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(54) **FLOW-THROUGH REACTOR FOR CONVERSION OF CARBON DIOXIDE AND METHOD FOR CONVERSION OF CARBON DIOXIDE USING SAME**

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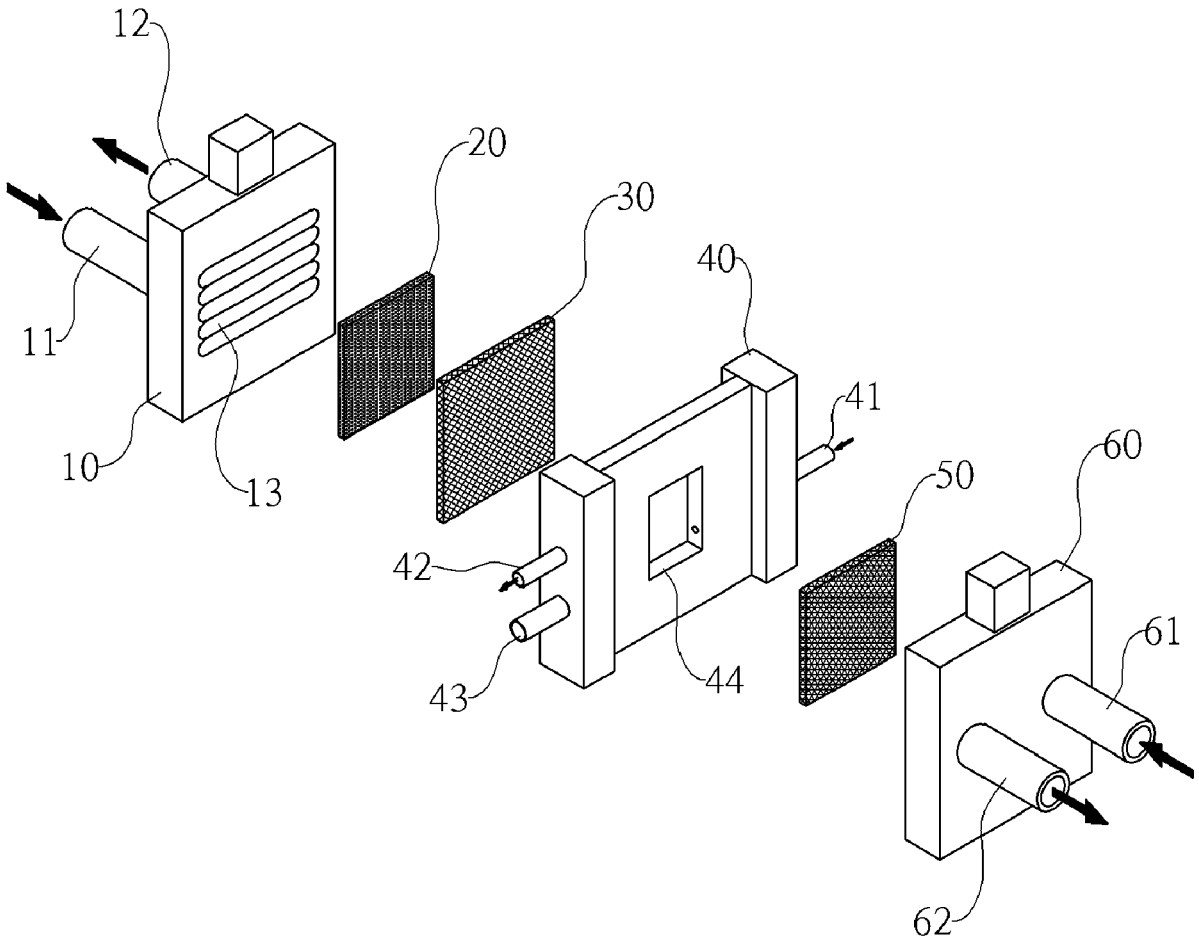
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(57) **ABSTRACT**

Proposed are a flow-through reactor for conversion of carbon dioxide and a method for conversion of carbon dioxide using the flow-through reactor. Carbon dioxide and a catholyte are separately supplied, and a reference electrode having a large volume is capable of being mounted on an electrolyte pocket without increasing resistance since a structure of the electrolyte pocket is improved.



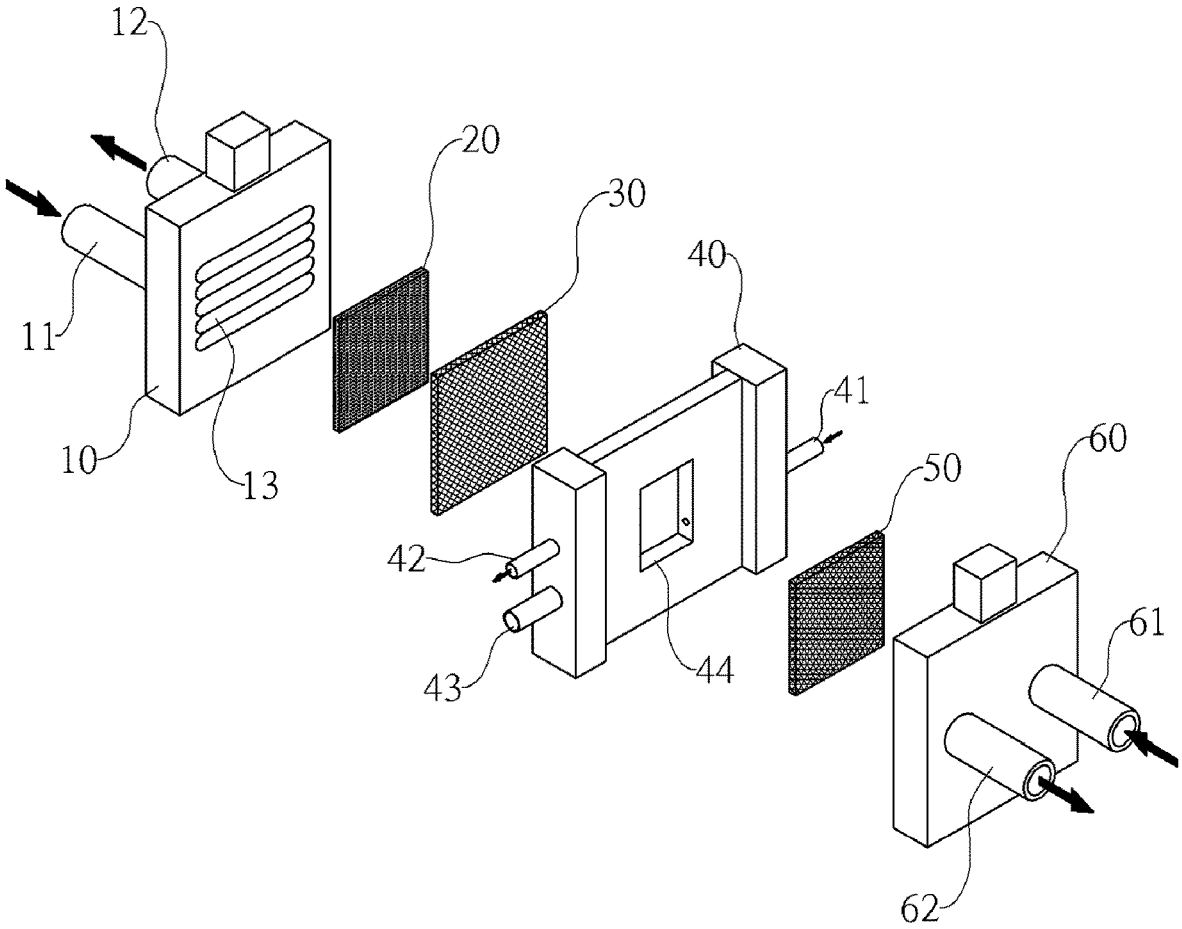


FIG. 1

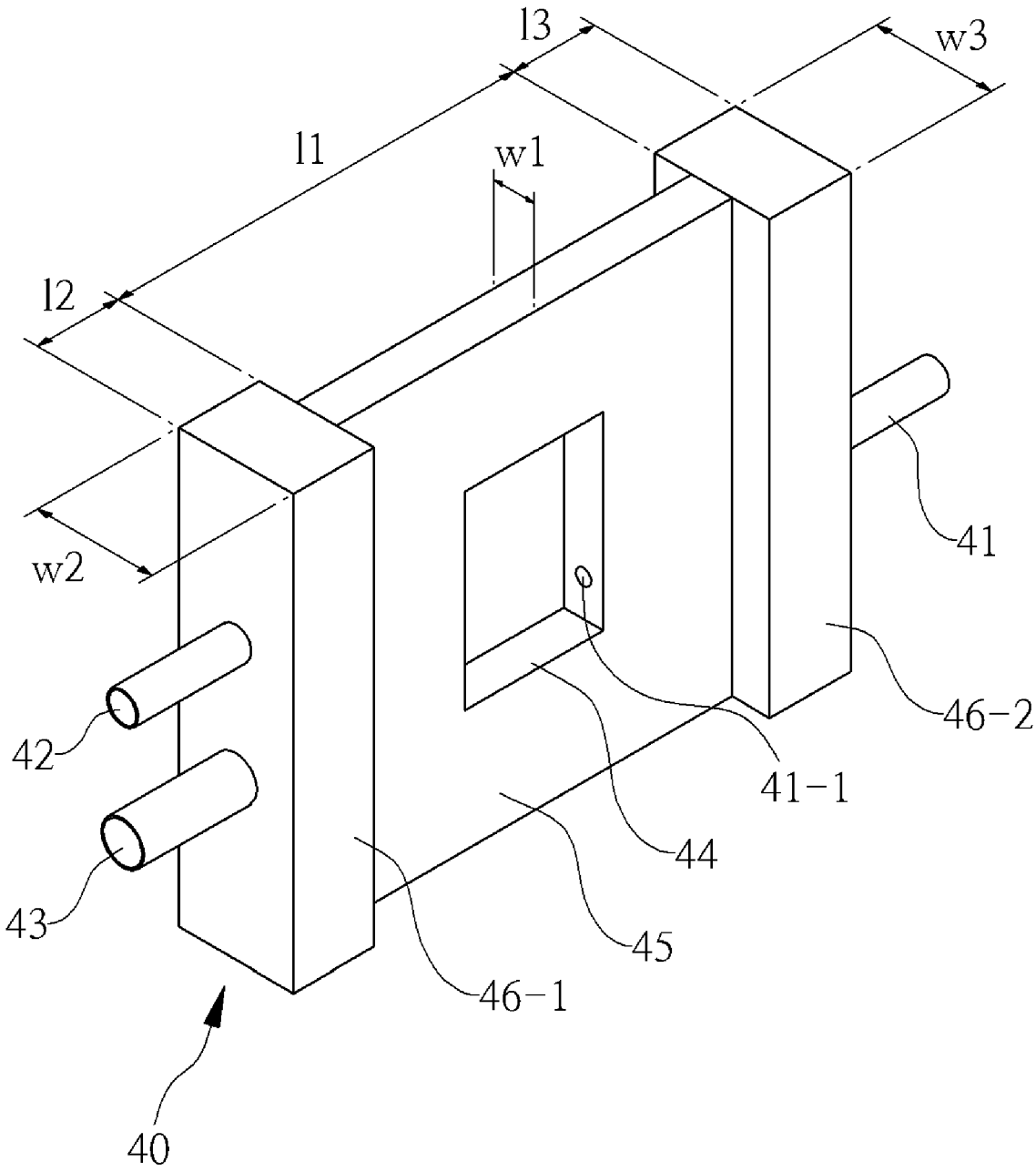


FIG. 2

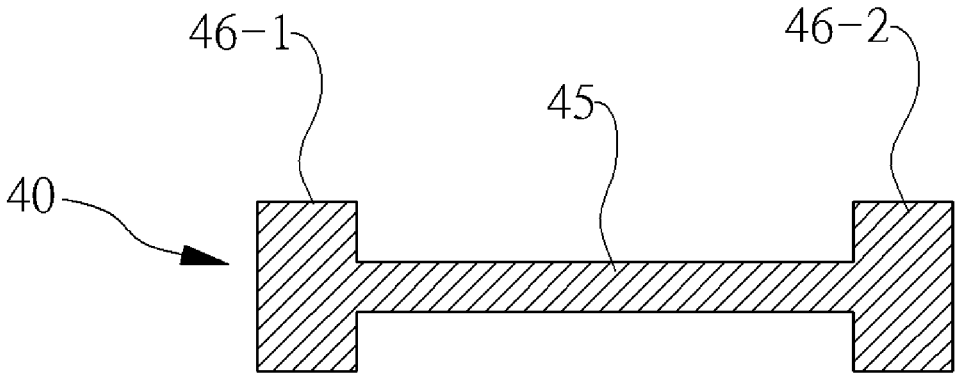


FIG. 3

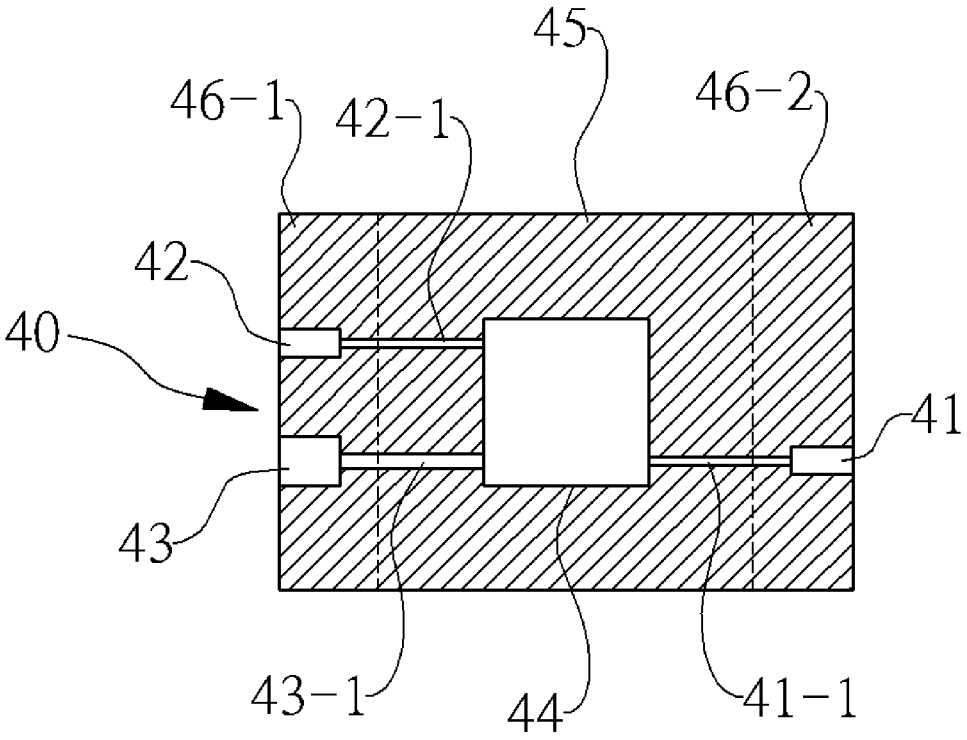


FIG. 4

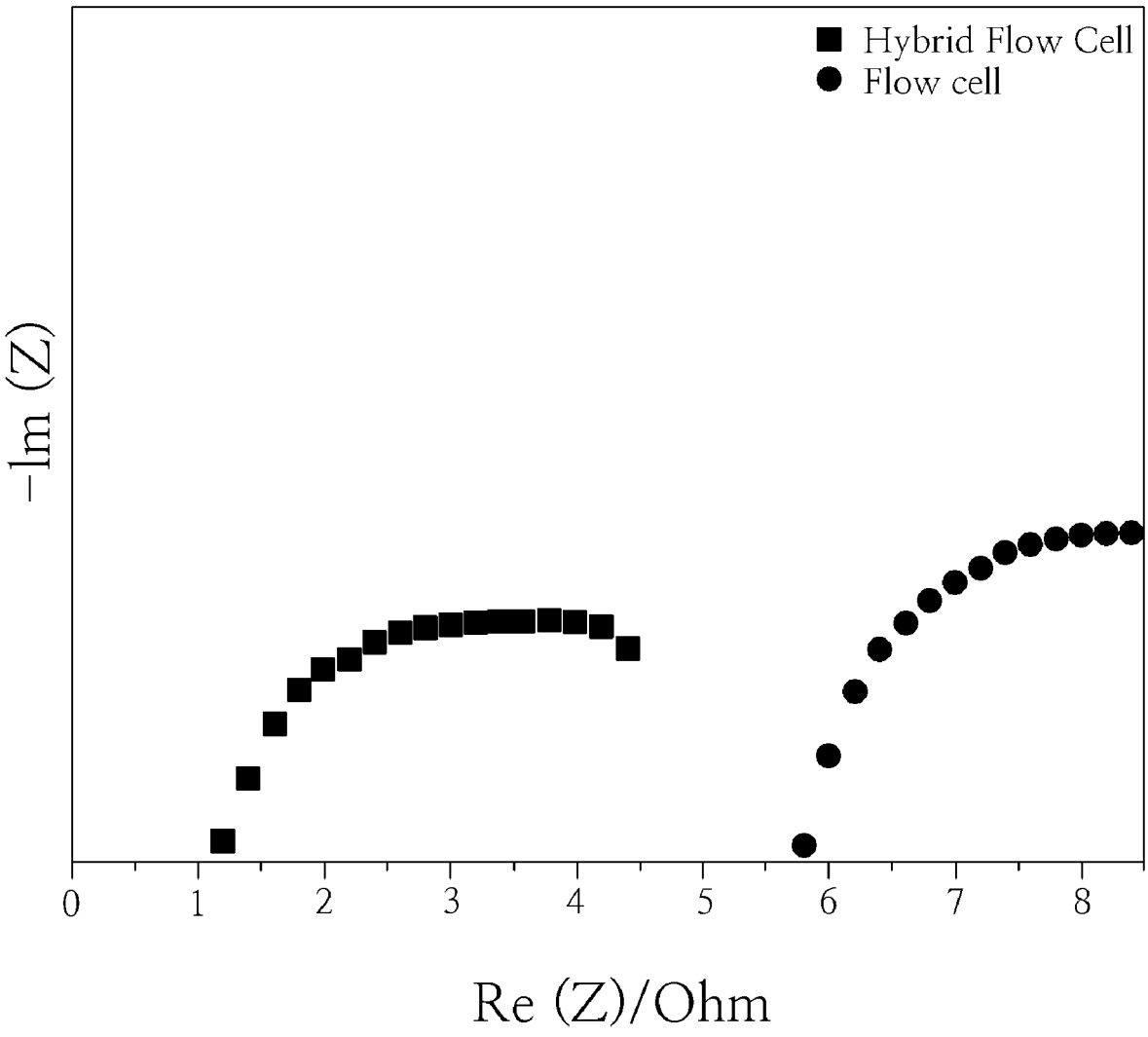


FIG. 5

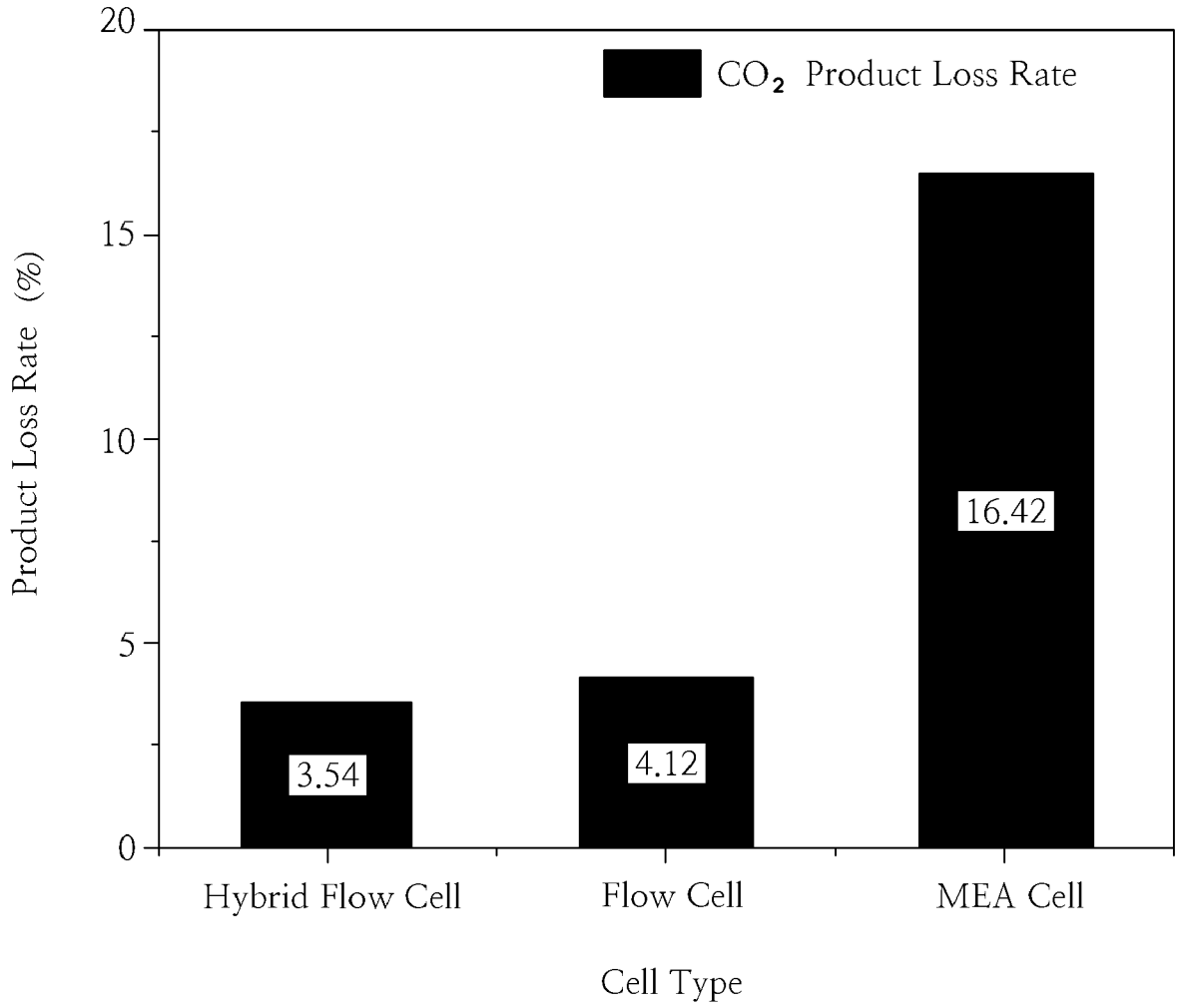

20
15
10
5
0
Product Loss Rate (%)
CO_2 Product Loss Rate
3.54
4.12
16.42
Hybrid Flow Cell
Flow Cell
MEA Cell
Cell Type

FIG. 6

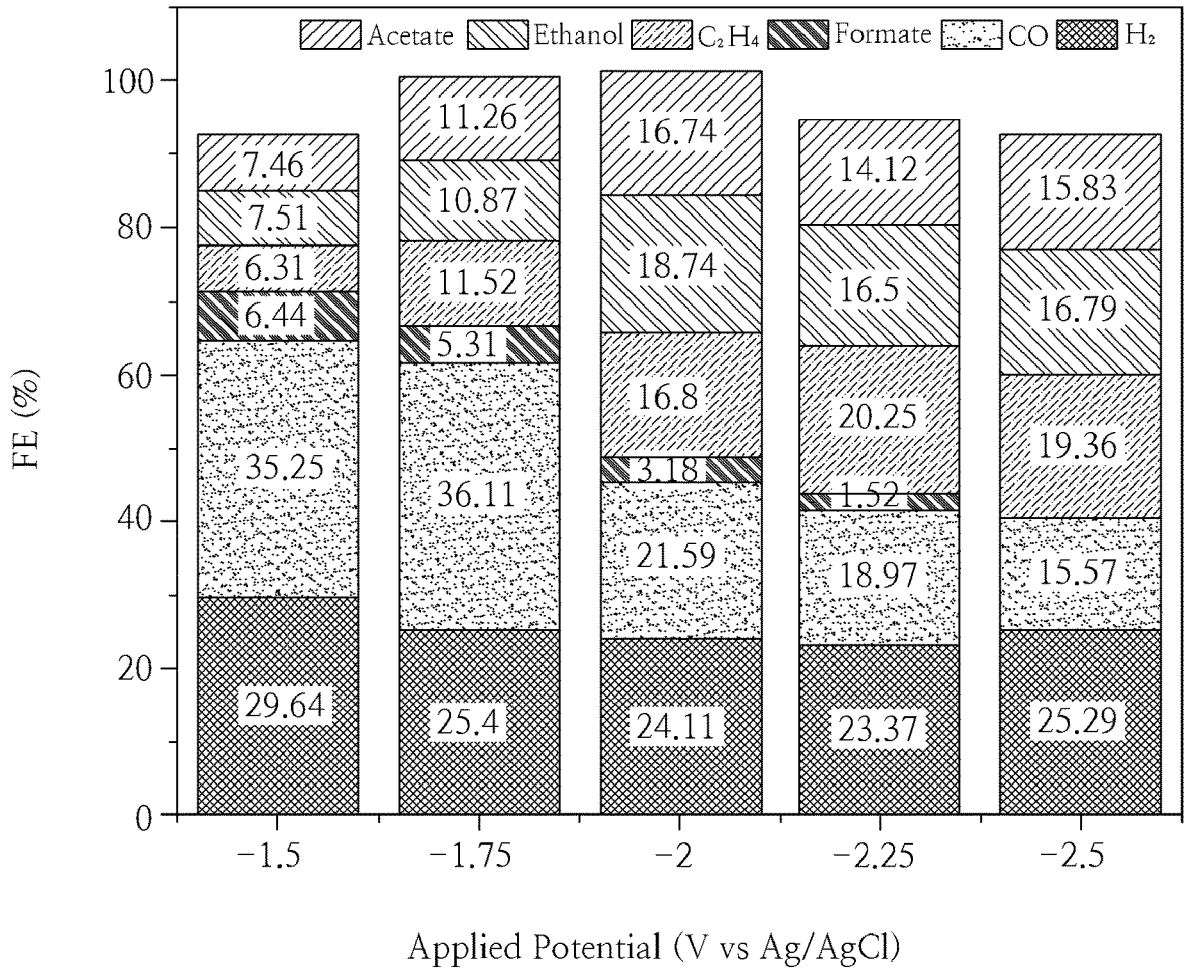

Acetate
Ethanol
C2H4
Formate
CO
H2
FE (%)
100
80
60
40
20
0
7.46
7.51
6.31
6.44
35.25
29.64
11.26
10.87
11.52
5.31
36.11
25.4
16.74
18.74
16.8
3.18
21.59
24.11
14.12
16.5
20.25
1.52
18.97
23.37
15.83
16.79
19.36
15.57
25.29
−1.5
−1.75
−2
−2.25
−2.5
Applied Potential (V vs Ag/AgCl)

FIG. 7

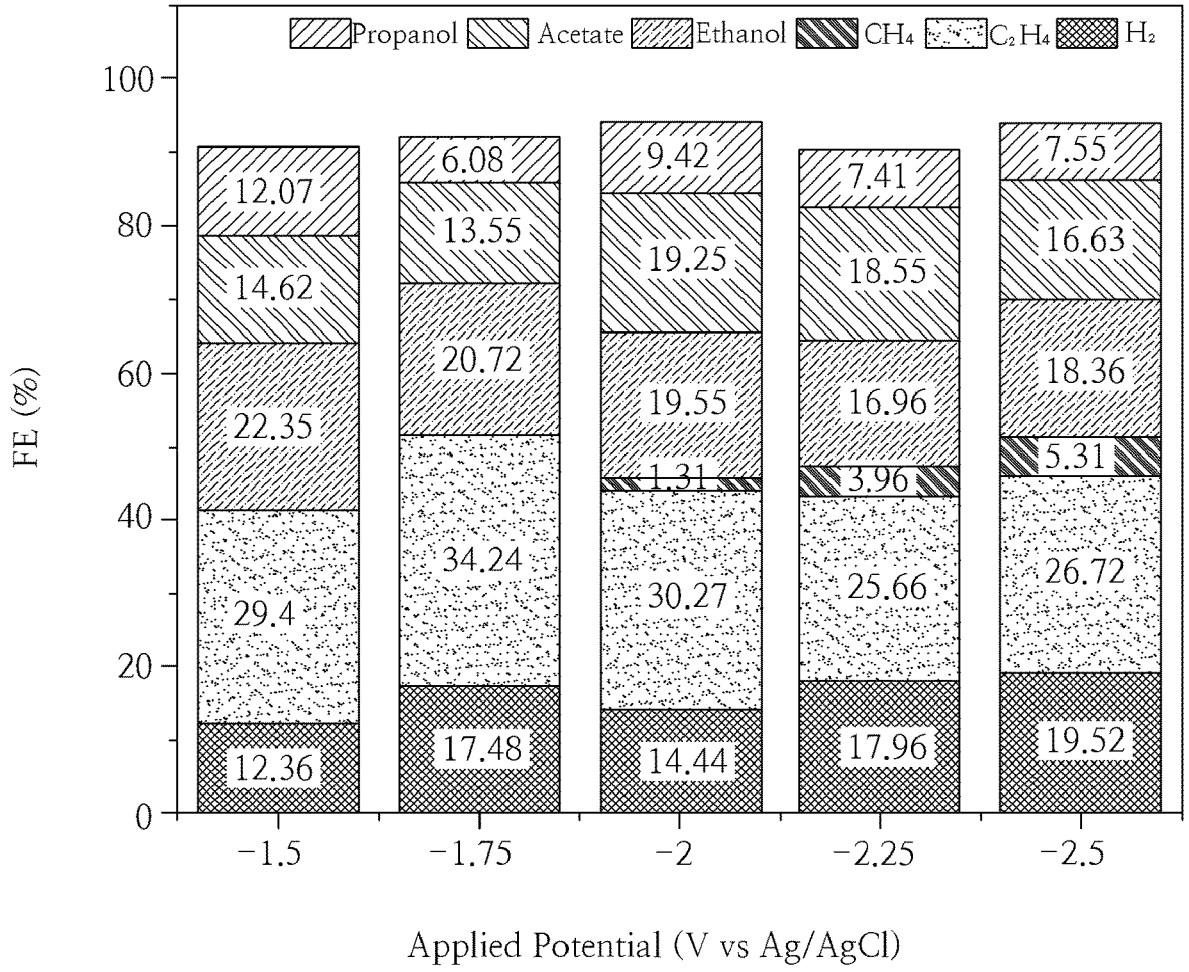

Propanol
Acetate
Ethanol
CH4
C2H4
H2
FE (%)
100
80
60
40
20
0
12.07
14.62
22.35
29.4
12.36
6.08
13.55
20.72
34.24
17.48
9.42
19.25
19.55
1.31
30.27
14.44
7.41
18.55
16.96
3.96
25.66
17.96
7.55
16.63
18.36
5.31
26.72
19.52
−1.5
−1.75
−2
−2.25
−2.5
Applied Potential (V vs Ag/AgCl)

FIG. 8

FLOW-THROUGH REACTOR FOR CONVERSION OF CARBON DIOXIDE AND METHOD FOR CONVERSION OF CARBON DIOXIDE USING SAME

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Korean Patent Application No. 10-2023-0141647, filed Oct. 23, 2023, the entire contents of which are incorporated herein for all purposes by this reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present disclosure relates to a carbon dioxide conversion technology. More particularly, the present disclosure relates to a flow-through reactor for conversion of carbon dioxide, and relates to a method for conversion of carbon dioxide using the flow-through reactor.

Description of the Related Art

[0003] Climate changes such as global warming are intensifying due to carbon dioxide that is a greenhouse gas discharged from various energy sources, and the importance of carbon neutrality is increasing so as to solve these problems. Electrochemical carbon dioxide conversion technology (or reduction technology) for carbon neutrality is attracting attention as a method of reducing carbon dioxide and converting carbon dioxide into high-value chemical compounds such as carbon monoxide, ethylene, and so on.

[0004] A reactor including a cathode, an anode, and a separator capable of performing an ion-exchange is required for an electrochemical carbon dioxide conversion reaction. Conventional patented technologies related to such a carbon dioxide conversion reactor are as follows.

[0005] In U.S. Pat. No. 11,053,597, instead of directly supplying carbon dioxide gas to a flow-through reactor, an electrolyte saturated with carbon dioxide is supplied as a reactant to a cathode, and the electrolyte passes through the nano-porous cathode and reacts in a reservoir, and then exits the reactor through a discharge line. In the related art, since carbon dioxide is saturated with the electrolyte and then is transferred to the reservoir for a reduction reaction, there is a disadvantage that the yield of a product is low as in the conventional carbon dioxide liquid phase reaction.

[0006] In U.S. Patent Application Publication No. 2020-0392631, a reactor having a structure in which gas in and out portions and a reference electrode fastening portion are added in a cathode solution flow path portion and a carbon dioxide reduction reaction is generated after carbon dioxide gas is bubbled and saturated in the cathode solution flow path portion is disclosed. In the related art, since carbon dioxide gas is bubbled into an electrolyte and a carbon dioxide liquid phase reaction is induced in the cathode, there is a disadvantage that the yield of a product is low as in U.S. Pat. No. 11,053,597.

[0007] In Korean Patent No. 10-2318719, a reactor in which an anode portion is separated by a proton exchange membrane is disclosed. In the reactor, a cathode portion (a first chamber) includes carbon dioxide in and out holes similar to the conventional flow-through reactor, a third chamber through which a catholyte flows includes electrolyte in and out holes, a gas product outlet, and a reference electrode fastening portion. In the related art, there is a disadvantage that a catalyst of the cathode is limited to a metal thin film layer formed by an electron beam irradiation treatment on a conductive substrate, and there is a disadvantage that there is a hassle of having to collect and analyze an exhaust gas of the first chamber and an exhaust gas of the third chamber together since the gas product outlet is provided in the third chamber.

[0008] The present inventors completed the present disclosure as a result of research on a flow-through reactor for conversion of carbon dioxide, the flow-through reactor being capable of monitoring a carbon dioxide conversion reaction in real time, being capable of overcoming the disadvantages of the conventional technology, and being capable of realizing a high yield of a product.

Document of Related Art

[0009] (Patent Document 1) U.S. Pat. No. 11,053,597

[0010] (Patent Document 2) U.S. Patent Application Publication No. 2020-0392631

[0011] (Patent Document 3) Korean Patent No. 10-2318719

SUMMARY OF THE INVENTION

[0012] Accordingly, the present disclosure has been made keeping in mind the above problems occurring in the related art, and an objective of the present disclosure is to provide a flow-through reactor having a high carbon dioxide conversion efficiency and being capable of processing large amounts of carbon dioxide.

[0013] In addition, since a conventional flow-through reactor is manufactured such that the conventional flow-through reactor is formed mainly of Teflon that is non-conductive, a conductive part for applying electricity to an electrode is required to be added. However, when the conductive part is added, there is a problem that the conductive part increases an electrode resistance and overall energy efficiency of the reactor is significantly reduced, but an objective of the present disclosure is to solve this problem.

[0014] In addition, the conventional flow-through reactor has a three-electrode system including a cathode, an anode, and a reference electrode, and the reactor is manufactured such that the reactor has a thick thickness so as to mount the reference electrode and a flow path for supplying an electrolyte, which also causes a problem of increasing a system resistance. In addition, an objective of the present disclosure is to solve the problems of the conventional technology in which the system resistance increases when the reference electrode is mounted.

[0015] In the present disclosure, there is provided a flow-through reactor for conversion of carbon dioxide, the flow-through reactor formed by sequentially coupling an anode endcap, an anode, an ion exchange membrane, an electrolyte pocket, a cathode, and a cathode endcap to each other, wherein carbon dioxide is supplied and discharged through the cathode endcap, a catholyte supply line and a catholyte discharge line are formed respectively on opposite sides of the electrolyte pocket, a hollow part in which a catholyte is filled is formed in a center of the electrolyte pocket, the catholyte supplied through the catholyte supply line of the electrolyte pocket is introduced into the hollow part, and the

catholyte and a reaction product after a carbon dioxide conversion reaction are discharged to the catholyte discharge line.

[0016] Particularly, the electrolyte pocket may have a generally hexahedral shape, and the hollow part may be formed in a middle of the hexahedral shape.

[0017] Particularly, the hollow part may have a rectangular shape.

[0018] Particularly, the electrolyte pocket may include a middle body in which the hollow part is positioned, and may include a second outer body in which the catholyte supply line is positioned and a first outer body in which the catholyte discharge line is positioned, the first outer body and the second outer body being positioned on opposite sides of the middle body.

[0019] Particularly, widths of the first outer body and the second outer body may be thicker than a width of the middle body, so that a plane shape of the middle body viewed from above may be a generally "H" shape.

[0020] Particularly, a reference electrode may be mounted on any one of the first outer body and the second outer body.

[0021] Particularly, the first outer body and the second outer body may be not engaged in a carbon dioxide conversion chemical reaction since the ion exchange membrane and the cathode are not in contact with the first outer body and the second outer body, so that resistance of the overall reaction may be not increased.

[0022] Particularly, an anolyte supply line and an anolyte discharge line may be formed on an outer side surface of the anode endcap.

[0023] Particularly, the cathode endcap may include a carbon dioxide supply line through which carbon dioxide gas not saturated with an electrolyte and/or water (ultrapure water) is supplied, and may include a gas product discharge line through which unreacted carbon dioxide and a gaseous product are discharged.

[0024] In addition, in the present disclosure, there is provided a method for electrochemical conversion of carbon dioxide, wherein carbon dioxide is supplied to a cathode from an outside while the carbon dioxide is in a gaseous state in which the carbon dioxide is not saturated with either water or a catholyte, and the catholyte is supplied and discharged through an electrolyte pocket positioned between the cathode and an ion exchange membrane, so that the catholyte and the carbon dioxide are separately supplied.

[0025] Particularly, the electrolyte pocket may have a generally hexahedral shape, and may have a hollow part provided in a middle of the hexahedral shape.

[0026] Particularly, the electrolyte pocket may include a middle body in which the hollow part is positioned, and may include a second outer body in which a catholyte supply line is positioned and a first outer body in which a catholyte discharge line is positioned, the first outer body and the second outer body being positioned on opposite sides of the middle body.

[0027] Particularly, widths of the first outer body and the second outer body may be thicker than a width of the middle body, so that a plane shape of the middle body viewed from above may be a generally "H" shape.

[0028] Particularly, a reference electrode may be mounted on any one of the first outer body and the second outer body.

[0029] In the present disclosure, in an anode reaction, various gases may be generated according to an objective, but an oxygen generation reaction generally occurs. However, since a liquid product of the cathode is not mixed into the anode due to the presence of a middle electrolyte layer and a separator, there is an advantage that other useful oxidation reactions such as a HMF oxidation reaction, a glycerol oxidation reaction, a methanol oxidation reaction, and so on are also capable of being realized. In addition, in the present disclosure, carbon dioxide (or a gaseous phase material such as carbon monoxide) may be reduced in a cathode reaction. In the present disclosure, unlike a conventional membrane-electrode assembly that requires humidification, there is no need to supply gas by humidifying the gas. In addition, unreacted carbon dioxide and a gas product are discharged through the cathode endcap.

[0030] In the electrolyte pocket of the present disclosure, the electrolyte flows toward the catholyte (a portion of a catholyte electrolyte flow path), and a three-electrode experiment is capable of being performed by inserting the reference electrode. Furthermore, in the present disclosure, since the reactor of the present disclosure is manufactured such that the part in the electrolyte pocket where a chemical reaction occurs has a small thickness and the part in the electrolyte pocket where the reference electrode that does not affect the system resistance is mounted has a thick thickness, there is an advantage that the system resistance is not increased while the reference electrode is capable of being mounted.

[0031] When the separator of the conventional technology is in contact with the cathode with a zero gap, there is a problem that a liquid product passes through the separator toward the anode. However, in the present disclosure, the electrolyte is introduced into the catholyte supply line of the electrolyte pocket and the electrolyte is discharged through the catholyte discharge line positioned on the opposite side of the electrolyte pocket, and a layer where the electrolyte flows is formed in the hollow part in the middle of the electrolyte pocket, so that there is an advantage that a liquid product generated from the cathode is not mixed with a liquid product generated from the anode while a reaction is performed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The above and other objectives, features, and other advantages of the present disclosure will be more clearly understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

[0033] FIG. **1** is an exploded perspective view illustrating a reactor according to an exemplary embodiment of the present disclosure;

[0034] FIG. **2** and FIG. **3** are a perspective view and a horizontal cross-sectional view illustrating an electrolyte pocket according to an exemplary embodiment of the present disclosure, respectively;

[0035] FIG. **4** is a vertical cross-sectional view illustrating the electrolyte pocket according to an exemplary embodiment of the present disclosure;

[0036] FIG. **5** is a graph showing data measuring resistance of reactors through electrochemistry impedance spectroscopy;

[0037] FIG. **6** is a graph showing a loss rate of a liquid phase product generated by carbon dioxide reduction for the reactor according to an exemplary embodiment of the present disclosure and for a reactor according to a comparative example;

[0038] FIG. **7** is a graph showing a result of a carbon dioxide reduction generation experiment using the flow-through reactor for conversion of carbon dioxide according to an exemplary embodiment of the present disclosure; and

[0039] FIG. **8** is a graph showing a result of the carbon dioxide reduction generation experiment using a flow-through reactor for conversion of carbon monoxide according to an exemplary embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0040] Hereinafter, the present disclosure will be described in detail with reference to drawings.

[0041] FIG. **1** is an exploded perspective view illustrating a reactor of the present disclosure. A reactor of the present disclosure is configured such that an anode endcap **10**, an anode, an ion exchange membrane **30**, an electrolyte pocket **40**, a cathode **50**, and a cathode endcap **60** that are from the left side of FIG. **1** are sequentially combined with each other, and at least one gasket may be added between each of the components so as to ensure tight coupling.

[0042] Hereinafter, each component will be described in more detail.

Anode Endcap **10**

[0043] The anode endcap **10** in which an oxygen generation reaction occurs has a generally hexahedral shape, and has a structure similar to an anode endcap structure in the conventional technology. An anolyte supply line **11** for supplying anolyte from outside and an anolyte discharge line **12** for discharging the anolyte after a carbon dioxide conversion reaction to the outside are formed on an outer side of the anode endcap **10**, and an anolyte supply port **13** serving as a passage through which the anolyte supplied from the anolyte supply line **11** is supplied to the anode **20** is formed in an inner side (an anode direction) of the anode endcap **10**.

Anode **20**

[0044] The anode **20** may be used by directly utilizing a nickel foam, a platinum mesh, a titanium mesh, and so on, or may be used by applying a catalyst for an oxidation reaction, such as iridium, ruthenium oxide, and so on, to a surface such as a nickel foam, a platinum mesh, a titanium mesh, and so on. Since the present disclosure is not intended to acquire rights of technical features of the anode **20**, the scope of the present disclosure is not limited to specific structures, specific components, and so on of the anode **20**.

Ion Exchange Membrane **30**

[0045] In the ion exchange membrane **30**, an anion exchange membrane, a cation exchange membrane, a bipolar membrane, and so on may be selectively used according to a carbon dioxide conversion reaction condition. The scope of the present disclosure is not limited to specific structures or specific components of the ion exchange membrane **30**.

Electrolyte Pocket **40**

[0046] FIG. **2** and FIG. **3** are a perspective view and a horizontal cross-sectional view of the electrolyte pocket **40** of the present disclosure, respectively.

[0047] The electrolyte pocket **40** is positioned between the ion exchange membrane **30** and the cathode **50**. The electrolyte pocket **40** of the present disclosure has a generally plate shape, and is formed of three parts. The three parts includes a middle body **45** in which a hollow part **44** that is a through-hole passing through an inner center of the middle body **45**, and includes a first outer body **46-1** and a second outer body **46-2** having widths wider than a width w**1** of the middle body **45** and being positioned on opposite sides of the middle body **45**.

[0048] It is preferable that the first outer body **46-1** and the second outer body **46-2** are manufactured such that the widths w**2** and w**3** of the first and second outer bodies **46-1** and **46-2** outer body **46-1** are the same for convenience of manufacturing, for aesthetic appearance of the entire reactor, and for ease of assembly of each component. However, the first outer body **46-1** and the second outer body **46-2** may be manufactured such that the widths w**2** and w**3** of the first and second outer bodies **46-1** and **46-2** outer body **46-1** are different from each other with slight difference.

[0049] In addition, the middle body **45**, the first outer body **46-1**, and the second outer body **46-2** that are the three parts may be manufactured in a separate type or an integral type.

[0050] In the present disclosure, the electrolyte pocket **40** includes a catholyte supply line **41**, a catholyte discharge line **42**. Particularly, in order to mount a reference electrode **43** on the electrolyte pocket **40**, the electrolyte pocket **40** includes the first outer body **46-1** and the second outer body **46-2** having the widths w**2** and w**3** larger than the width w**1** of the middle body **45** as described above. Although the reference electrode **43** is mounted on only one of the two outer bodies **46-1** and **46-2**, it is preferable that the first outer body **46-1** and the second outer body **46-2** are manufactured in the generally same shape due to a problem of a balance of the structure of the entire reactor and the convenience of manufacturing.

[0051] Unlike the present disclosure, the middle body **45** may have a thick width and the reference electrode **43** may be mounted on the middle body **45** that has the thick width without the first outer body **46-1** and the second outer body **46-2**. However, in this case, since the width (the thickness) of the middle body **45** is required to be increased in order to mount the reference electrode **43**, a system resistance increases, which adversely affects carbon dioxide conversion efficiency.

[0052] As described above, in the present disclosure, in order to reduce the overall system resistance and to secure a width sufficient for mounting the reference electrode **43** while the reference electrode **43** is mounted, the first outer body **46-1** and the second outer body **46-2** that are respectively corresponding to wings with reference to the middle body **45** are provided on the middle body **45**. The anode **20** and the cathode **50** are not positioned on the first outer body **46-1** and the second outer body **46-2**, and are positioned such that sizes of the anode **20** and the cathode **50** correspond to a size of the middle body **45**. Furthermore, the anode **20** and the cathode **50** are positioned such that the anode **20** and the cathode **50** cover the middle body **45**. Particularly, the anode **20** and the cathode **50** at least have sizes corresponding to a size of the hollow part **44** positioned at a center portion of the middle body **45** so that the anode **20** and the cathode **50** cover the hollow part **44**. Therefore, since the first outer body **46-1** and the second outer body **46-2** that have relatively thick thicknesses are not parts that

are involved in chemical reactions of the electrolyte, the first outer body **46-1** and the second outer body **46-2** are not factors that increase resistance of the entire chemical reaction system even though the widths of the first and second outer bodies **46-1** and **46-2** are larger than the width of the middle body **45**.

[0053] In addition, the first outer body **46-1** and the second outer body **46-2** are formed such that lengths l_2 and l_3 of the first and second outer bodies **46-1** and **46-2** are shorter than a length l_1 of the middle body **45**. The first outer body **46-1** and the second outer body **46-2** are intended to respectively secure a space for mounting the catholyte supply line **41** and a space for mounting the catholyte discharge line **42** and the reference electrode **43**, so that the lengths l_2 and l_3 do not need to be as long as the length l_1 of the middle body **45** since lengths for mounting the components are only required. That is, as illustrated in FIG. **3**, a horizontal cross-sectional area of the exemplary electrolyte pocket **40** of the present disclosure has an "H" shape.

[0054] FIG. **4** is a vertical cross-sectional view illustrating the electrolyte pocket **40** as an exemplary embodiment of the present disclosure.

[0055] The catholyte supply line **41**, the catholyte discharge line **42**, and the reference electrode **43** are mounted on the first outer body **46-1** and the second outer body **46-2**. It is preferable that the reference electrode **43** is mounted on the first outer body **46-1** that is where the catholyte discharge line **42** is mounted, but the reference electrode **43** may be mounted on the second outer body **46-2** that is where the catholyte supply line **41** is mounted. In the catholyte supply line **41**, the catholyte is transmitted to the hollow part **44** through a channel **41-1** connected to the hollow part **44**, and the catholyte discharge line **42** and the reference electrode **43** are also connected to the hollow part **44** through channels **42-1** and **43-1**, respectively.

[0056] Generally, the reference electrode **43** has a circular shape having a relatively large diameter. In the present disclosure, the width w**2** of the first outer body **46-1** is larger than a diameter of the reference electrode **43**, so that the reference electrode **43** is capable of being mounted on the first outer body **46-1**.

[0057] In the present disclosure, catholyte electrolyte is supplied to the hollow part **44**, and the reference electrode **43** is mounted on a lower end of the electrolyte pocket **40** such that the reference electrode **43** faces a direction in which the catholyte is supplied. In the present disclosure, a flow rate of anolyte electrolyte at a portion of the anode **20** may also be freely modified according to an experimental condition. In a use experiment of the reactor, a high flow rate of an oxidizing electrolyte is separately required, so that electrolyte flow rates of two parts may be supplied differently.

Cathode **50**

[0058] In the present disclosure, the cathode **50** uses a substrate that is capable of transmitting gas and is electrically conductive, such as a carbon paper, as a supporting body. Copper, silver, gold, tin, zinc, nickel, bismuth, and so on may be utilized as a catalyst. A catalyst ink is prepared by dispersing the catalyst and an ionic polymer that acts as a binder to a solvent that has rapid evaporation, such as isopropanol. The cathode **50** is prepared by applying the catalyst ink on the carbon paper with an air brush. In addition to the carbon paper, a PTFE paper, a carbon felt, and so on may be used for preparing the cathode **50**.

Cathode Endcap **60**

[0059] The cathode endcap **60** has a generally hexahedral shape, and has a structure similar to that of the conventional technology. That is, carbon dioxide acting as a reaction gas is supplied from the outside of the cathode endcap **60** without humidification (water humidification and/or electrolyte humidification). A carbon dioxide supply line **61** for supplying external carbon dioxide and a gas product discharge line **62** that allows a gaseous product and residual carbon dioxide after the carbon dioxide conversion reaction to be discharged to the outside are formed on an outer side surface of the cathode endcap **60**, and the two lines **61** and **62** are formed such that the two lines **61** and **62** are in communication with the cathode **50**. In the present disclosure, unlike a conventional reactor in which a membrane-electrode assembly is applied, carbon dioxide is supplied to the carbon dioxide supply line **61** of the cathode endcap **60** without being saturated to a liquid, for example, the electrolyte. Furthermore, in a catalyst layer of the cathode **50**, the catholyte supplied through the electrolyte pocket **40** meets carbon dioxide and a carbon dioxide reduction reaction occurs.

Other

[0060] Although not illustrated in the drawings of the present disclosure, a gasket may be mounted between each of the components so as to prevent leakage from occurring. For example, respective gaskets may be installed between the anode endcap **10** and the anode **20**, between the anode **20** and the ion exchange membrane **30**, between the ion exchange membrane **30** and the electrolyte pocket **40**, between the electrolyte pocket **40** and the cathode **50**, and between the cathode **50** and the cathode endcap **60**. Since the use of the gasket is a known technology, a detailed description of the gasket will be omitted. Hereinafter, the present disclosure will be described through experiments.

Experiment example

[0061] An experimental application condition of the reactor of the present disclosure is as follows. A cathode electrode was prepared by dispersing copper particles, an ionic polymer that acts as a binder, and a conductive carbon to isopropanol, and then by applying a catalyst ink on a carbon paper.

[0062] 1 M of KOH that is a basic electrolyte was supplied simultaneously as catholyte and anolyte electrolytes.

[0063] As an anode, a nickel foam was used, and the anode is separated from the cathode electrolyte part by inserting an anion exchange membrane therebetween. The anode and the anion exchange membrane were applied by bonding the anode and the anion exchange membrane with a zero gap. The anode electrolyte was supplied by a pump at 20 rpm, and the cathode electrolyte was supplied by a pump at 5 rpm, so that each of the anode electrolyte and the cathode electrolyte at different flow rates are supplied through the two pumps. A reference electrode was inserted when an electrolyte pocket was completely filled with liquid without gas. As a reference electrode, AG/AgCl Saturated Calomel Reference Electrode (SCE) was used.

[0064] When it was confirmed that each electrolyte flows well in the anode and the two parts of the electrolyte pocket,

carbon dioxide (or carbon monoxide) at 20 SCCM was supplied to the cathode portion, so that a three-phase interface in which the electrolyte and the reactant gas are supplied to the copper catalyst was formed. In a three-electrode system, carbon dioxide (or carbon monoxide) reduction was performed by applying voltages of −1.5 V, −1.75 V, −2 V, −2.25 V, and −2.5 V to the cathode portion with reference to the reference electrode.

Experiment Example 1: Electrochemistry Impedance Spectroscopy

[0065] FIG. **5** is a graph showing data measuring a resistance of reactors through electrochemistry impedance spectroscopy (in FIG. **5**, a flow cell=a conventional flow-through reactor, a hybrid flow cell=a flow-through reactor of the present disclosure).

[0066] The conventional flow-through reactor is formed such that the conventional flow-through reactor is formed mainly of Teflon that is non-conductive, and is thick so that a flow path for supplying an electrolyte and a reference electrode are mounted, so that the conventional flow-through reactor shows a high resistance value (an X-intercept value) of about 6Ω. On the other hand, in the flow-through reactor of the present disclosure, an anode portion and a cathode portion have structures in which only a thin electrolyte pocket part is added on a current collector of a conventional membrane-electrode assembly part, and the flow-through reactor of the present shows a low resistance value.

Experiment Example 2: Loss Rate of Liquid Phase Product Experiment

[0067] FIG. **6** is a graph of a loss rate of a liquid phase product generated by carbon dioxide reduction for each reactor. Since an anode, an anion exchange membrane, and a cathode are bonded with a zero gap in a conventional membrane-electrode assembly, a liquid phase product generated from the cathode is crossed over to a part of the anode through the anion exchange membrane. In this case, the generated liquid phase product is oxidized from the anode again, then is discharged as carbon dioxide, and then is lost. However, in the conventional flow-through reactor and a hybrid flow-through reactor, an electrolyte layer exists between two electrodes, and a liquid phase product generated by the reduction of carbon dioxide is dissolved in the electrolyte layer, so that the lose amount of liquid phase product is significantly small.

Experiment Example 3: Carbon Dioxide Conversion Experiment

[0068] Data of carbon dioxide reduction product using the reactor of the present disclosure is illustrated in FIG. **7**. Referring to FIG. **7**, although Faradaic Efficiency (FE) is different according to a voltage, high efficiency of FE is shown in all voltages, and it can be seen that acetate, ethanol, ethylene, formate, and carbon monoxide were generated.

Experiment Example 4: Carbon Monoxide Conversion Experiment

[0069] The reactor of the present disclosure may also be used for conversion of gases other than carbon dioxide, for example, carbon monoxide. In the experiment example 4, a carbon monoxide conversion experiment was performed (see FIG. **8**).

[0070] As shown in the experiment result in FIG. **8**, high FE was shown for carbon monoxide, and it can be seen that propanol, acetate, ethanol, methane, ethylene, and hydrogen were generated.

What is claimed is:

1. A flow-through reactor for conversion of carbon dioxide, the flow-through reactor formed by sequentially coupling an anode endcap, an anode, an ion exchange membrane, an electrolyte pocket, a cathode, and a cathode endcap to each other,

wherein carbon dioxide is supplied and discharged through the cathode endcap, and

a catholyte supply line and a catholyte discharge line are formed respectively on opposite sides of the electrolyte pocket, a hollow part in which a catholyte is filled is formed in a center of the electrolyte pocket, the catholyte supplied through the catholyte supply line of the electrolyte pocket is introduced into the hollow part, and the catholyte and a reaction product after a carbon dioxide conversion reaction are discharged to the catholyte discharge line.

2. The flow-through reactor of claim **1**, wherein the electrolyte pocket has a generally hexahedral shape, and the hollow part is formed in a middle of the hexahedral shape.

3. The flow-through reactor of claim **2**, wherein the hollow part is a rectangular hollow part.

4. The flow-through reactor of claim **2**, wherein the electrolyte pocket comprises a middle body in which the hollow part is positioned, and comprises a second outer body in which the catholyte supply line is positioned and a first outer body in which the catholyte discharge line is positioned, the first outer body and the second outer body being positioned on opposite sides of the middle body.

5. The flow-through reactor of claim **4**, wherein widths of the first outer body and the second outer body are thicker than a width of the middle body, so that a plane shape of the middle body viewed from above is a generally "H" shape.

6. The flow-through reactor of claim **5**, wherein a reference electrode is mounted on any one of the first outer body and the second outer body.

7. The flow-through reactor of claim **4**, wherein the first outer body and the second outer body are not engaged in a carbon dioxide conversion chemical reaction since the ion exchange membrane and the cathode are not in contact with the first outer body and the second outer body.

8. The flow-through reactor of claim **1**, wherein an anolyte supply line and an anolyte discharge line are formed on the anode endcap.

9. The flow-through reactor of claim **1**, wherein the cathode endcap comprises a carbon dioxide supply line through which unsaturated carbon dioxide gas is supplied, and comprises a gas product discharge line through which unreacted carbon dioxide and a gaseous product are discharged.

10. A method for electrochemical conversion of carbon dioxide,

wherein carbon dioxide is supplied to a cathode from an outside while the carbon dioxide is in a gaseous state in which the carbon dioxide is not saturated with either water or a catholyte, and the catholyte is supplied and discharged through an electrolyte pocket positioned

between the cathode and an ion exchange membrane, so that the catholyte and the carbon dioxide are separately supplied.

11. The method of claim **10**, wherein the electrolyte pocket has a generally hexahedral shape, and has a hollow part provided in a middle of the hexahedral shape.

12. The method of claim **11**, wherein the electrolyte pocket comprises a middle body in which the hollow part is positioned, and comprises a second outer body in which a catholyte supply line is positioned and a first outer body in which a catholyte discharge line is positioned, the first outer body and the second outer body being positioned on opposite sides of the middle body.

13. The method of claim **12**, wherein widths of the first outer body and the second outer body are thicker than a width of the middle body, so that a plane shape of the middle body viewed from above is a generally "H" shape.

14. The method of claim **13**, wherein a reference electrode is mounted on any one of the first outer body and the second outer body.

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