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(54) FUEL CELL

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(57) **ABSTRACT**

A fuel flow groove formed in a fuel electrode current collector of a fuel electrode of a fuel cell includes a plurality of flow groove portions disposed in parallel, and a plurality of return groove portions connecting an end portion of one side edge portion or an end portion of the other side edge portion of the flow groove portions of two adjacent groups. Each of the return groove portions has an inner wall surface portion facing the end portion of the flow groove portions in the return groove portions. The inner wall surface portion has a curved surface shape in which a distance facing each other from the inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward both end portions of the inner side wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

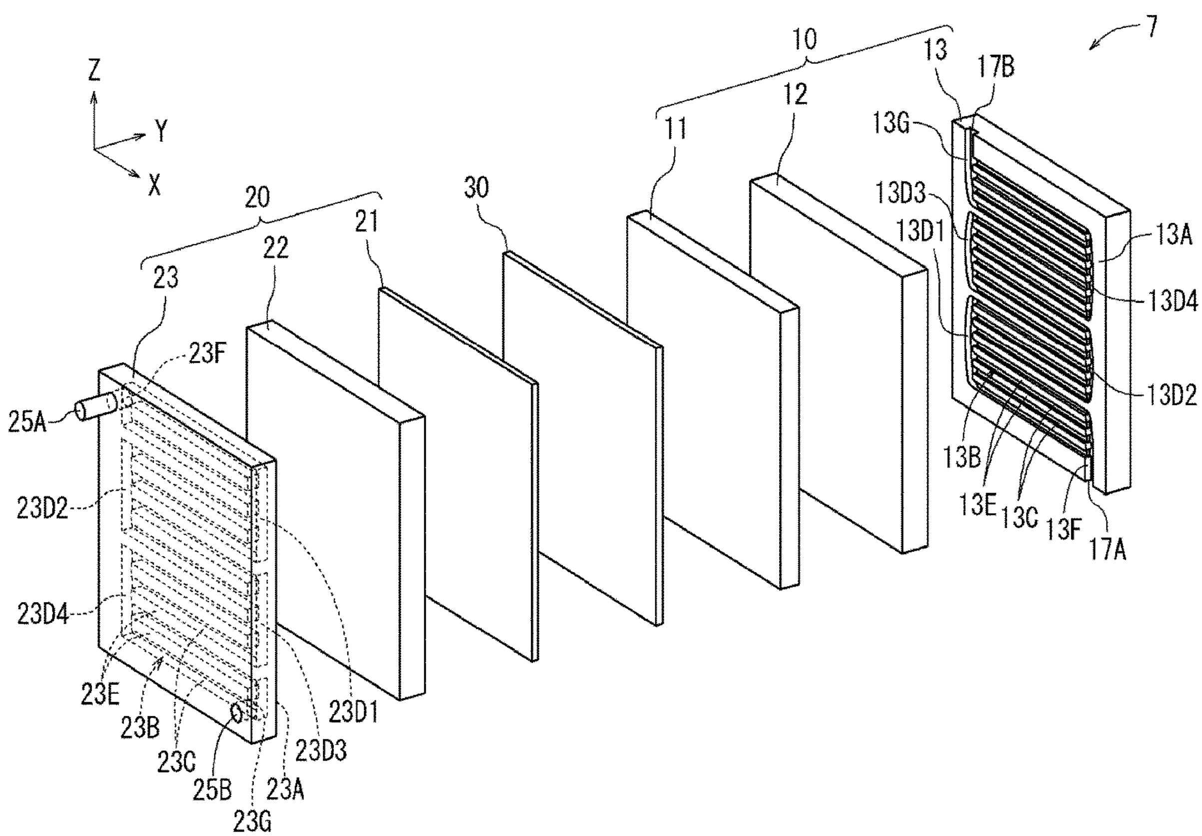
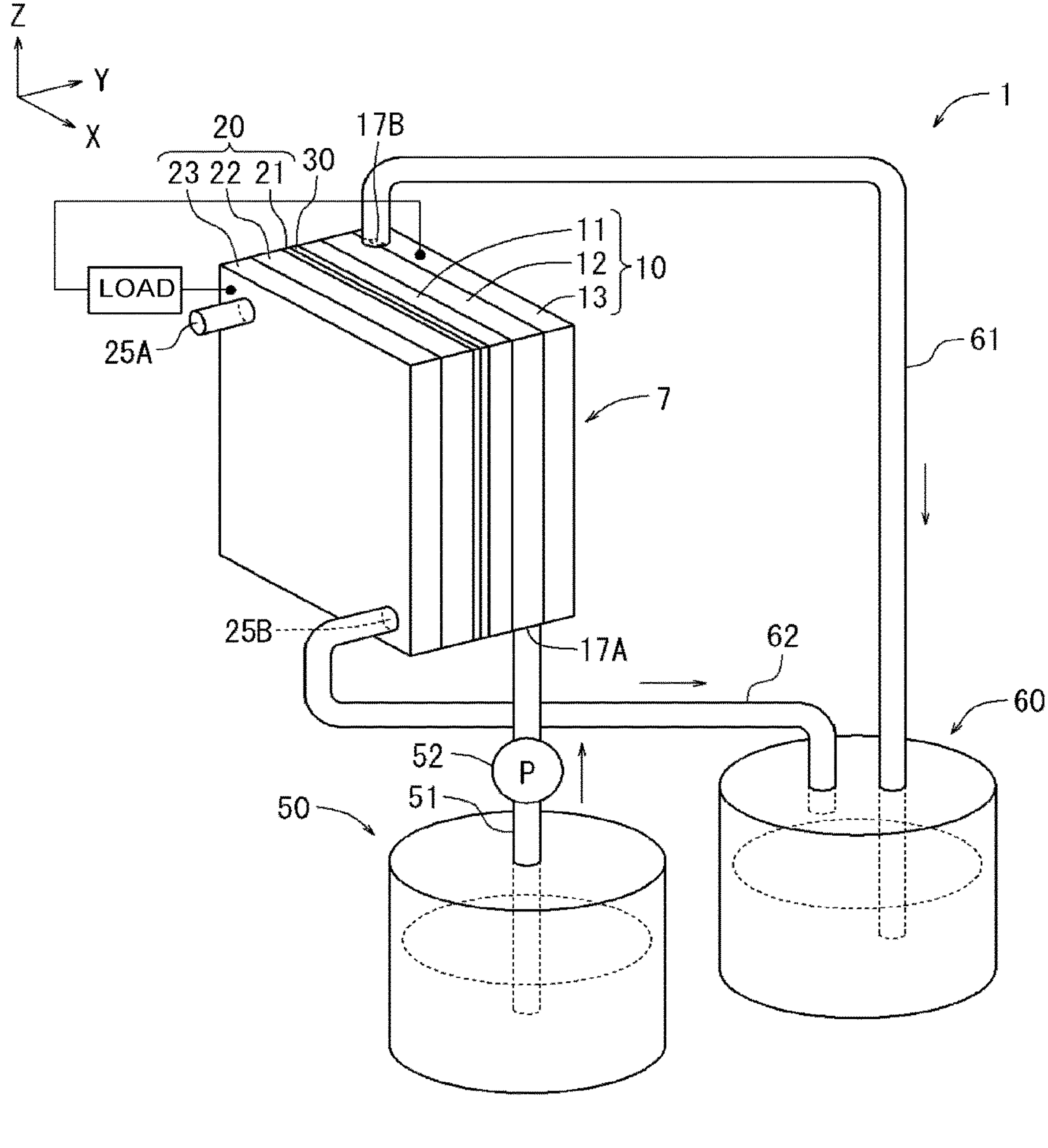


FIG.1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X
20
23 22 21
30
17B
1
11
12
13
10
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61
7
25B
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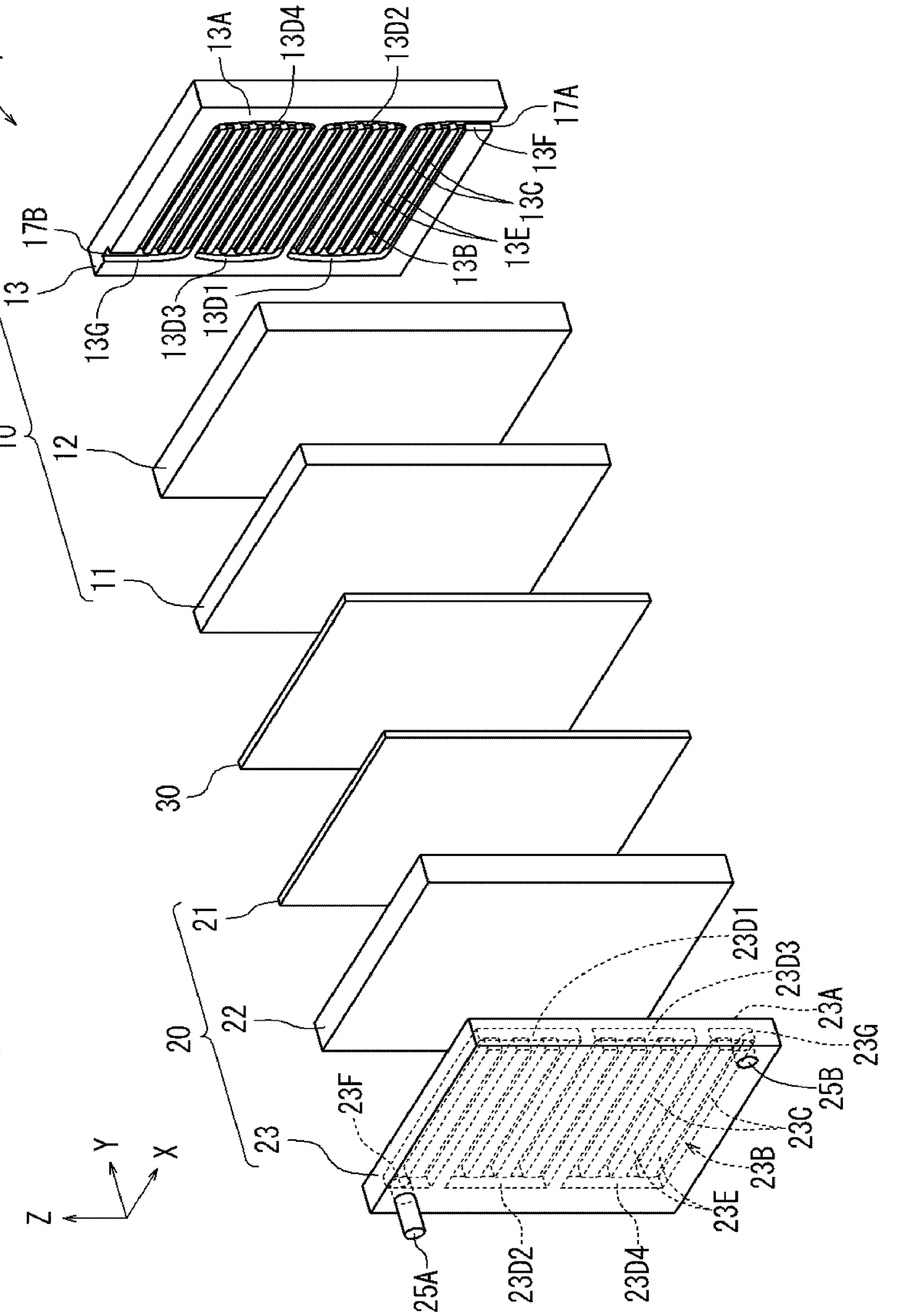
60
52
P
51
50

FIG.2


7
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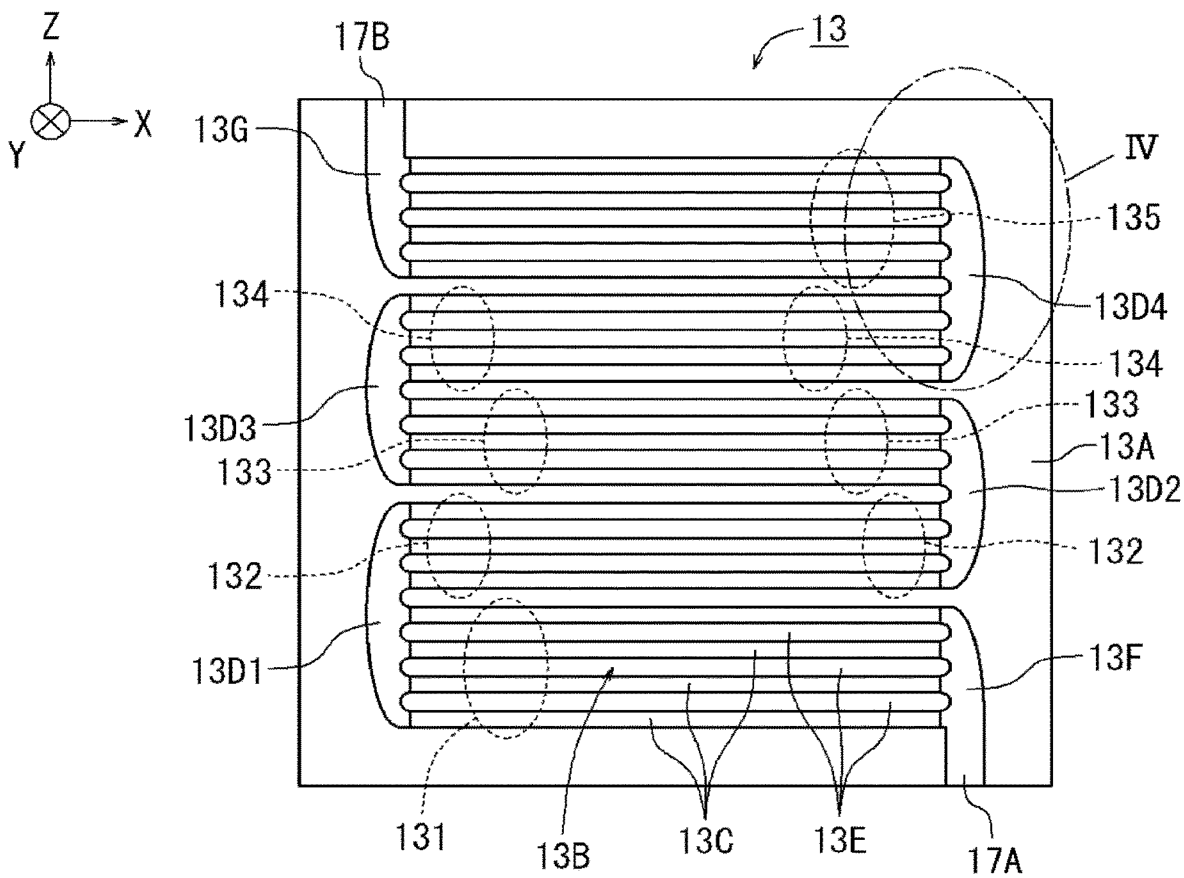
13D4
13D2
17A
13F
13C
13E
13B
17B
13
13G
13D3
13D1
10
12
11
30
21
20
22
23
23F
23D1
23D3
23A
23G
25B
23C
23B
23E
25A
23D2
23D4
Z
Y
X

FIG.3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13
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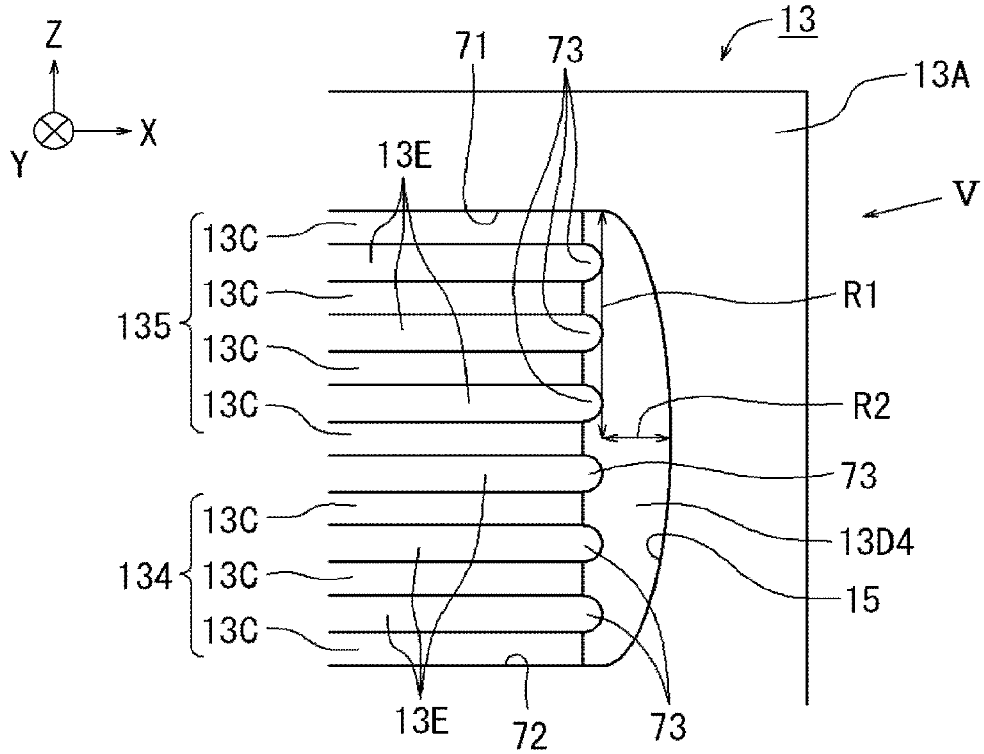
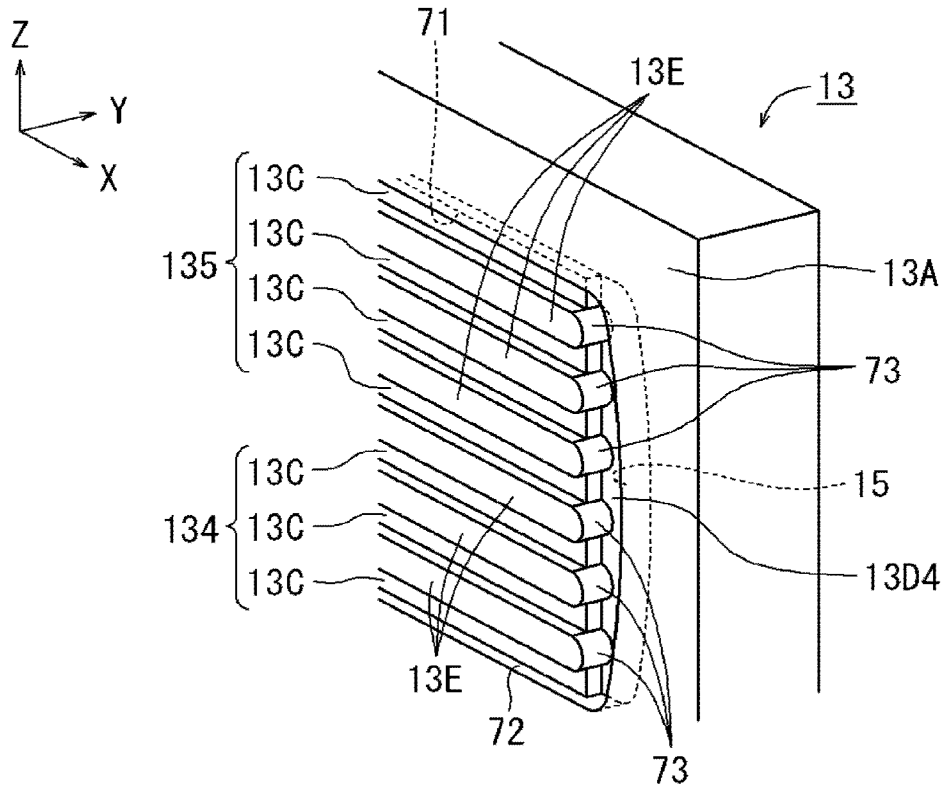
135
134
13D4
134
13D3
133
133
13A
13D2
132
132
13D1
13F
131
13B
13C
13E
17A

FIG.4



Z
Y
X
13
71
73
13A
13E
V
13C
13C
135
13C
R1
13C
R2
73
13C
13D4
134
13C
15
13C
13E
72
73

FIG.5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13C
13C
13C
13C
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13A
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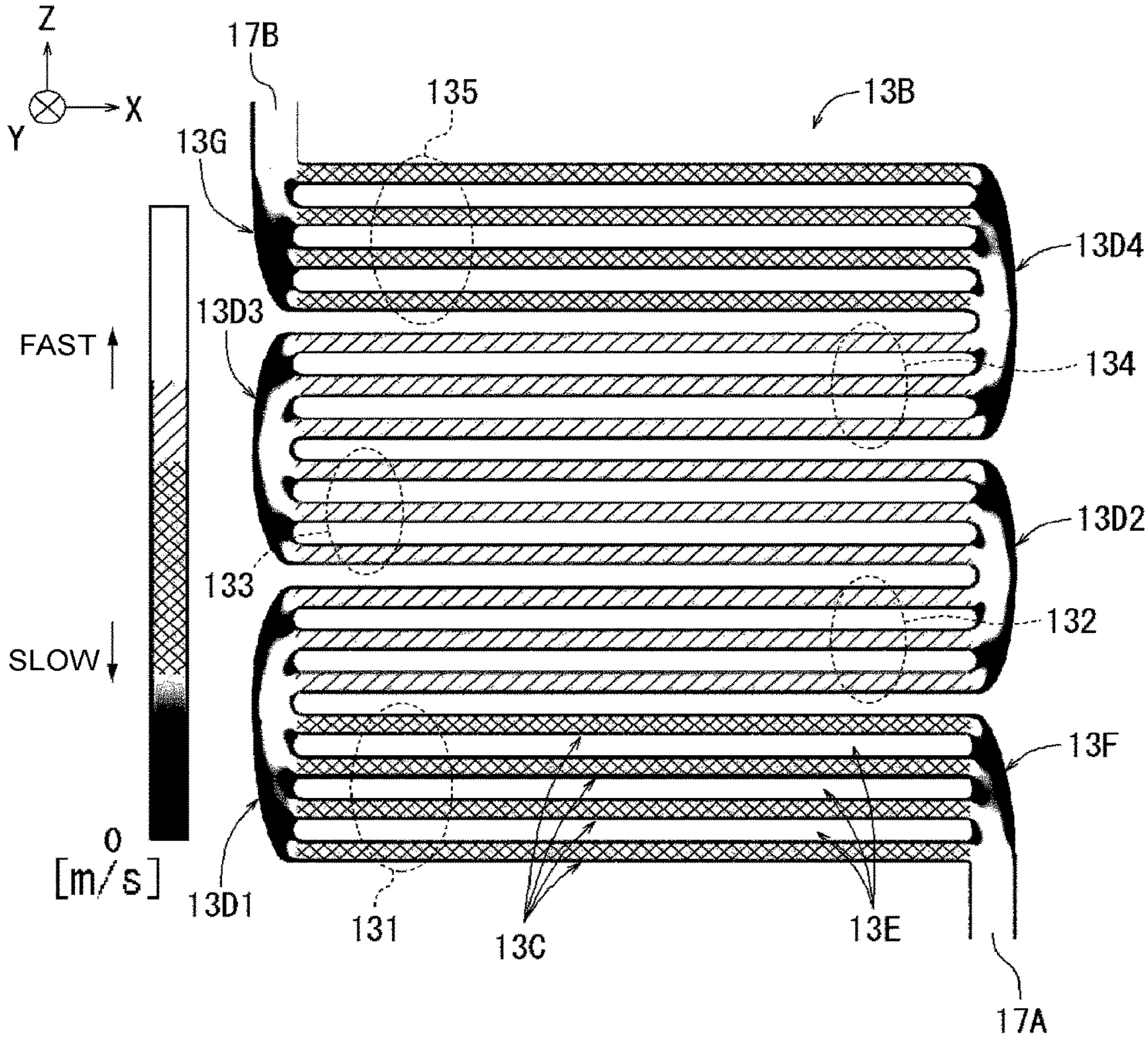
13E
72
73

FIG.6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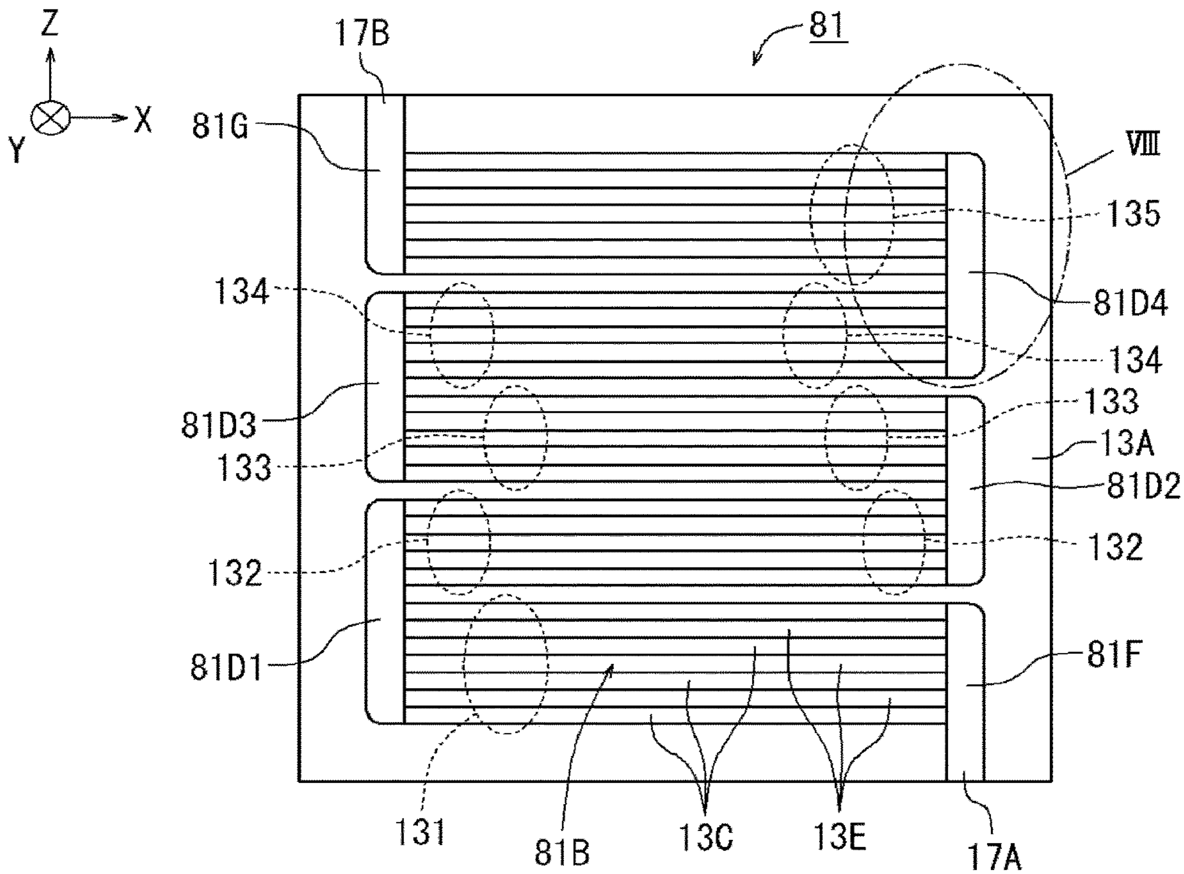
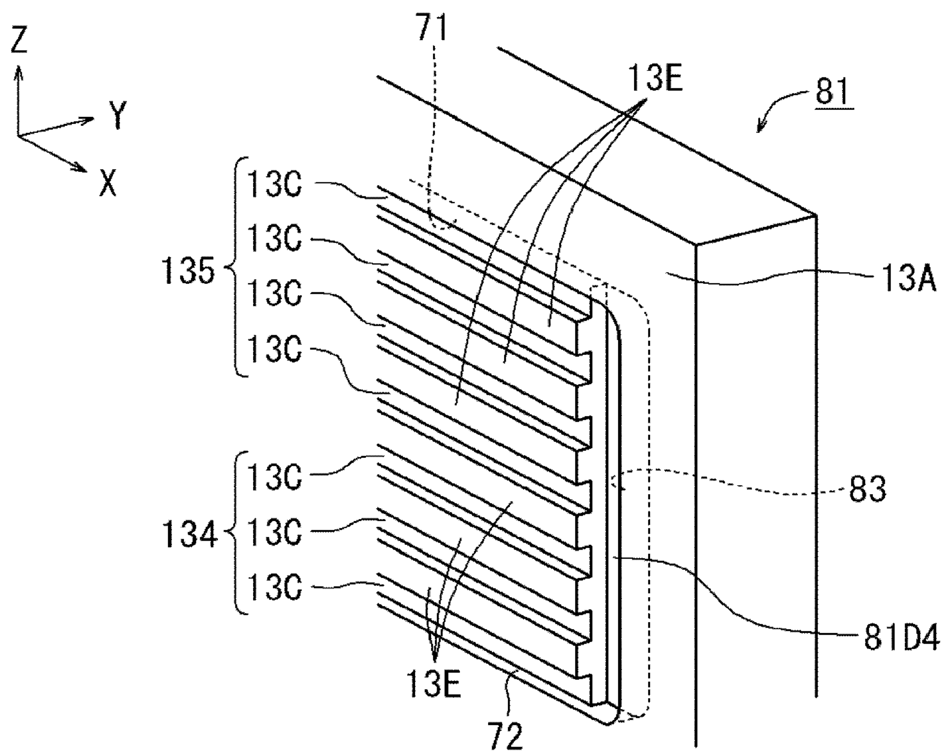
X
Y
17B
135
13B
13G
13D4
13D3
FAST
134
13D2
133
132
SLOW
13F
0
[m/s]
13D1
131
13C
13E
17A

FIG.7



Z
X
Y
17B
81
81G
VIII
135
134
81D4
134
133
81D3
133
13A
81D2
132
132
81D1
81F
131
81B
13C
13E
17A

FIG. 8



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X
71
13E
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13C
13C
135
13C
13C
13A
83
13C
134
13C
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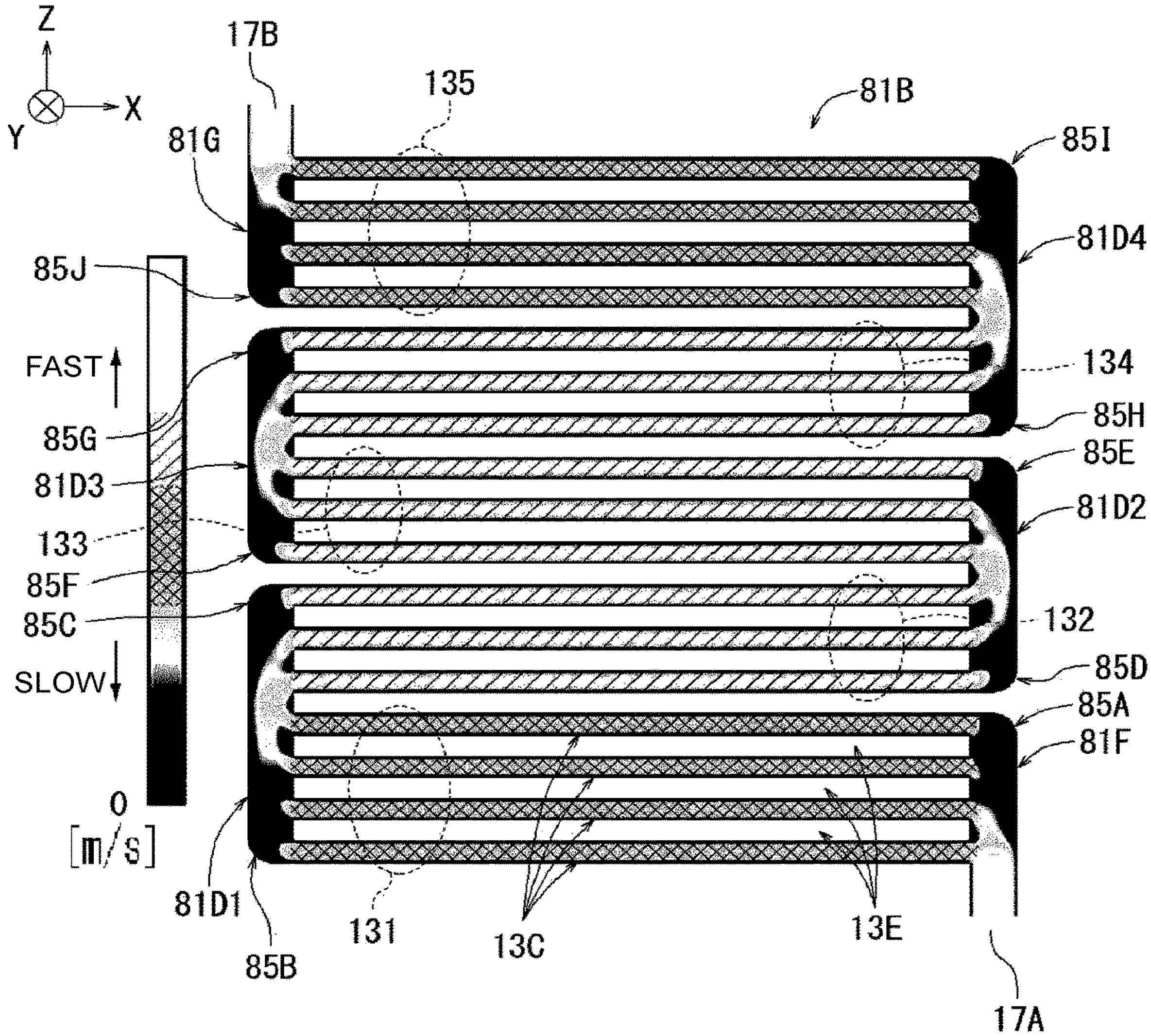
81D4
13E
72

FIG.9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17B
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81G
85I
81D4
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FAST
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85G
85H
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81D2
85F
85C
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85A
81F
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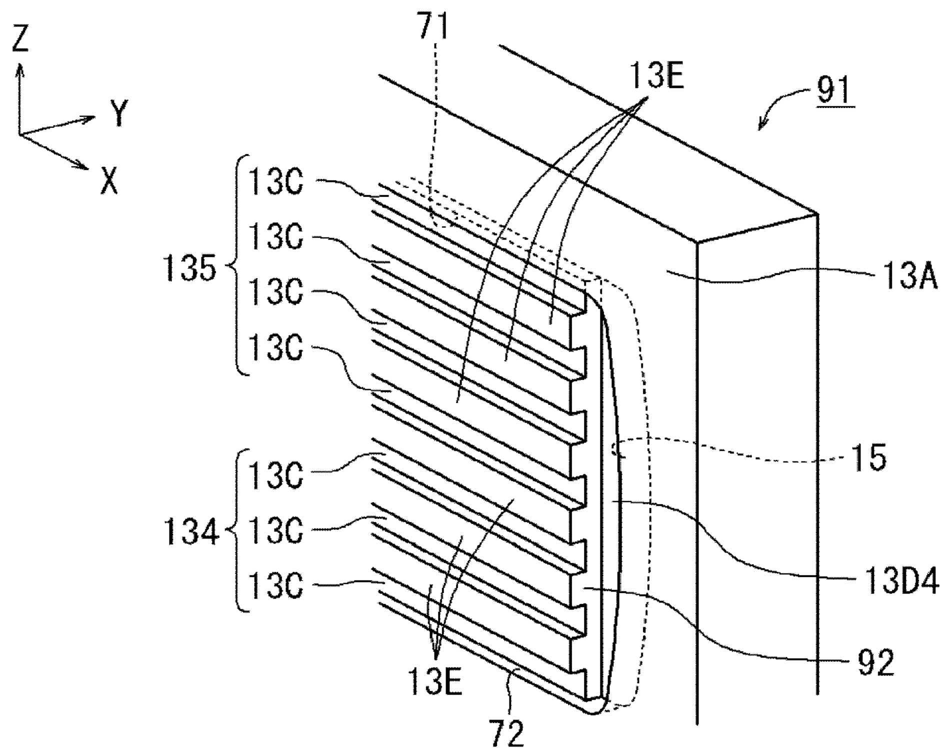
131
13C
13E
85B
17A

FIG.10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13E
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13C
13C
13C
135
13A
15
13C
134
13C
13C
13D4
92
13E
72

FUEL CELL

TECHNICAL FIELD

[0001] The present disclosure relates to a fuel cell.

BACKGROUND ART

[0002] In recent years, various techniques relating to a fuel cell using a liquid fuel such as formic acid and methanol have been proposed as fuel cells. For example, a fuel cell disclosed in JP2007-095692A is provided with a plurality of electricity generation units disposed at regular intervals in a longitudinal direction so as to face each other on both sides of a separator having insulation properties. Each of the electricity generation units includes an anode portion disposed in close contact with each of both sides of the separator, a membrane-electrode assembly (MEA) disposed in close contact with the anode portion, and a cathode portion disposed in close contact with the MEA.

[0003] The anode portion is provided with a first flow path. The first flow path is arranged in a linear state at an arbitrary interval along a length direction of a first path member having a vertically long rectangular shape, is formed in a meandering shape by alternately connecting both ends thereof, and penetrates the first path member in a thickness direction. One end portion (lower-side end portion) of the first flow path communicates with an outflow port of a manifold formed in the separator. The other end portion (upper-side end portion) of the first flow path communicates with an inflow port of the manifold. Accordingly, a fuel flows from the inflow port of the manifold, through the first flow path formed in the meandering shape, and back to the manifold via the upper-side outflow port, and is distributed and supplied to a first electrode layer of the MEA.

[0004] However, in the fuel cell disclosed in JP2007-095692A, since both end portions of the first flow path are bent at a substantially right angle, carbon dioxide (CO) generated by oxidizing the fuel and the fuel may stay at a corner portion on an upper side of the flow path connecting the both end portions in an up-down direction, the fuel may be less likely to flow smoothly, and the power generation amount may be reduced.

SUMMARY OF INVENTION

[0005] The present disclosure provides a fuel cell capable of preventing a fuel and carbon dioxide from stagnating in a fuel flow groove formed in a fuel electrode and suppressing a decrease in power generation amount.

[0006] According to a first aspect of the present disclosure, a fuel cell being a direct liquid fuel cell in which a liquid containing a formic acid or an alcohol is used as a fuel includes: a fuel electrode that includes a fuel electrode catalyst layer, a fuel electrode diffusion layer, and a fuel electrode current collector; an air electrode that includes an air electrode catalyst layer, an air electrode diffusion layer, and an air electrode current collector, and an electrolyte membrane that is disposed between the fuel electrode catalyst layer and the air electrode catalyst layer. The fuel electrode current collector has: a fuel inflow port to which the fuel is supplied; a fuel outflow port from which the fuel is discharged; and a fuel flow groove that is formed on a fuel flow surface on a side abutting the fuel electrode diffusion layer and guides the fuel from the fuel inflow port to the fuel outflow port. The fuel flow groove has: a plurality of flow groove portions that extend from one side edge portion of the fuel flow surface to the other side edge portion opposite to the one side edge portion and that are disposed in parallel at predetermined intervals; and a plurality of return groove portions that, in a manner of containing a plurality of groups adjacent to each other with directions of the fuel flowing in the plurality of flow groove portions being opposite, connect an end portion of the one side edge portion or an end portion of the other side edge portion of two adjacent groups among the plurality of groups in the plurality of flow groove portions. Each of the plurality of return groove portions has a first inner wall surface portion facing the end portion of the flow groove portions in the plurality of return groove portions. The first inner wall surface portion has a curved surface shape in which a distance facing with each other from the first inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward both end portions of the first inner wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

[0007] According to a second aspect of the present disclosure, the fuel flow groove has an inflow groove portion that is connected to the fuel inflow port and to which an end portion on a side opposite to the return groove portion of one group among the plurality of groups in the plurality of flow groove portions is connected, the one group of the plurality of flow groove portions being configured such that the fuel first flows therein. The inflow groove portion has a second inner wall surface portion facing the end portion of the flow groove portions in the inflow groove portion. The second inner wall surface portion has a curved surface shape in which a distance facing with each other from the second inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward an outflow side end portion of the second inner wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

[0008] According to a third aspect of the present disclosure, the fuel flow groove has an outflow groove portion that is connected to the fuel outflow port and to which an end portion on a side opposite to the return groove portion of one group among the plurality of groups in the plurality of flow groove portions is connected, the one group of the plurality of flow groove portions being configured such that the fuel lastly flows therein. The outflow groove portion has a third inner wall surface portion facing the end portion of the flow groove portions in the outflow groove portion. The third inner wall surface portion has a curved surface shape in which a distance facing with each other from the third inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward an inflow side end portion of the third inner wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

[0009] According to a fourth aspect of the present disclosure, the fuel flow groove has a plurality of rib portions that are disposed between the plurality of flow groove portions. The plurality of rib portions have a plurality of protruding portions protruding in a circular arc shape in a plan view outward from the flow groove portions, at the end portion of the flow groove portions facing each of the first inner wall surface portion, the second inner wall surface portion, and the third inner wall surface portion.

[0010] According to a fifth aspect of the present disclosure, the plurality of protruding portions protruding into the return groove portion are formed such that a protruding height of the protruding portion gradually decreases from both end portions of the return groove portion in a direction orthogonal to the extending direction of the flow groove portions toward a boundary, at which a direction of the fuel flowing in the two groups is reversed, between two groups of the flow groove portions among the plurality of groups.

[0011] According to the first aspect, in the fuel electrode current collector, the fuel flow groove that guides the fuel containing formic acid or alcohol from the fuel inflow port to the fuel outflow port is formed on the fuel flow surface on the side abutting the fuel electrode diffusion layer. The fuel flow groove includes a plurality of flow groove portions that extend from one side-edge side of the fuel flow surface to the other side-edge side opposite to the one side edge and that are disposed in parallel at predetermined intervals, and a plurality of return groove portions that, in a manner of forming a plurality of groups adjacent to each other with directions of the fuel flowing in two adjacent groups of the plurality of flow groove portions being opposite to each other, connect the end portions of the one side edge portion or the end portions of the other side edge portion of two adjacent groups of the plurality of flow groove portions. The inner wall surface portion facing the end portion of the flow groove portion of each of the plurality of return groove portions is formed in a curved surface shape in which the distance from the inner wall surface portion to the end portion of the flow groove portion, which face each other, gradually decreases toward both end portions in the direction orthogonal to the extending direction of the flow groove portion.

[0012] Accordingly, in the plurality of return groove portions formed on the fuel flow surface of the fuel electrode, the distance from the inner wall surface portion to the end portion of the flow groove portion decreases toward both end portions in the direction orthogonal to the extending direction of the flow groove portion, and thus the fuel and carbon dioxide stagnating at both end portions in the direction orthogonal to the extending direction of the flow groove portion can be reduced. Further, since the fuel flowing out of the flow groove portion into the return groove portion flows along the inner wall surface portion of the return groove portion and smoothly flows into the plurality of flow groove portions on the downstream side in flowing, the reaction of the fuel by the fuel electrode catalyst layer increases, and a decrease in the power generation amount can be suppressed.

[0013] According to the second aspect, the fuel flow groove has the inflow groove portion that is connected to the fuel inflow port and to which an end portion on the side opposite to the return groove portion of the group of the plurality of flow groove portions is connected, the fuel first flowing into the group of the plurality of flow groove portions. The inner wall surface portion facing the end portion of the flow groove portion of the inflow groove portion is formed in a curved surface shape in which the distance from the inner wall surface portion to the end portion of the flow groove portion, which face each other, gradually decreases toward the outflow side end portion in the direction orthogonal to the extending direction of the flow groove portion. Accordingly, in the inflow groove portion, the fuel or carbon dioxide stagnating at the outflow side end portion in the direction orthogonal to the extending direction of the flow groove portion can be reduced, and the fuel flowing in from the fuel inflow port can be smoothly guided to the plurality of flow groove portions. As a result, the reaction of the fuel by the fuel electrode catalyst layer increases, and a decrease in the power generation amount can be suppressed.

[0014] According to the third aspect, the fuel flow groove has the outflow groove portion that is connected to the fuel outflow port and to which an end portion on the side opposite to the return groove portion of the group of the plurality of flow groove portions is connected, the fuel lastly flowing into the group of the plurality of flow groove portions. The inner wall surface portion facing the end portion of the flow groove portion of the inflow groove portion is formed in a curved surface shape in which the distance from the inner wall surface portion to the end portion of the flow groove portion, which face each other, gradually decreases toward the inflow side end portion in the direction orthogonal to the extending direction of the flow groove portion. Accordingly, the fuel or carbon dioxide stagnating at the inflow side end portion in the direction orthogonal to the extending direction of the flow groove portion of the outflow groove portion can be reduced, and the fuel flowing from the plurality of flow groove portions can be smoothly guided to the fuel outflow port. As a result, the reaction of the fuel by the fuel electrode catalyst layer increases, and a decrease in the power generation amount can be suppressed.

[0015] According to the fourth aspect, the plurality of rib portions disposed between the flow groove portions have, at the end portion facing the inner wall surface portion, a protruding portion that protrudes in a circular arc shape in a plan view toward an outer side with respect to the adjacent flow groove portions. Accordingly, the fuel flowing out of the flow groove portion can be smoothly guided along the outer peripheral surface of the protruding portion to the downstream side in the direction orthogonal to the extending direction of the flow groove portion, and then smoothly guided again into the flow groove portion disposed on the downstream side, and the fuel and carbon dioxide stagnating at the end portions in the direction orthogonal to the extending direction of the flow groove portion of the return groove portion, the inflow groove portion, or the outflow groove portion can be further reduced.

[0016] According to the fifth aspect, the plurality of protruding portions protruding into the return groove portion are formed such that the protruding height gradually decreases from both end portions in the direction orthogonal to the extending direction of the flow groove portion of the return groove portion, toward a portion between two groups of the plurality of flow groove portions, flow directions of the fuel in the two groups being reversed. Accordingly, the fuel flowing into the return groove portion from the flow groove portion can be guided so as to smoothly flow in a substantially central portion in the direction orthogonal to the extending direction of the flow groove portion, and the fuel and carbon dioxide stagnating at both end portions in the direction orthogonal to the extending direction of the flow groove portion of the return groove portion can be further reduced.

BRIEF DESCRIPTION OF DRAWINGS

[0017] FIG. **1** is a perspective view illustrating an overall configuration of a fuel cell system according to an embodiment.

[0018] FIG. **2** is an exploded perspective view illustrating a configuration of a fuel cell according to the present embodiment.

[0019] FIG. **3** is a front view of the fuel electrode current collector as viewed from a fuel flow surface.

[0020] FIG. **4** is an enlarged view of a portion IV in FIG. **3**.

[0021] FIG. **5** is an enlarged perspective view as viewed along an arrow V of FIG. **4**.

[0022] FIG. **6** is a diagram illustrating an example of flow speed distribution of a fuel flowing through the fuel electrode current collector illustrated in FIG. **3**.

[0023] FIG. **7** is a front view of a fuel electrode current collector according to a comparative example as viewed from a fuel flow surface.

[0024] FIG. **8** is an enlarged perspective view of a portion VIII in FIG. **7**.

[0025] FIG. **9** is a diagram illustrating an example of flow speed distribution of a fuel flowing through the fuel electrode current collector illustrated in FIG. **7**.

[0026] FIG. **10** is an enlarged perspective view of a fuel electrode current collector according to another first embodiment.

DESCRIPTION OF EMBODIMENTS

[0027] Hereinafter, a fuel cell according to an embodiment of the present disclosure will be described in detail with reference to the accompanying drawings. First, a schematic configuration of a fuel cell system **1** including a fuel cell **7** according to the present embodiment will be described with reference to FIG. **1**. The fuel cell **7** of the fuel cell system **1** to be described in the present embodiment is a direct liquid fuel cell using an aqueous solution of formic acid or alcohol such as methanol as fuel, and a direct formic acid fuel cell using formic acid as fuel will be described as an example thereof in the following description.

[0028] Here, the direct liquid fuel cell refers to a fuel cell in which a liquid fuel is directly supplied to a fuel electrode without being reformed. Further, a direct formic acid fuel cell is a fuel cell, in which formic acid is used as fuel and is directly supplied to a fuel electrode **10** (see FIG. **1**) constituting the fuel cell **7** without being reformed. Note that in the drawings, an X axis, a Y axis, and a Z axis are orthogonal to one another. A Z-axis direction corresponds to an up-down direction (vertical direction), a Y-axis direction corresponds to a thickness direction, and an X-axis direction corresponds to a horizontal width direction.

[0029] [Schematic Configuration of Fuel Cell System]

[0030] As illustrated in FIG. **1**, the fuel cell system **1** includes a fuel tank **50**, a pump **52**, the fuel cell **7**, a waste-liquid tank **60**, and the like. A solution containing formic acid of a predetermined concentration (aqueous solution of formic acid) is stored in the fuel tank **50**. The concentration of the formic acid in the aqueous solution is, for example, about 10% to about 40%. One end of a fuel supply pipe **51** is connected to the fuel tank **50**. The other end of the fuel supply pipe **51** is connected to a fuel inflow port **17**A that opens at a lower end portion of the fuel cell **7**. The pump **52** is an electric pump, is disposed in the middle of the fuel supply pipe **51**, and supplies (pumps) the fuel in the fuel tank **50** to the fuel inflow port **17**A of the fuel cell **7**.

[0031] The fuel, which is discharged after being used in the fuel cell **7**, and water, which is generated and is recovered at an air electrode **20** constituting the fuel cell **7**, are stored in the waste-liquid tank **60**. The other end of a fuel discharge pipe **61** is connected to the waste-liquid tank **60**. One end of the fuel discharge pipe **61** is connected to a fuel outflow port **17**B that opens at an upper end portion of the fuel cell **7**. The other end of a recovery pipe **62** is connected to the waste-liquid tank **60**. One end of the recovery pipe **62** is connected to an air outflow port **25**B provided on a lower side of the air electrode **20**.

[0032] Further, an exhaust port (not shown) that communicates an inside and an outside is provided in an upper portion of the waste-liquid tank **60**. When pressure of a gas in the waste-liquid tank **604**) becomes higher than predetermined pressure, the gas in the waste-liquid tank **60** is discharged to the outside of the waste-liquid tank **60** from the exhaust port (not shown) provided in the upper portion thereof. In addition, the fuel cell **7** generates electric power using the fuel flowing in from the fuel inflow port **17**A and discharged from the fuel outflow port **17**B. A structure of the fuel cell **7** will be described in detail below.

[0033] [Schematic Configuration of Fuel Cell]

[0034] Next, a schematic configuration of the fuel cell **7** will be described with reference to FIGS. **1** and **2**. As illustrated in FIGS. **1** and **2**, the fuel cell **7** is configured integrally with the air electrode **20** and the fuel electrode **10** sandwiching an electrolyte membrane **30** therebetween in the thickness direction. The air electrode **20** is formed by stacking an air electrode catalyst layer **21**, an air electrode diffusion layer **22**, and an air electrode current collector **23**, which are in close contact with one surface of the electrolyte membrane **30**, in this order. The fuel electrode **10** is formed by stacking a fuel electrode catalyst layer **11**, a fuel electrode diffusion layer **12**, and a fuel electrode current collector **13**, which are in close contact with the other surface of the electrolyte membrane **30**, in this order.

[0035] The air electrode current collector **23** is formed of, for example, a flat plate-shaped metal having a thickness of about 1 [mm] to 10 [mm] and having conductivity. As illustrated in FIG. **1**, one end of an electric load (for example, an electric motor) is electrically connected to the air electrode current collector **23**. As illustrated in FIG. **2**, the air electrode current collector **23** has an air flow surface **23**A abutting the air electrode diffusion layer **22**, and an air flow groove **23**B opened on the air electrode diffusion layer **22** side is formed on the air flow surface **23**A.

[0036] The air flow groove **23**B guides air, which is supplied (pumped) from the air inflow port **25**A formed on an upper side of a diagonal line with respect to the air outflow port **25**B of the air electrode current collector **23**, to the air outflow port **25**B formed on a lower side of the air electrode current collector **23** while bringing the air into contact with the air electrode diffusion layer **22**. Accordingly, the air flowing in the air flow groove **23**B is diffused into the air electrode diffusion layer **22**. Note that dried oxygen may be supplied (pumped) from the outside to the air inflow port **25**A.

[0037] The air flow groove **23**B is provided with a plurality of flow groove portions **23**C that extend in a width direction from one side-edge side (for example, a left side-edge side in FIG. **2**) of the air flow surface **23**A to the other side-edge side (for example, a right side-edge side in FIG. **2**) opposite to the one side-edge, that are arranged in parallel with one another at predetermined intervals, and in which air flows. Further, land portions (rib portions) **23**E abutting the air electrode diffusion layer **22** are formed between the flow groove portions **23**C in the up-down direction so as to have a width in the up-down direction substantially the same as a width of the flow groove portion **23**C in the up-down direction, for example. The land portion (rib portion) **23**E electrically connects the air electrode current collector **23** and the air electrode diffusion layer **22**.

[0038] The air inflow port **25**A is connected to an inflow groove portion **23**F that extends in the vertical direction at an upper left corner in FIG. **2**. The air outflow port **25**B is connected to an outflow groove portion **23**G that extends in the vertical direction at a lower right corner in FIG. **2**. The plurality of flow groove portions **23**C are connected by return groove portions **23**D**1** to **23**D**4** that extend in a substantially vertical direction and that are formed in the vicinity of one side edge of the air electrode current collector **23** or the other side edge thereof. In addition, the plurality of flow groove portions **23**C are connected to the inflow groove portion **23**F at the upper left corner in FIG. **2**, and are connected to the outflow groove portion **23**G at the lower right corner in FIG. **2**.

[0039] Accordingly, air flowing into the inflow groove portion **23**F from the air inflow port **25**A is guided from one side edge to the other side edge in the flow groove portions **23**C, is repeatedly changed in direction by the return groove portions **23**D**1** to **23**D**4** to flow in the air flow groove **23**B, and is diffused into the air electrode diffusion layer **22**. Thereafter, the air flowing into the outflow groove portion **23**G flows from the air outflow port **25**B to the recovery pipe **62** (see FIG. **1**).

[0040] The air electrode diffusion layer **22** is formed in a layer having a thickness of about 0.05 [mm] to about 0.5 [mm]. The air electrode diffusion layer **22** is a porous material having electron conductivity that allows water and air to pass through. For example, carbon paper or carbon cloth may be used as the air electrode diffusion layer **22**. The air electrode diffusion layer **22** guides air (oxygen), which flows from the air inflow port **25**A of the air electrode current collector **23**, to the air electrode catalyst layer **21** while diffusing the air (oxygen). Oxygen contained in the outside air penetrates the air electrode diffusion layer **22** and reaches electrode catalyst particles of the air electrode catalyst layer **21**.

[0041] The air electrode catalyst layer **21** is formed in a layer having a thickness of about 0.05 [mm] to 0.5 [mm]. The air electrode catalyst layer **21** includes electrode catalyst particles (not shown) of the air electrode and an electrode catalyst support (not shown) supporting the electrode catalyst particles. The electrode catalyst particles of the air electrode **20** are particles of a catalyst for promoting a reaction rate in a reaction which reduces oxygen in the air. For example, platinum (Pt) particles may be used as the electrode catalyst particles. It is preferable that the electrode catalyst support can support the electrode catalyst particles and has conductivity. For example, carbon powder may be used as the electrode catalyst support. When formic acid is used as the fuel, the redox reaction represented by the following formula (I) proceeds by the electrode catalyst particles of the air electrode catalyst layer **21**. Note that the generated water (H_2O) flows in the air flow groove **23**B and is guided from the air outflow port **25**B of the air electrode current collector **23** to the waste-liquid tank **60** via the recovery pipe **62** (see FIGS. **1** and **2**).

$$2H^{+}+\frac{1}{2}O_2+2e^{-}\rightarrow H_2O \quad (1)$$

[0042] The fuel electrode current collector **13** is formed of a flat plate-shaped metal having a thickness of about 1.0 [mm] to about 10 [mm]. The fuel electrode current collector **13** has a fuel flow surface **13**A abutting the fuel electrode diffusion layer **12**, and a fuel flow groove **13**B opened on the fuel electrode diffusion layer **12** side is formed on the fuel flow surface **13**A. The fuel flow groove **13**B guides fuel supplied from the fuel inflow port **17**A formed on a lower side of the fuel electrode current collector **13** to the fuel outflow port **17**B formed on an upper side of the fuel electrode current collector **13** while bringing the fuel into contact with the fuel electrode diffusion layer **12**. Accordingly, the fuel flowing in the fuel flow groove **13**B is diffused into the fuel electrode diffusion layer **12**.

[0043] The fuel flow groove **13**B is provided with a plurality of flow groove portions **13**C that extend in a width direction from one side-edge side (for example, a right side-edge side in FIG. **2**) of the fuel flow surface **13**A to the other side-edge side (for example, a left side-edge side in FIG. **2**) opposite to the one side edge, that are arranged in parallel at predetermined intervals, and in which the fuel flows. In addition, rib-shaped land portions (rib portions) **13**E abutting on the fuel electrode diffusion layer **12** in order to recover electrons e^{-} are formed between the flow groove portions **13**C in the up-down direction so as to have a width in the up-down direction substantially the same as a width of the flow groove portion **13**C in the up-down direction, for example. As illustrated in FIG. **1**, the other end of the electric load (for example, the electric motor) is connected to the fuel electrode current collector **13**.

[0044] The fuel electrode diffusion layer **12** is formed in a layer having a thickness of about 0.05 [mm] to 0.5 (mm). The fuel electrode diffusion layer **12** is a porous material having electron conductivity that allows the aqueous solution of formic acid to penetrate into the inside thereof. For example, carbon paper or carbon cloth may be used as the fuel electrode diffusion layer **12**. The fuel electrode diffusion layer **12** guides the fuel flowing in the fuel flow groove **13**B formed on the fuel flow surface **13**A of the fuel electrode current collector **13** to the fuel electrode catalyst layer **11** while diffusing the fuel.

[0045] The fuel electrode catalyst layer **11** is formed in a layer having a thickness of about 0.05 [mm] to 0.5 [mm]. The fuel electrode catalyst layer **11** includes electrode catalyst particles (not shown) and an electrode catalyst support (not shown) supporting the electrode catalyst particles. The electrode catalyst particles of the fuel electrode **10** are particles of a catalyst for promoting an oxidation reaction rate of formic acid, which is the fuel. For example, palladium (Pd) particles may be used as the electrode catalyst particles. It is preferable that the electrode catalyst support can support the electrode catalyst particles and has conductivity. For example, carbon powder may be used as the electrode catalyst support. When formic acid is used as the fuel, the oxidation reaction represented by the following formula (2) proceeds by the electrode catalyst particles of the fuel electrode catalyst layer **11**.

$$HCOOH\rightarrow CO_2+2H^{+}+2e^{-} \quad (2)$$

[0046] The electrolyte membrane **30** is formed in a thin film shape having a thickness of about 0.01 [mm] to about 0.3 [mm]. The electrolyte membrane **30** is sandwiched between the fuel electrode catalyst layer **11** of the fuel electrode **10** and the air electrode catalyst layer **21** of the air electrode **20**, and is a proton exchange membrane having no electron conductivity that allows water and hydrogen ion (proton) H^+ to pass through. As the electrolyte membrane **30**, for example, a perfluoroethylene sulfonic acid-based membrane such as Nafion (registered trademark) manufactured by DuPont may be used. Note that the fuel electrode catalyst layer **11**, the fuel electrode diffusion layer **12**, the electrolyte membrane **30**, the air electrode catalyst layer **21**, and the air electrode diffusion layer **22** may be joined and integrated.

[0047] [Configuration of Fuel Flow Groove]

[0048] Next, a configuration of the fuel flow groove **13**B formed in the fuel electrode current collector **13** will be described with reference to FIGS. **2** to **5**. As illustrated in FIGS. **2** and **3**, the fuel flow groove **13**B is provided with the plurality of flow groove portions **13**C that extend in the horizontal width direction from the one side-edge side (for example, the right side-edge side in FIG. **2**) of the fuel flow surface **13**A to the other side-edge side (for example, the left side-edge side in FIG. **2**), that are arranged in parallel at predetermined intervals, and in which the fuel flows.

[0049] End portions on the one side-edge side (a right side in FIG. **3**) of four flow groove portions **13**C on a lower end side are connected to an inflow groove portion **13**F having an upper half shape of a semi-ellipse in a front view that extends upward from the fuel inflow port **17**A formed in the lower end portion and that protrudes outward in the width direction. In addition, end portions on the other side-edge side (a left side in FIG. **3**) of the four flow groove portions **13**C on the lower end side, and end portions on the other side-edge side (the left side in FIG. **3**) of three flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **13**D**1** having a semi-elliptical shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0050] Accordingly, the fuel flowing into the inflow groove portion **13**F from the fuel inflow port **17**A flows into the four flow groove portions **13**C on the lower end side, flows toward the other side-edge side (the left side in FIG. **3**), and flows to a lower side of the return groove portion **13**D**1**. Then, the fuel flowing into the return groove portion **13**D**1** flows into the three flow groove portions **13**C disposed on an upper side of the return groove portion **13**D**1**, and flows toward the one side-edge side (the right side in FIG. **3**). Accordingly, the four flow groove portions **13**C on the lower end side and the three flow groove portions **13**C on the upper side thereof constitute two groups, that is, flow groove portion groups **131** and **132** adjacent to each other in which flow directions of the fuel are opposite to each other.

[0051] In addition, end portions on the one side-edge side (the right side in FIG. **3**) of the three flow groove portions **13**C constituting the flow groove portion group **132**, and end portions on the one side-edge side (the right side in FIG. **3**) of three flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **13**D**2** having a semi-elliptical shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0052] Accordingly, the fuel flowing to a lower side of the return groove portion **13**D**2** from the three flow groove portions **13**C constituting the flow groove portion group **132** flows into the three flow groove portions **13**C disposed on an upper side of the return groove portion **13**D**2**, and flows toward the other side-edge side (the left side in FIG. **3**). Accordingly, the three flow groove portions **13**C disposed on the upper side of the three flow groove portions **13**C constituting the flow groove portion group **132** are disposed adjacently on the upper side of the flow groove portion group **132**, and constitute one group, that is, a flow groove portion group **133** in which the flow direction of the fuel is reversed.

[0053] In addition, end portions on the other side-edge side (the left side in FIG. **3**) of the three flow groove portions **13**C constituting the flow groove portion group **133**, and end portions on the other side-edge side (the left side in FIG. **3**) of three flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **13**D**3** having a semi-elliptical shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0054] Accordingly, the fuel flowing to a lower side of the return groove portion **13**D**3** from the three flow groove portions **13**C constituting the flow groove portion group **133** flows into the three flow groove portions **13**C disposed on an upper side of the return groove portion **13**D**3**, and flows toward the one side-edge side (the right side in FIG. **3**). Accordingly, the three flow groove portions **13**C disposed on the upper side of the three flow groove portions **13**C constituting the flow groove portion group **133** are disposed adjacently on the upper side of the flow groove portion group **133**, and constitute one group, that is, a flow groove portion group **134** in which the flow direction of the fuel is reversed.

[0055] In addition, end portions on the one side-edge side (the right side in FIG. **3**) of the three flow groove portions **13**C constituting the flow groove portion group **134**, and end portions on the one side-edge side (the right side in FIG. **3**) of four flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **13**D**4** having a semi-elliptical shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0056] Accordingly, the fuel flowing to a lower side of the return groove portion **13**D**4** from the three flow groove portions **13**C constituting the flow groove portion group **134** flows into the four flow groove portions **13**C disposed on an upper side of the return groove portion **131**D**4**, and flows toward the other side-edge side (the left side in FIG. **3**). Accordingly, the four flow groove portions **13**C disposed on the upper side of the three flow groove portions **13**C constituting the flow groove portion group **134** are disposed adjacently on the upper side of the flow groove portion group **134**, and constitute one group, that is, a flow groove portion group **135** in which the flow direction of the fuel is reversed.

[0057] Further, end portions on the other side-edge side (the left side in FIG. **3**) of the four flow groove portions **13**C constituting the flow groove portion group **135** are connected to an outflow groove portion **13**G having a lower half shape of a semi-ellipse in a front view that extends downward from the fuel outflow port **17**B formed in an upper end portion of the fuel electrode current collector **13** and that protrudes outward in the width direction. Accordingly, the fuel flowing into the outflow groove portion **13**G from the four flow groove portions **13**C constituting the flow groove portion group **135** flows from the fuel outflow port **17**B to the fuel discharge pipe **61** (see FIG. **1**).

[0058] Here, a configuration of the return groove portion **13**D4 will be described with reference to FIGS. **4** and **5**. Note that the return groove portion **13**D**2** has substantially the same configuration as the return groove portion **13**D**4**. The inflow groove portion **13**F has substantially the same configuration as an upper half in the up-down direction of the return groove portion **13**D**4**. In addition, each of the return groove portions **13**D**1** and **13**D**3** has a configuration substantially the same as the configuration of the return groove portion **13**D**4** that is linearly symmetrical with respect to a vertical line. The outflow groove portion **13**G has substantially the same configuration as a lower half of the configuration of the return groove portion **13**D4 that is linearly symmetrical with respect to a vertical line.

[0059] As illustrated in FIGS. **4** and **5**, the return groove portion **131**D**4** is formed in a semi-elliptical shape in a front view extending in the up-down direction and protruding outward in the width direction, and is recessed in the thickness direction at a depth of about twice the depth of each of the flow groove portions **13**C. Further, an inner wall surface portion **15**, which faces the end portions on the one side-edge side (a right side in FIG. **4**) of the flow groove portions **13**C, is formed in a curved surface shape in which a distance from the inner wall surface portion **15** to the end portion of the flow groove portion **13**C, which face each other, gradually decreases from a central portion in the up-down direction of the return groove portion **13**D4 toward both end portions in the up-down direction of the return groove portion **13**D**4**. Here, the inner wall surface portion **15** in the return groove portions **13**D**1** to **13**D**4** may be referred to as, for example, a first inner wall surface portion. The inner wall surface portion **15** in the inflow groove portion **13**F may be referred to as, for example, a second inner wall surface portion. The inner wall surface portion **15** in the outflow groove portion **13**G may be referred to as, for example, a third inner wall surface portion.

[0060] Specifically, for example, the inner wall surface portion **15** of the return groove portion **13**D4 is formed in a semi-elliptical shape in a front view in which a length of about ½ of a distance from a side wall portion **71** on an upper side of the flow groove portion **13**C located at an upper end to a side wall portion **72** on a lower side of the flow groove portion **13**C located at a lower end is set as a long radius R**1**, and a length that is about twice the depth of the return groove portion **13**D**4**, that is, about four times the depth of each flow groove portion **13**C is set as a short radius R**2**.

[0061] In each end portion of each land portion (rib portion) **13**E that faces the inner wall surface portion **15**, a protruding portion **73** that protrudes in a circular arc shape in a plan view toward an outer side in the width direction with respect to the adjacent flow groove portions **13**C is formed over an entire height of each land portion **13**E from a bottom surface of the return groove portion **131**D**4**. In addition, a major axis of the inner wall surface portion **15** having a semi-elliptical shape in a plan view is disposed, for example, so as to pass through a distal end portion of each of the protruding portions **73**.

[0062] Accordingly, the fuel flowing through the flow groove portions **13**C of the flow groove portion group **134** is guided by the respective protruding portions **73** and a lower portion of the inner wall surface portion **15**, and smoothly flows to the lower side in the return groove portion **13**D4. Then, the fuel flowing into the return groove portion **13**D4 is guided upward in the return groove portion **13**D4 by the respective protruding portions **73** and an upper portion of the inner wall surface portion **15**, and flows into the flow groove portions **13**C of the flow groove portion group **135**.

[0063] Next, an example of a result of flow speed distribution of the fuel, which is subjected to fluid analysis by computer-aided engineering (CAE) analysis at the time when the fuel of the aqueous solution of formic acid having a concentration of about 10% to 40% is supplied (pumped) to the fuel electrode current collector **13** of the fuel cell **7** configured as described above, will be described with reference to FIG. **6**. As illustrated in FIG. **6**, the fuel flowing into the inflow groove portion **13**F from the fuel inflow port **17**A formed in a lower end portion of the fuel electrode current collector **13** flows into the four flow groove portions **13**C constituting the flow groove portion group **131** without a substantial stagnation.

[0064] Then, the fuel flowing into the return groove portion **13**D**1** from the four flow groove portions **13**C constituting the flow groove portion group **131** flows into the three flow groove portions **13**C constituting the flow groove portion group **132** without substantially stagnating in the return groove portion **13**D**1**. Therefore, a flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **132** is slightly higher than a flow speed of the fuel flowing through the four flow groove portions **13**C constituting the flow groove portion group **131**.

[0065] Subsequently, the fuel flowing into the return groove portion **13**D**2** from the three flow groove portions **13**C constituting the flow groove portion group **132** flows into the three flow groove portions **13**C constituting the flow groove portion group **133** without substantially stagnating in the return groove portion **13**D**2**. Therefore, a flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **133** is substantially the same as the flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **132**.

[0066] Then, the fuel flowing into the return groove portion **13**D**3** from the three flow groove portions **13**C constituting the flow groove portion group **133** flows into the three flow groove portions **13**C constituting the flow groove portion group **134** without substantially stagnating in the return groove portion **13**D**3**. Therefore, a flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **134** is substantially the same as the flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **133**.

[0067] Subsequently, the fuel flowing into the return groove portion **13**D**4** from the three flow groove portions **13**C constituting the flow groove portion group **134** flows into the four flow groove portions **13**C constituting the flow groove portion group **135** without substantially stagnating in the return groove portion **13**D**4**. Therefore, a flow speed of the fuel flowing through the four flow groove portions **13**C constituting the flow groove portion group **135** is slightly lower than the flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **134**.

[0068] Then, the fuel flowing into the outflow groove portion **13**G from the four flow groove portions **13**C constituting the flow groove portion group **135** flows into the fuel outflow port **17**B without substantially stagnating in the outflow groove portion **13**G and is discharged. Therefore, a flow speed of the fuel flowing through the fuel outflow port **17**B is substantially the same as a flow speed of the fuel flowing through the fuel inflow port **17**A.

[0069] As described above, in the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G, the distance from the inner wall surface portion **15** to the end portion of the flow groove portion **13**C decreases toward the respective end portions in the up-down direction. Therefore, it is presumed that the inflow groove portion **13**F, the return groove portions **13**D**1** to **131**D**4**, and the outflow groove portion **130** have substantially no portions where the flow speed of the fuel at the respective end portions in the up-down direction is zero [m/sec] and the fuel stagnates.

[0070] As a result, carbon dioxide (CO_2) generated by the oxidation reaction of formic acid represented by the above formula (2) flows smoothly together with the fuel of the aqueous solution of formic acid through the flow groove portions **13**C, and thus an occurrence that carbon dioxide accumulates to form bubbles in the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G, and the fuel (aqueous solution of formic acid) and carbon dioxide stagnate therein can be suppressed. That is, the oxidation reaction of the fuel (aqueous solution of formic acid) by the electrode catalyst particles of the fuel electrode catalyst layer **11** increases, and a decrease in a power generation amount of the fuel cell **7** can be suppressed.

Comparative Example

[0071] Here, a fuel electrode current collector **81** as a comparative example of the fuel electrode current collector **13** of the fuel cell **7** will be described with reference to FIGS. **7** to **9**. Note that in the following description, the same reference signs as those of the configuration and the like of the fuel electrode current collector **13** according to the above-described embodiment denote portions same as or equivalent to those of the configuration and the like of the fuel electrode current collector **13** according to the above-described embodiment.

[0072] First, a configuration of the fuel electrode current collector **81** will be described with reference to FIGS. **7** and **8**. As illustrated in FIGS. **7** and **8**, the configuration of the fuel electrode current collector **81** is substantially the same as the configuration of the fuel electrode current collector **13**. However, as illustrated in FIG. **7**, the fuel electrode current collector **81** is different in that a fuel flow groove **81**B is provided instead of the fuel flow groove **13**B. In addition, the fuel electrode current collector **81** is different in that the protruding portions **73** are not formed in both end portions of each land portion (rib portion) **13**E in the horizontal width direction.

[0073] Specifically, the fuel flow groove **81** is provided with a plurality of flow groove portions **13**C that extend in the width direction from one side-edge side (for example, a right side-edge side in FIG. **7**) of the fuel flow surface **13**A to the other side-edge side (for example, a left side-edge side in FIG. **7**), that are arranged in parallel at predetermined intervals, and in which the fuel flows. Further, end portions on the one side-edge side (the right side in FIG. **7**) of four flow groove portions **13**C on a lower end side is connected to an inflow groove portion **81**F having a vertically long and substantially rectangular shape in a front view that extends upward from the fuel inflow port **17**A formed in a lower end portion and that has a closed upper end portion. In addition, end portions on the other side-edge side (the left side in FIG. **7**) of the four flow groove portions **13**C on the lower end side, and end portions on the other side-edge side (the left side in FIG. **7**) of three flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **81**D**1** having a vertically long and substantially rectangular shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0074] Accordingly, a fuel flowing into the inflow groove portion **81**F from the fuel inflow port **17**A flows into the four flow groove portions **13**C on the lower end side, flows toward the other side-edge side (the left side in FIG. **7**), and flows to a lower side of the return groove portion **81**D**1**. Then, the fuel flowing into the return groove portion **81**D**1** flows into the three flow groove portions **13**C disposed on an upper side of the return groove portion **81**D**1**, and flows toward the one side-edge side (the right side in FIG. **7**). Accordingly, the four flow groove portions **13**C on the lower end side and the three flow groove portions **13**C on the upper side thereof constitute two groups, that is, the flow groove portion groups **131** and **132** adjacent to each other in which flow directions of the fuel are opposite to each other.

[0075] In addition, end portions on the one side-edge side (the right side in FIG. **7**) of the three flow groove portions **13**C constituting the flow groove portion group **132**, and end portions on the one side-edge portion (the right side in FIG. **7**) of three flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **81**D**2** having a vertically long and substantially rectangular shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0076] Accordingly, the fuel flowing to a lower side of the return groove portion **81**D**2** from the three flow groove portions **13**C constituting the flow groove portion group **132** flows into the three flow groove portions **13**C disposed on an upper side of the return groove portion **81**D**2**, and flows toward the other side-edge side (the left side in FIG. **7**). Accordingly, the three flow groove portions **13**C disposed on the upper side of the three flow groove portions **13**C constituting the flow groove portion group **132** are disposed adjacently on the upper side of the flow groove portion group **132**, and constitute one group, that is, the flow groove portion group **133** in which the flow direction of the fuel is reversed.

[0077] In addition, end portions on the other side-edge side (the left side in FIG. **7**) of the three flow groove portions **13**C constituting the flow groove portion group **133**, and end portions on the other side-edge side (the left side in FIG. **7**) of three flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **81**D**3** having a vertically long and substantially rectangular shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0078] Accordingly, the fuel flowing to a lower side of the return groove portion **81**D**3** from the three flow groove portions **13**C constituting the flow groove portion group **133** flows into the three flow groove portions **13**C disposed on an upper side of the return groove portion **13**D**3**, and flows toward the one side-edge side (the right side in FIG. **3**). Accordingly, the three flow groove portions **13**C disposed on the upper side of the three flow groove portions **13**C constituting the flow groove portion group **133** are disposed adjacently on the upper side of the flow groove portion group **133**, and constitute one group, that is, the flow groove portion group **134** in which the flow direction of the fuel is reversed.

[0079] In addition, end portions on the one side-edge side (the right side in FIG. **7**) of the three flow groove portions **13**C constituting the flow groove portion group **134**, and end portions on the one side-edge side (the right side in FIG. **7**) of four flow groove portions **13**C on an upper side thereof, are connected to, for example, a return groove portion **81**D**4** having a vertically long and substantially rectangular shape in a front view that extends in the up-down direction and that protrudes outward in the width direction.

[0080] Accordingly, the fuel flowing to a lower side of the return groove portion **81**D**4** from the three flow groove portions **13**C constituting the flow groove portion group **134** flows into the four flow groove portions **13**C disposed on an upper side of the return groove portion **81**D**4**, and flows toward the other side-edge side (the left side in FIG. **7**). Accordingly, the four flow groove portions **13**C disposed on the upper side of the three flow groove portions **13**C constituting the flow groove portion group **134** are disposed adjacently on the upper side of the flow groove portion group **134**, and constitute one group, that is, the flow groove portion group **135** in which the flow direction of the fuel is reversed.

[0081] Further, end portions on the other side-edge side (left side in FIG. **7**) of the four flow groove portions **13**C constituting the flow groove portion group **135** are connected to an outflow groove portion **81**G having a vertically long and substantially rectangular shape in a front view that extends downward from the fuel outflow port **17**B formed in an upper end portion of the fuel electrode current collector **81** and that protrudes outward in the width direction. Accordingly, the fuel flowing into the outflow groove portion **81**G from the four flow groove portions **13**C constituting the flow groove portion group **135** flows from the fuel outflow port **17**B to the fuel discharge pipe **61** (see FIG. **1**).

[0082] Here, a configuration of the return groove portion **81**D**4** will be described with reference to FIGS. **7** and **8**. Note that the return groove portion **81**D**2** has substantially the same configuration as the return groove portion **81**D**4**. The inflow groove portion **81**F has substantially the same configuration as an upper half of the return groove portion **81**D**4** in the up-down direction. In addition, each of the return groove portions **81**D**1** and **81**D**3** has substantially the same configuration as the return groove portion **81**D**4** that is linearly symmetrical with respect to a vertical line. The outflow groove portion **81**G has substantially the same configuration as a lower half of the configuration of the return groove portion **81**D**4** that is linearly symmetrical with respect to a vertical line.

[0083] As illustrated in FIGS. **7** and **8**, the return groove portion **81**D**4** is formed in a vertically long and substantially rectangular shape in a front view that extends in the up-down direction and that protrudes outward in the width direction, and is recessed in the thickness direction at a depth of about twice the depth of each of the flow groove portions **13**C. In addition, an inner wall surface portion **83** facing the end portions on the one side-edge side (the right side in FIG. **8**) of the flow groove portions **13**C is formed so that a distance from the inner wall surface portion **83** to the end portion of the flow groove portion **13**C, which face each other, is substantially constant over an entire length in the up-down direction.

[0084] Specifically, for example, the return groove portion **81**D**4** is formed in a vertically long and substantially rectangular shape in a front view in which a length of a distance from a side wall portion **71** on an upper side of the flow groove portion **13**C located at an upper end to a side wall portion **72** on a lower side of the flow groove portion **13**C located at a lower end is set as one side in the up-down direction, and a length of about twice the depth of the return groove portion **81**D**4**, that is, about four times the depth of each flow groove portion **13**C is set as one side in a left-right width direction.

[0085] Therefore, the end portions of the land portions (rib portions) **13**E facing the inner wall surface portion **83** form a wall surface portion parallel to the inner wall surface portion **83** together with the end portions of the flow groove portions **13**C facing the inner wall surface portion **83**. That is, the fuel flow groove **81**B is different from the fuel flow groove **13**B in configuration in that each end portion of each land portion (rib portion) **13**E facing the inner wall surface portion **83** is not provided with the protruding portion **73** having a circular arc shape in a plan view. Therefore, the fuel flowing through the flow groove portions **13**C of the flow groove portion group **134** flows to the lower side in the return groove portion **81**D**4**. Then, the fuel flowing into the return groove portion **81**D**4** is guided upward in the return groove portion **81**D**4** by an upper side portion of the inner wall surface portion **83**, and flows into the flow groove portions **13**C of the flow groove portion group **135**.

[0086] Next, an example of a result of flow speed distribution of the fuel, which is subjected to fluid analysis by computer-aided engineering (CAE) analysis at the time when the fuel of the aqueous solution of formic acid having a concentration of about 10% to 40% is supplied (pumped) to the fuel electrode current collector **81** of the fuel cell **7** configured as described above, will be described with reference to FIG. **9**. As illustrated in FIG. **9**, the fuel flowing into the inflow groove portion **81**F from the fuel inflow port **17**A formed in a lower end portion of the fuel electrode current collector **81** flows into the four flow groove portions **13**C constituting the flow groove portion group **131**, and a stagnation region **85**A where the flow speed is substantially zero [m/sec] is formed at an upper end corner portion on an outer side in the width direction (a right side in FIG. **9**) of the inflow groove portion **81**F.

[0087] Then, the fuel flowing into the return groove portion **81**D**1** from the four flow groove portions **13**C constituting the flow groove portion group **131** flows into the three flow groove portions **13**C constituting the flow groove portion group **132**, and stagnation regions **85**B and **85**C where the flow speed is substantially zero [m/sec] are formed respectively at a lower end corner portion and an upper end corner portion on the outer side in the width direction (a left side in FIG. **9**) of the return groove portion **81**D**1**. A flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **132** is slightly higher than a flow speed of the fuel flowing through the four flow groove portions **13**C constituting the flow groove portion group **131**.

[0088] Subsequently, the fuel flowing into the return groove portion **81**D**2** from the three flow groove portions **13**C constituting the flow groove portion group **132** flows into the three flow groove portions **13**C constituting the flow groove portion group **133**, and stagnation regions **85**D and **85**E where the flow speed is substantially zero [m/sec] are formed respectively at a lower end corner portion and an upper end corner portion on the outer side in the width direction (the right side in FIG. **9**) of the return groove portion **81**D**2**. In addition, a flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **133** is substantially the same as the flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **132**.

[0089] Then, the fuel flowing into the return groove portion **81**D**3** from the three flow groove portions **13**C constituting the flow groove portion group **133** flows into the three flow groove portions **13**C constituting the flow groove portion group **134**, and stagnation regions **85**F and **85**G where the flow speed is substantially zero [m/sec] are formed respectively at a lower end corner portion and an upper end corner portion on the outer side in the width direction (the left side in FIG. **9**) of the return groove portion **81**D**3**. In addition, a flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **134** is substantially the same as the flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **133**.

[0090] Subsequently, the fuel flowing into the return groove portion **81**D**4** from the three flow groove portions **13**C constituting the flow groove portion group **134** flows into the four flow groove portions **13**C constituting the flow groove portion group **135**, and stagnation regions **85**H and **85**I where the flow speed is substantially zero [m/sec] are formed respectively at a lower end corner portion and an upper end corner portion on the outer side in the width direction (the right side in FIG. **9**) of the return groove portion **81**D**4**. In addition, a flow speed of the fuel flowing through the four flow groove portions **13**C constituting the flow groove portion group **135** is slightly lower than the flow speed of the fuel flowing through the three flow groove portions **13**C constituting the flow groove portion group **134**.

[0091] Then the fuel flowing into the outflow groove portion **81**G from the four flow groove portions **13**C constituting the flow groove portion group **135** flows into the fuel outflow port **17**B and is discharged, and a stagnation region **853** where the flow speed is substantially zero [m/sec] is formed at a lower end corner portion on the outer side in the width direction (the left side in FIG. **9**) of the outflow groove portion **81**G. Therefore, a flow speed of the fuel flowing through the fuel outflow port **17**B is substantially the same as a flow speed of the fuel flowing through the fuel inflow port **17**A.

[0092] As described above, the inflow groove portion **81**F, the return groove portions **81**D **1** to **81**D**4**, and the outflow groove portion **81**G are formed in a vertically long and substantially rectangular shape in a front view that extends in the up-down direction and that protrudes outward in the width direction. Therefore, it is presumed that the inflow groove portion **81**F, the return groove portions **81**D**1** to **81**D**4**, and the outflow groove portion **81**G are formed with the stagnation regions **85**A to **85**J, in which the flow speed of the fuel is substantially zero [m/sec], at the upper end corner portions and the lower end corner portions on the outer sides in the width direction.

[0093] Therefore, carbon dioxide (CO_2) generated by the oxidation reaction of formic acid represented by the above formula (2) stagnates together with the fuel of the aqueous solution of formic acid in the stagnation regions **85**A to **85**J and becomes bubbles, and there is a possibility that carbon dioxide remains on surfaces of the electrode catalyst particles (for example, Pd) of the fuel electrode catalyst layer **11**. As a result, since formic acid is less likely to be adsorbed on the surfaces of the electrode catalyst particles when carbon dioxide remains on the surfaces of the electrode catalyst particles (for example, Pd) of the fuel electrode catalyst layer **11**, there is a possibility that procession of the oxidation reaction of formic acid represented by the above formula (2) is hindered and the power generation amount of the fuel cell **7** is reduced.

[0094] As described above in detail, in the fuel cell **7** according to the present embodiment, the distance from the inner wall surface portion **15** to the end portion of the flow groove portion **13**C decreases toward the respective end portions in the up-down direction in the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G, which constitute the fuel flow groove **13**B of the fuel electrode current collector **13**. That is, the inner wall surface portion **15** of the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G is formed in a curved surface shape in which the distance from the inner wall surface portion **15** to the end portion of the flow groove portion **13**C, which face each other, gradually decreases toward both end portions in the up-down direction.

[0095] Accordingly, the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G have substantially no portions where the flow speed of the fuel at the respective end portions in the up-down direction is zero [m/sec] and the fuel stagnates. As a result, carbon dioxide (CO_2) generated by the oxidation reaction of formic acid represented by the above formula (2) flows smoothly together with the fuel of the aqueous solution of formic acid through the flow groove portions **13**C, and thus an occurrence that carbon dioxide accumulates to form bubbles in the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G, and the fuel (aqueous solution of formic acid) and carbon dioxide stagnate therein can be suppressed. That is, the oxidation reaction of the fuel (aqueous solution of formic acid) by the electrode catalyst particles of the fuel electrode catalyst layer **11** increases, and a decrease in the power generation amount of the fuel cell **7** can be suppressed.

[0096] In addition, the plurality of land portions **13**E disposed between the flow groove portions **13**C have, at the end portions thereof facing the inner wall surface portion **15**, the protruding portions **73** that protrude in a circular arc shape in a plan view toward the outer side with respect to the adjacent flow groove portions **13**C. Accordingly, the fuel flowing out of the flow groove portion **13**C can be smoothly guided along an outer peripheral surface of the protruding portion **73** to the upper side, and then smoothly guided again into the flow groove portion **13**C disposed on the upper side, and the fuel and carbon dioxide stagnating at the end portions in the up-down direction of the return groove portions **13**D**1** to **13**D**4**, the inflow groove portion **13**F, or the outflow groove portion **13**G can be further reduced.

[0097] It goes without saying that the present disclosure is not limited to the above-described embodiment, and various improvements, modifications, additions, and deletions can be made without departing from the gist of the present disclosure. Note that in the following description, the same reference signs as those of the configuration and the like of the fuel cell system **1** according to the above-described embodiment illustrated in FIGS. **1** to **6** denote portions same as or equivalent to those of the configuration and the like of the fuel cell system **1** according to the above-described embodiment.

Other First Embodiment

[0098] (A) For example, a fuel electrode current collector **91** illustrated in FIG. **10** may be used instead of the fuel electrode current collector **13**. A configuration of the fuel electrode current collector **91** will be described with reference to FIG. **10**. As illustrated in FIG. **10**, the fuel electrode current collector **91** has substantially the same configuration as the fuel electrode current collector **13**, but is different in that both end portions in the horizontal width direction of each land portion **13**E is not formed with the protruding portion **73**. Therefore, the end portions of the land portions (rib portions) **13**E facing the inner wall surface portion **15** form a flat portion **92** along the vertical direction together with the end portions of the flow groove portions **13**C facing the inner wall surface portion **15**.

[0099] Further, as illustrated in FIG. **10**, the inner wall surface portion **15** facing the flat portion **92** is formed in a curved surface shape in which a distance from the inner wall surface portion **15** to the end portion of the flow groove portion **13**C, which face each other, gradually decreases from a central portion in the up-down direction of the return groove portion **13**D**4** toward both end portions in the up-down direction of the return groove portion **13**D**4**. Accordingly, the fuel flowing into the return groove portion **13**D**4** from the flow groove portions **13**C of the flow groove portion group **134** is guided upward by the flat portion **92** and the inner wall surface portion **15**, and flows into the flow groove portions **13**C of the flow groove portion group **135**.

[0100] Therefore, the fuel flowing into the return groove portion **13**D**4** from the three flow groove portions **13**C constituting the flow groove portion group **134** flows into the four flow groove portions **13**C constituting the flow groove portion group **135** without substantially stagnating in the return groove portion **13**D**4**. Similarly, in the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G, the distance from the inner wall surface portion **15** to the end portion of the flow groove portion **13**C decreases toward the respective end portions in the up-down direction. Therefore, it is presumed that the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G have substantially no portions where the flow speed of the fuel at the respective end portions in the up-down direction is zero [m/sec] and the fuel stagnates.

[0101] As a result, carbon dioxide (CO_2) generated by the oxidation reaction of formic acid represented by the above formula (2) flows smoothly together with the fuel of the aqueous solution of formic acid through the flow groove portions **13**C, and thus an occurrence that carbon dioxide accumulates to form bubbles in the inflow groove portion **13**F, the return groove portions **13**D**1** to **13**D**4**, and the outflow groove portion **13**G, and the fuel (aqueous solution of formic acid) and carbon dioxide stagnate therein can be suppressed. That is, the oxidation reaction of the fuel (aqueous solution of formic acid) by the electrode catalyst particles of the fuel electrode catalyst layer **11** increases, and a decrease in the power generation amount of the fuel cell **7** can be suppressed.

Other Second Embodiment

[0102] (B) For example, a protruding height of the protruding portion **73** protruding from both end portions of each land portion **13**E in the horizontal width direction to the inside of each of the return groove portions **13**D**1** to **13**D**4** may be gradually decreased from both end portions in the up-down direction of each of the return groove portions **13**D**1** to **13**D**4** toward a portion between adjacent flow groove portion groups **131** to **135** in which the flow directions of the fuel are reversed. Accordingly, the fuel flowing into the return groove portions **13**D**1** to **13**D**4** from the flow groove portions **13**C can be guided so as to smoothly flow to a substantially central portion in the up-down direction, and the fuel and carbon dioxide stagnating at both end portions in the up-down direction of the return groove portions **13**D**1** to **13**D**4** can be further reduced.

[0103] The present application is based on Japanese Patent Application No. 2019-189185 filed on Oct. 16, 2019, the contents of which are incorporated herein as reference.

1. A fuel cell being a direct liquid fuel cell in which a liquid containing a formic acid or an alcohol is used as a fuel, the fuel cell comprising:

a fuel electrode that includes a fuel electrode catalyst layer, a fuel electrode diffusion layer, and a fuel electrode current collector;

an air electrode that includes an air electrode catalyst layer, an air electrode diffusion layer, and an air electrode current collector; and

an electrolyte membrane that is disposed between the fuel electrode catalyst layer and the air electrode catalyst layer,

wherein the fuel electrode current collector has:

a fuel inflow port to which the fuel is supplied;

a fuel outflow port from which the fuel is discharged; and

a fuel flow groove that is formed on a fuel flow surface on a side abutting the fuel electrode diffusion layer and guides the fuel from the fuel inflow port to the fuel outflow port,

wherein the fuel flow groove has:

a plurality of flow groove portions that extend from one side edge portion of the fuel flow surface to the other side edge portion opposite to the one side edge portion and that are disposed in parallel at predetermined intervals; and

a plurality of return groove portions that, in a manner of containing a plurality of groups adjacent to each other with directions of the fuel flowing in the plurality of flow groove portions being opposite, connect an end portion of the one side edge portion or an end portion of the other side edge portion of two adjacent groups among the plurality of groups in the plurality of flow groove portions, wherein each of the plurality of return groove portions has a first inner wall surface portion facing the end portion of the flow groove portions in the plurality of return groove portions, and

wherein the first inner wall surface portion has a curved surface shape in which a distance facing with each other from the first inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward both end portions of the first inner wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

2. The fuel cell according to claim **1**,

wherein the fuel flow groove has an inflow groove portion that is connected to the fuel inflow port and to which an end portion on a side opposite to the return groove portion of one group among the plurality of groups in the plurality of flow groove portions is connected, the one group of the plurality of flow groove portions being configured such that the fuel first flows therein,

wherein the inflow groove portion has a second inner wall surface portion facing the end portion of the flow groove portions in the inflow groove portion, and

wherein the second inner wall surface portion has a curved surface shape in which a distance facing with each other from the second inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward an outflow side end portion of the second inner wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

3. The fuel cell according to claim **1** or **2**,

wherein the fuel flow groove has an outflow groove portion that is connected to the fuel outflow port and to which an end portion on a side opposite to the return groove portion of one group among the plurality of groups in the plurality of flow groove portions is connected, the one group of the plurality of flow groove portions being configured such that the fuel lastly flows therein,

wherein the outflow groove portion has a third inner wall surface portion facing the end portion of the flow groove portions in the outflow groove portion, and

wherein the third inner wall surface portion has a curved surface shape in which a distance facing with each other from the third inner wall surface portion to the end portion of the flow groove portions, gradually decreases toward an inflow side end portion of the third inner wall surface portion in a direction orthogonal to an extending direction of the flow groove portions.

4. The fuel cell according to any one of claims **1** to **3**,

wherein the fuel flow groove has a plurality of rib portions that are disposed between the plurality of flow groove portions, and

wherein the plurality of rib portions have a plurality of protruding portions protruding in a circular arc shape in a plan view outward from the flow groove portions, at the end portion of the flow groove portions facing each of the first inner wall surface portion, the second inner wall surface portion, and the third inner wall surface portion.

5. The fuel cell according to claim **4**,

wherein the plurality of protruding portions protruding into the return groove portion are formed such that a protruding height of the protruding portion gradually decreases from both end portions of the return groove portion in a direction orthogonal to the extending direction of the flow groove portions toward a boundary, at which a direction of the fuel flowing in the two groups is reversed, between two groups of the flow groove portions among the plurality of groups.

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