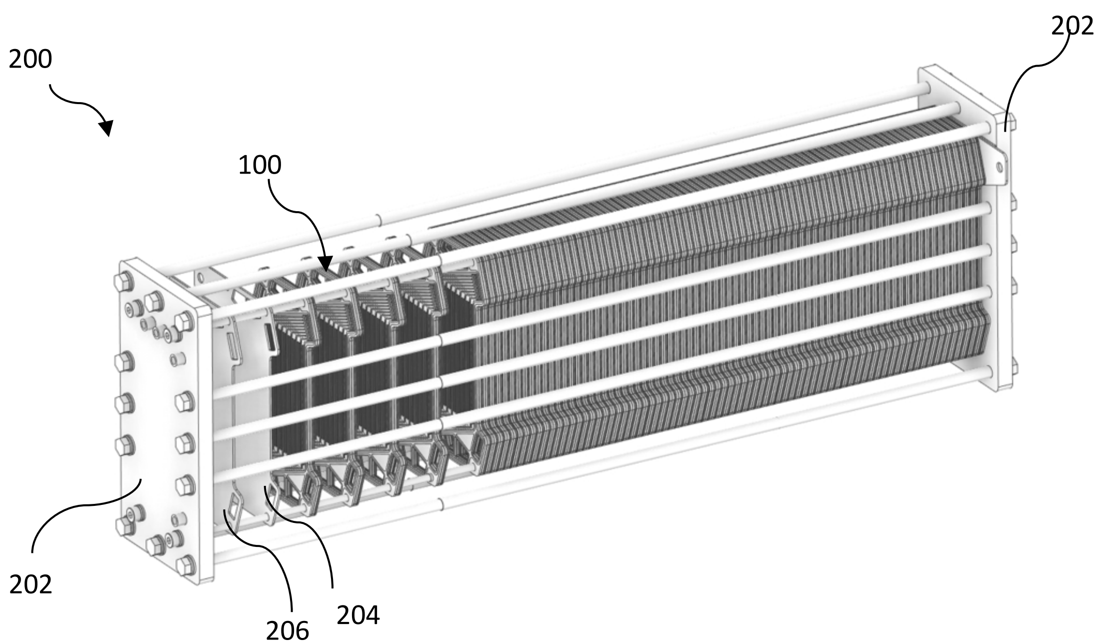

Fig.11

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