(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 741 533 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
13.05.2026 Bulletin 2026/20

(21) Application number: **24860411.8**

(22) Date of filing: **28.08.2024**

(51) International Patent Classification (IPC):
C25B 9/23 *(2021.01)* ***C25B 13/02*** *(2006.01)*
C25B 13/08 *(2006.01)* ***C25B 3/26*** *(2021.01)*
C25B 3/03 *(2021.01)* ***C25B 3/07*** *(2021.01)*

(52) Cooperative Patent Classification (CPC):
C25B 1/23; C25B 3/03; C25B 3/07; C25B 3/26; C25B 9/23; C25B 13/02; C25B 13/08

(86) International application number:
PCT/KR2024/012868

(87) International publication number:
WO 2025/048491 (06.03.2025 Gazette 2025/10)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
GE KH MA MD TN

(30) Priority: **28.08.2023 KR 20230112690**

(71) Applicant: **LG Chem, Ltd.**
Seoul 07336 (KR)

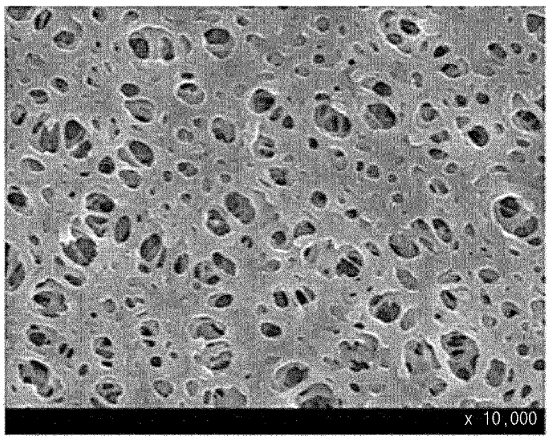
(72) Inventors:
- **KIM, Sung Yeon**
  Daejeon 34122 (KR)
- **NOH, Tae Geun**
  Daejeon 34122 (KR)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) ELECTROLYSIS CELL AND MANUFACTURING METHOD THEREFOR

(57) The present invention relates to an electrolysis cell including: a gas diffusion layer, a cathode, an anode, an electrolyte, and a separation membrane positioned between the cathode and the anode, wherein the separation membrane includes a porous substrate and a coating layer disposed on at least one surface of the porous substrate, wherein the coating layer includes an anion exchange ionomer, and the anion exchange ionomer is not included inside the pores of the porous substrate, so as to have low interfacial resistance and obtain high electric conversion efficiency.

[FIG. 1b]



EP 4 741 533 A1

Description

[Technical Field]

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of priority to Korean Patent Application No. 10-2023-0112690 filed on August 28, 2023, the disclosure of which is incorporated herein by reference in its entirety.

Technical Field

[0002] The present invention relates to an electrolysis cell for electrolyzing carbon dioxide and a manufacturing method thereof.

[Background Art]

[0003] Carbon dioxide is a greenhouse gas that causes global warming and must be reduced. Methods such as capture, chemical conversion, or electrochemical conversion are known as methods for reducing carbon dioxide. Among them, the electrochemical conversion method can precisely control the components so that other synthetic gases can be produced, resulting in economic benefits rather than simply removing carbon dioxide. In addition, carbon dioxide can be electrolyzed with water to obtain organic substances such as carbon monoxide, ethylene, methane, formic acid, formate, various hydrocarbons, and aldehyde or alcohol.

[0004] The process of electrochemically decomposing carbon dioxide is similar to the water electrolysis technology, but since the activity of the electrochemical reaction is improved in a strongly alkaline atmosphere, an aqueous solution of KOH having a certain concentration is generally used as the electrolyte. When an electric current is applied while supplying water to the anode, the water is decomposed into hydrogen ions and electrons along with the generation of oxygen gas. The electrons move to the cathode through an external conductor, and the hydrogen ions move to the cathode through an ion-selective separation membrane. The moved electrons react with carbon dioxide and water supplied to the cathode to decompose them into carbon monoxide and hydroxide ions (OH^-), and the generated hydroxide ions react with the hydrogen ions (H^+) of the anode to generate water, thereby becoming electrically neutral. The electrochemical decomposition reaction of carbon dioxide is completed through the above process. In this case, the water supplied together with the carbon dioxide reacts with the moved electrons separately from the generation reaction of the carbon monoxide to be electrolyzed, thereby generating hydrogen gas and simultaneously generating hydroxide ions. This reaction between water and electrons can be said to be a reaction in a competitive relationship with the above carbon monoxide generation reaction. Since the above reactions are electrochemical reactions, the amount of carbon monoxide produced and the hydrogen/carbon dioxide ratio can be easily controlled by adjusting the voltage.

[0005] Meanwhile, the electrolysis cell includes a cathode, an anode, an electrolyte, and a separation membrane. Conventionally, a commercially available anion exchange membrane is generally used as the separation membrane, and in particular, Sustainion from Dioxide Materals is the most widely used anion exchange separation membrane. However, this is expensive and may have economical cost problem for use, cannot be supplied in large quantities, and may crack and crumble in a dry state due to low mechanical strength, so the work processability was very low when the Sustainion anion exchange separation membrane was fastened to the electrolysis cell. Accordingly, research on a porous substrate that can replace the Sustainion anion exchange separation membrane is underway, but such a porous substrate still has poor mechanical strength due to its porosity, and has a problem in that cations cross over from the electrolyte at the anode side to the cathode side due to the porosity, thereby lowering the electrolysis efficiency.

[0006] Therefore, research is required on a separation membrane that is capable of mass production at low cost, has high durability and mechanical strength, and has an equivalent or higher carbon dioxide conversion efficiency, and thus can replace the Sustainion anion exchange separation membrane or improve the porous substrate.

[0007] (Patent Document 1) KR 2019-0125822 A

[Disclosure]

[Technical Problem]

[0008] An object to be achieved by the present invention is to provide a separation membrane that improves electrolysis efficiency by maintaining pore characteristics of a porous substrate and also having ion selectivity of an ionic polymer separation membrane, and an electrolysis cell including the same.

[0009] In addition, another object to be achieved by the present invention is to provide a separation membrane that can

be used on a large area instead of a commercial anion exchange separation membrane fastened to an existing electrolysis cell and has high chemical and mechanical strength, and a method for manufacturing an electrolysis cell including the same.

[Technical Solution]

[0010] The present invention provides an electrolysis cell and a method of manufacturing the same.

(1) The present invention provides an electrolysis cell including: a gas diffusion layer, a cathode, an anode, an electrolyte, and a separation membrane positioned between the cathode and the anode, wherein the separation membrane includes a porous substrate and a coating layer disposed on at least one surface of the porous substrate, wherein the coating layer includes an anion exchange ionomer, and the anion exchange ionomer is not included inside the pores of the porous substrate.

(2) The present invention provides the electrolysis cell according to (1) above, wherein the coating layer is disposed on a surface facing the cathode among both surfaces of the porous substrate.

(3) The present invention provides the electrolysis cell according to (1) or (2) above, wherein the porous substrate comprises at least one selected from the group consisting of polyethersulfone, polyvinylidene difluoride, cellulose acetate, polytetrafluoroethylene, and polyimide.

(4) The present invention provides the electrolysis cell according to any one of (1) to (3) above, wherein the anion exchange ionomer is a hydrocarbon-based ionomer or a perfluorinated ionomer.

(5) The present invention provides the electrolysis cell according to any one of (1) to (4) above, wherein the electrolysis cell is a zero-gap membrane electrode assembly cell in which the gas diffusion layer, the cathode, the separation membrane, and the anode having an anolyte path formed therein are sequentially stacked without gaps.

(6) The present invention provides the electrolysis cell according to any one of (1) to (5) above, wherein the ratio of the thickness of the coating layer to the thickness of the porous substrate is 1:10 to 200.

(7) The present invention provides the electrolysis cell according to any one of (1) to (6) above, wherein the thickness of the coating layer is 1.0 μm or more and 10.0 μm or less.

(8) The present invention provides the electrolysis cell according to any one of (1) to (7) above, wherein the thickness of the porous substrate is 5.0 μm or more and 250.0 μm or less.

(9) The present invention provides the electrolysis cell according to any one of (1) to (8) above, wherein the average pore size of the pores of the porous substrate is 10.0 nm or more and 450.0 nm or less.

(10) The present invention provides the electrolysis cell according to any one of (1) to (9) above, wherein the electrolysis cell electrolyzes carbon dioxide.

(11) The present invention provides the electrolysis cell according to any one of (1) to (10) above, wherein the electrolysis cell generates at least one product selected from the group consisting of carbon monoxide, ethylene, methane, formic acid, hydrocarbon, aldehyde, and alcohol.

(12) The present invention provides a method for manufacturing an electrolysis cell, the method including the steps of: manufacturing a separation membrane having a coating layer disposed on one surface (S10); installing a cathode on one surface of the separation membrane having the coating layer disposed and installing an anode on the other surface of both surfaces of the separation membrane (S20); and installing a bipolar plate on the outside of each of the cathode and the anode (S30), wherein the step (S10) of manufacturing the separation membrane includes the steps of: preparing a coating composition comprising an anion exchange ionomer and an organic solvent, and a porous substrate (S1); applying the coating composition on one surface of the porous substrate to form a coating layer (S2); and drying the coating layer to manufacture the separation membrane (S3).

(13) The present invention provides the method for manufacturing an electrolysis cell according to (12) above, wherein the coating composition includes 1 wt% or more and 10 wt% or less of the anion exchange ionomer.

(14) The present invention provides the method for manufacturing an electrolysis cell according to (12) or (13) above, wherein in the step (S30), the coating layer is formed to have a thickness of 1.0 μm or more and 10.0 μm or less.

[Advantageous Effects]

[0011] According to the electrolysis cell of the present invention, by fastening the separation membrane of the present invention having high chemical and mechanical strength and improved ion selectivity, the carbon dioxide conversion efficiency of the electrolysis cell can be increased.

[0012] In addition, according to the electrolysis cell of the present invention, the contact between the cathode and the separation membrane increases and the interfacial resistance decreases, thereby lowering the overvoltage.

[Description of Drawings]

[0013]

FIG. 1(a) is an SEM photograph of a surface of Example 2 of the present invention before coating, and FIG. 1(b) is an SEM photograph of a surface of Example 2 of the present invention after coating.
FIG. 2 is an SEM photograph of a surface showing that the pores of a porous substrate are blocked by a coating layer of Comparative Example 8.

[Best Modes of the Invention]

[0014] Hereinafter, the present invention will be described in more detail to help understand the present invention. The terms or words used in the specification and claims of the present application should not be construed as being limited to their ordinary or dictionary meanings, but should be interpreted as meanings and concepts consistent with the technical spirit of the present invention, based on the principle that the inventor may adequately define the concepts of terms to best describe his invention.

[0015] The terms used in the specification are used only to describe exemplary embodiments, and are not intended to limit the present invention. Singular expressions include plural expressions unless the context clearly implies otherwise.

[0016] It should be understood that terms such as "comprise", "include", and "have" as used herein are intended to designate the presence of implemented features, numbers, steps, components, or combinations thereof, but not to preclude a possibility of existence or addition of one or more other features, numbers, steps, components, or combinations thereof.

Electrolysis Cell

[0017] The present invention provides an electrolysis cell including: a gas diffusion layer, a cathode, an anode, an electrolyte, and a separation membrane positioned between the cathode and the anode, wherein the separation membrane includes a porous substrate and a coating layer disposed on at least one surface of the porous substrate, wherein the coating layer includes an anion exchange ionomer, and the anion exchange ionomer is not included inside the pores of the porous substrate.

[0018] In the case of a commercial anion exchange separation membrane conventionally used in an electrolysis cell, it cannot be used on a large area, and crumbles in a dry state without moisture, so the work processability was very low when fastened to the electrolysis cell. To replace this, a porous substrate was used, but it was difficult to significantly improve the mechanical strength due to the porosity, and there was a problem that cations (Cs^+, K^+, etc.) cross over from the electrolyte at the anode side through the porosity to the cathode side to generate salts, thereby lowering the carbon dioxide conversion efficiency. In addition, the porous substrate has poor contact with the electrode, which increases the interfacial resistance, and as a result, here is also a problem that the overvoltage increases.

[0019] Accordingly, the present inventors have conducted research on a separation membrane that can increase ion selectivity to prevent cations from crossing over from the anode to the cathode, increase the mechanical strength of the porous substrate, and increase the contact between the separation membrane and the electrode to reduce the interfacial resistance, and developed the electrolysis cell of the present invention.

[0020] The electrolysis cell of the present invention includes: a gas diffusion layer, a cathode, an anode, an electrolyte, and a separation membrane positioned between the cathode and the anode, wherein the separation membrane includes a porous substrate and a coating layer disposed on at least one surface of the porous substrate, wherein the coating layer includes an anion exchange ionomer. The anion exchange ionomer has a + charge and can form an anion transport channel, wherein the anion transport channel can smoothly transport anions therethrough, while preventing the transport of cations. That is, the anion exchange ionomer can prevent cations from being transported from the anode through the pores of the porous substrate to the cathode. As a result, by disposing a coating layer including the anion exchange ionomer on at least one surface of the porous substrate, the ion selectivity of the porous substrate can be improved.

[0021] FIG. 1(a) is an SEM photograph of a surface of Example 2 of the present invention before coating, and FIG. 1(b) is an SEM photograph of a surface of Example 2 of the present invention after coating. Specifically, they are photographs before/after coating showing that the pore size of the porous substrate is maintained even after the coating layer is formed on the porous substrate. The anion exchange ionomer is not impregnated or included in the pores of the porous substrate, but is included only in the coating layer. By adjusting the concentration of the anion exchange ionomer and the thickness of the coating layer formed during the process of coating on the surface of the porous substrate, the anion exchange ionomer can be controlled so as not to be impregnated into the pores of the porous substrate. Since the anion exchange ionomer is not impregnated or included in the pores of the porous substrate, the pore size of the porous substrate is not affected and the pore size before coating can be maintained as it is. That is, by maintaining the pore size of the porous substrate even

after coating, the ion exchange performance of the original porous substrate is not lowered, but rather the ion selectivity can be increased, so that when the separation membrane is fastened to the electrolysis cell and operated, the electrolysis efficiency can be further improved. Meanwhile, whether or not it is impregnated or included inside the pores of the porous substrate can be controlled according to the concentration of the anion exchange ionomer included in the coating composition, the thickness of the formed coating layer, the material of the porous substrate, the pore size, etc.

[0022] Meanwhile, if the coating layer includes a cation exchange ionomer instead of an anion exchange ionomer, it is difficult to prevent cations from being transferred from the anode to the cathode, so the ion selectivity is significantly reduced, and the overvoltage increases during the operation of the electrolysis cell, which may reduce the electrolysis efficiency.

[0023] According to one embodiment of the present invention, the coating layer may be disposed on a surface facing the cathode among both surfaces of the porous substrate. Both surfaces of the porous substrate may each face the anode and the cathode, and the coating layer may be disposed on a surface facing the cathode among both surfaces of the separation membrane. In this case, anion exchange can be made more smoothly, and cation transfer can be prevented more effectively. In particular, in the case of a cell having a zero-gap membrane electrode assembly structure described later, since the anode side is in contact with the anolyte, the anolyte may sufficiently permeate into the pores of the porous substrate. Therefore, since ion movement is easy, it may be difficult to have a large effect even if there is a coating layer on the surface facing the anode. However, on the cathode side, although the porous substrate wetted with the anolyte is in contact with the cathode catalyst, there is no medium that can connect the porous substrate and the cathode catalyst to each other, so ion movement is not easy. In this case, the anion exchange ionomer of the coating layer can serve as a passage that can move ions between the cathode catalyst layer and the surface of the porous substrate. Here, the ion may be OH^- generated in the process of CO_2 being converted into CO.

[0024] Meanwhile, in the case of a cell having a zero-gap membrane electrode assembly structure described later, the separation membrane and the cathode may form a structure in which they are stacked without a gap between them, and in this case, the coating layer improves the adhesion between the separation membrane and the cathode, thereby reducing the interfacial resistance, and consequently improving the electrolysis efficiency. On the other hand, in the zero-gap membrane electrode assembly structure, when the coating layer is disposed on the surface facing the anode among both sides of the porous substrate, the electrolyte flows between the separation membrane and the anode, so the adhesion between the separation membrane and the anode is reduced, and it is difficult for the adhesion-enhancing function of the coating layer to be properly exerted. Therefore, the electrolysis efficiency may be lowered compared to when the coating layer is disposed on the surface of the separation membrane facing the cathode.

[0025] According to one embodiment of the present invention, the ratio of the coating layer to the thickness of the porous substrate may be 1:10 to 200. For example, the ratio may be 1:10 or more, 1:20 or more, 1:30 or more, 1:40 or more, 1:50 or more, 1:60 or more, 1:70 or more, 1:80 or more, or 1:90 or more, and 1:200 or less, 1:190 or less, 1:180 or less, 1:170 or less, 1:160 or less, 1:150 or less, 1:140 or less, 1:130 or less, 1:120 or less, 1:110 or less, or 1:100 or less. Specifically, the ratio of the thickness of the coating layer to the thickness of the porous substrate may be 1:20 to 100. When the ratio of the thickness of the coating layer to the thickness of the porous substrate satisfies the above numerical range, the ion selectivity can be increased without increasing the separation membrane resistance due to the thickness, and the electrolysis efficiency can be improved.

[0026] According to one embodiment of the present invention, the porous substrate may include at least one selected from the group consisting of polyethersulfone, polyvinylidene difluoride, cellulose acetate, polytetrafluoroethylene, polyimide, polyamide, polyacrylate, polycarbonate, and polyolefin, and the specific examples thereof may include polyethylene, polypropylene, polybutylene, polypentene, polymethylpentene, polyethylene terephthalate, polybutylene terephthalate, polyacetal, polyethersulfone, polyphenylene oxide, polyphenylene sulfide, polyethylene naphthalene, and nylon. Specifically, the porous substrate may include polyethersulfone. When the porous substrate includes the polyethersulfone, the ion permeability and ion selectivity are excellent, and thus, the electrolysis efficiency can be improved when fastened to the electrolysis cell as a separation membrane.

[0027] Additionally, the thickness of the porous substrate may be 5.0 μm or more and 250.0 μm or less. For example, the thickness of the porous substrate may be 5.0 μm or more, 10.0 μm or more, 20.0 μm or more, 30.0 μm or more, 40.0 μm or more, 50.0 μm or more, 60.0 μm or more, 70.0 μm or more, 80.0 μm or more, 90.0 μm or more, 100.0 μm or more, 110.0 μm or more, 120.0 μm or more, 130.0 μm or more, 140.0 μm or more, or 150.0 μm or more, and 250.0 μm or less, 230.0 μm or less, 210.0 μm or less, 200.0 μm or less, 190.0 μm or less, 180.0 μm or less, 170.0 μm or less, or 160.0 μm or less. Specifically, the thickness of the porous substrate may be 100.0 μm or more and 170.0 μm or less. When the porous substrate satisfies the thickness, the crossover phenomenon in which the cation of the electrolyte passes through the porous substrate can be reduced, the regions of the anode and cathode can be separated to prevent a short circuit, and the overvoltage can be lowered to improve the performance of the electrolysis cell.

[0028] In addition, the average pore size of the pores of the porous substrate may be 10.0 nm or more and 450.0 nm or less. For example, the average pore size of the pores of the porous substrate may be 10.0 nm or more, 20.0 nm or more, 30.0 nm or more, 40.0 nm or more, 50.0 nm or more, 60.0 nm or more, 70.0 nm or more, 80.0 nm or more, 90.0 nm or more,

100.0 nm or more, 110.0 nm or more, 120.0 nm or more, or 130.0 nm or more, and 450.0 nm or less, 425.0 nm or less, 400.0 nm or less, 375.0 nm or less, 350.0 nm or less, 275.0 nm or less, 250.0 nm or less, 240.0 nm or less, 230.0 nm or less, 220.0 nm or less, 210.0 nm or less, 200.0 nm or less, 190.0 nm or less, 180.0 nm or less, 170.0 nm or less, 160.0 nm or less, 150.0 nm or less, or 140.0 nm or less. Specifically, the average pore size of the pores of the porous substrate may be 100.0 nm or more and 200.0 nm or less, When the pores of the porous substrate satisfy the average pore size, smooth ion transport can be achieved, resistance inside the porous substrate can be reduced, and excellent mechanical strength and durability can be maintained.

[0029] The average pore size of the pores can be measured by measuring the surface of the sample at 6,000 times magnification using a scanning electron microscope (FE-SEM) (ZEISS MINI300 Scanning Electron Microscope), and then measuring the major axis length of the surface pores confirmed in a randomly sampled range (10 μm or more in width and 15 μm or more in length) in the measured image as the pore size. The number of measurements is at least 10 or more, and the average and maximum/minimum values of the pore sizes obtained after the measurement can be obtained.

[0030] According to one embodiment of the present invention, the anion exchange ionomer may be a hydrocarbon-based ionomer or a fluorine-based ionomer. For example, the anion exchange ionomer may be a fluorine-based or hydrocarbon-based anionic ionomer containing alkylammonium, guanidinium, imidazolium, piperidinium and derivatives thereof in a side chain. Specifically, the anion exchange ionomer may be at least one selected from the group consisting of a sustain ionomer, a polybenzimidazole-based anion exchange membrane (AEM), an Aemion ionomer, an Orion ionomer, a functionalized imidazolium, a functionalized piperidinium, a functionalized quaternary ammonium, a functionalized guanidinium, a polystyrene, a polyfluoroolefin and a polyallyl. Preferably, the anion exchange ionomer may be a sustain ionomer.

[0031] In addition, the thickness of the coating layer may be 1.0 μm or more and 10.0 μm or less. For example, the thickness of the coating layer may be 1.0 μm or more, 1.5 μm or more, 2.0 μm or more, 2.5 μm or more, 3.0 μm or more, 3.5 μm or more, 4.0 μm or more, or 4.5 μm or more, and 10.0 μm or less, 9.5 μm or less, 9.0 μm or less, 8.5 μm or less, 8.0 μm or less, 7.5 μm or less, 7.0 μm or less, 6.5 μm or less, 6.0 μm or less, 5.5 μm or less, or 5.0 μm or less, and specifically, the thickness of the coating layer may be 1.0 μm or more and 5.0 μm or less. When the coating layer satisfies the above thickness, a separate layer can be formed on the surface of the porous substrate, and the material of the anion exchange ionomer is not impregnated or included inside the pores of the porous substrate, so that the pore size of the porous substrate can be maintained, thereby improving ion selectivity and simultaneously maintaining excellent electrolysis efficiency.

[0032] According to one embodiment of the present invention, there is provided an electrolysis cell, which is a zero-gap membrane electrode assembly cell in which the gas diffusion layer, the cathode, the separation membrane, and the anode having an anolyte path formed therein are sequentially stacked without gaps. Specifically, the zero-gap membrane electrode assembly may be formed in the form of a very thin plate film by sequentially stacking the gas diffusion layer, the cathode, the separation membrane, and the anode having an anolyte path formed therein in order to increase driving voltage and current efficiency.

[0033] Conventional electrolysis cells have a gap structure in which the electrodes and the separation membrane are spaced apart by several mm, but the zero-gap is a sandwich-type electrolysis cell in which the cathode electrode and the anode electrode are in contact with each other with the separation membrane therebetween, so that the gap between the electrodes and the separation membrane is eliminated. The zero-gap type electrolysis cell can reduce the solution ion resistance due to the presence of the electrolyte and reduce an increase in mass transfer resistance due to the generated gas when implementing a large-area electrode.

[0034] Specifically, the electrolyte flowing toward the cathode is referred to as a catholyte, and the electrolyte flowing toward the anode is referred to as an anolyte, and the zero-gap membrane electrode assembly may not include the catholyte but may include only the anolyte. The electrolysis cell having the zero-gap membrane electrode assembly structure has a structure in which the electrolyte does not flow on the front surface of the cathode but only on the front surface of the anode, so that the gap between the cathode, the anode, and the separation membrane is minimized, thereby enabling rapid ion transport, increasing current efficiency, and solving an additional problem of an increase in voltage during the electrolysis reaction and thus having the advantage of lowering the overvoltage. In this case, bipolar plates may also be disposed on both surfaces of the zero-gap membrane electrode assembly to form one cell.

[0035] When the separation membrane of the present invention is fastened in the electrolysis cell having the above zero-gap membrane electrode assembly structure, the coating layer may be disposed between the porous substrate and the cathode. In this case, the coating layer can improve the adhesion between the separation membrane and the cathode to reduce the interfacial resistance, thereby reducing the overvoltage and thus increasing the electrolysis efficiency.

[0036] Hereinafter, the decomposition principle of the electrolysis device and each component of the electrolysis device will be described.

[0037] The electrolysis means decomposing a material through a redox reaction by applying a direct current voltage to a decomposition reaction that does not occur spontaneously. The anode is an oxidation electrode that oxidizes water to generate oxygen, and at this time, hydrogen ions are generated. The hydrogen ions generated at the anode are transferred

to the cathode through the electrolyte, and the cathode is a reduction electrode in which the reactants input to the cathode can react with the electrons and hydrogen ions transferred from the anode to generate products. In addition, the separation membrane may be disposed between the anode and the cathode. The separation membrane may be composed of an inactive material that does not participate in the electrochemical reaction by itself, but may provide a path for ions to move between the anode and the cathode and may serve to separate the physical contact between the anode and the cathode.

[0038] In addition, each of the anode and the cathode of the electrolysis device of the present invention may include a catalyst layer. In addition, water vapor supplied together with carbon dioxide in the cathode region generates a reduction product by an electroreduction reaction on the cathode surface. Therefore, the cathode may include a gas diffusion layer to evenly supply humidified carbon dioxide gas to the cathode region side. When the cathode includes a hydrophobic gas diffusion layer, the supplied carbon dioxide can be smoothly diffused, distributed, and supplied to the catalyst layer of the cathode. In addition, the hydrophobic gas diffusion layer effectively prevents moisture condensation, thereby allowing carbon dioxide to be continuously and uniformly supplied and also allowing the electrolysis reaction to proceed smoothly. In addition, the catalyst layer may have a surface such as a porous structure so that gas permeability on the surface is well exhibited.

[0039] According to one embodiment of the present invention, the anode may include a catalyst active in the electrolysis of water, and the catalyst layer of the anode may include at least one selected from the group consisting of Pt, Au, Pd, Ir, Ag, Rh, Ru, Ni, Al, Mo, Cr, Cu, Ti, W, alloys thereof, or mixed metal oxides, such as Ta_2O_5, IrO_2, etc., for the oxygen evolution reaction. Specifically, the anode in the electrolysis device of the present invention may include titanium (Ti) coated with iridium oxide (IrO_2).

[0040] In addition, since the carbon dioxide reduction reaction occurring at the cathode competes with the hydrogen evolution reaction, it may include a catalyst showing activity in the carbon dioxide reduction reaction while having a high voltage required for the hydrogen evolution reaction. The catalyst layer of the cathode may include at least one selected from the group consisting of Sn, Sn alloy, Al, Au, Ag, C, Cd, Co, Cr, Cu, Cu alloy, Ga, Hg, In, Mo, Nb, Ni, $NiCo_2O_4$, Ni alloy, Ni-Fe alloy, Pb, Rh, Ti, V, W, Zn, and mixtures thereof for hydrogen evolution reaction. Specifically, the cathode in the electrolysis device of the present invention may include silver (Ag).

[0041] In addition, as described above, the separation membrane may include a porous substrate and a coating layer including an anion exchange ionomer.

[0042] In addition, the electrolyte may be at least one electrolyte selected from the group consisting of aqueous solutions containing $KHCO_3$, K_2CO_3, KOH, KCl, $KClO_4$, K_2SiO_3, Na_2SO_4, $NaNO_3$, NaCl, NaF, $NaClO_4$, $CaCl_2$, Cs_2CO_3, H_3PO_4, $KHPO_4$, a guanidinium cation, an H^+ cation, an alkali metal cation, an ammonium cation, an alkylammonium cation, a halide ion, an alkyl amine, a borate, a carbonate, a guanidinium derivative, a nitrite, a nitrate, a phosphate, a polyphosphate, a perchlorate, a silicate, a sulfate, a tetraalkyl ammonium salt, or a mixture thereof. Specifically, the electrolyte of the carbon dioxide electrolysis cell of the present invention may include an aqueous solution containing at least one selected from the group consisting of KOH, $KHCO_3$, Cs_2CO_3, H_3PO_4, or a mixture of H_3PO_4 and $KHPO_4$.

[0043] In addition, the gas diffusion layer may use a porous body using a carbon material such as carbon fiber cloth, carbon fiber felt, carbon fiber paper, or a metal porous body formed of a thin metal plate having a mesh structure such as expanded metal or metal mesh, and the gas diffusion layer in the electrolysis device of the present invention may use carbon fiber cloth.

[0044] According to one embodiment of the present invention, the electrolysis device can be used in all fields requiring electrochemical conversion, and in particular, can electrochemically decompose carbon dioxide to obtain a desired product. Specifically, the electrolysis device can electrolyze carbon dioxide to produce at least one selected from the group consisting of carbon monoxide, ethylene, methane, formic acid, hydrocarbon, aldehyde, and alcohol.

Electrolysis Cell Manufacturing Method

[0045] The present invention provides a method for manufacturing an electrolysis cell, the method including the steps of: manufacturing a separation membrane having a coating layer disposed on one surface (S10); installing a cathode on one surface of the separation membrane having the coating layer disposed and installing an anode on the other surface of both surfaces of the separation membrane (S20); and installing a bipolar plate on the outside of each of the cathode and the anode (S30), wherein the step (S10) of manufacturing the separation membrane includes the steps of: preparing a coating composition comprising an anion exchange ionomer and an organic solvent, and a porous substrate (S1); applying the coating composition on one surface of the porous substrate to form a coating layer (S2); and drying the coating layer to manufacture the separation membrane (S3).

[0046] The cathode and anode may be the cathode and anode described in the electrolysis cell, and the separation membrane manufactured by the step of manufacturing the separation membrane may be the separation membrane described in the electrolysis cell. The bipolar plate may be installed on the outside of each of the cathode and the anode, wherein the bipolar plate installed on the outside of the cathode may be provided with an inlet and an outlet through which the supplied material and the generated material are introduced and discharged. In addition, the bipolar plate installed on

the outside of the anode may be provided with an inlet and an outlet so that the electrolyte can be introduced and discharged.

[0047] According to one embodiment of the present invention, the coating composition may include 1 wt% or more and 10 wt% or less of the anion exchange ionomer. For example, the coating composition may contain the anion exchange ionomer in an amount of 1.0 wt% or more, 2.0 wt% or more, 3.0 wt% or more, or 4.0 wt% or more, and 10.0 wt% or less, 9.0 wt% or less, 8.0 wt% or less, 7.0 wt% or less, 6.0 wt% or less, or 5.0 wt% or less. Specifically, the coating composition may contain the anion exchange ionomer in an amount of 1.0 wt% or more and 5.0 wt% or less. When the coating composition contains the anion exchange ionomer in the above content range, the material of the anion exchange ionomer may not be impregnated into the pores of the porous substrate, but may be contained only in the coating layer. In this case, since the material of the anion exchange ionomer does not affect the pore size of the porous substrate, the phenomenon of cation crossover can be prevented, excellent ion selectivity can be achieved, and high electrolysis efficiency can be obtained.

[0048] In addition, the ionomer coating composition may further include an organic solvent. Specifically, the coating composition may be one in which the anion exchange ionomer is dissociated in the organic solvent. The organic solvent may include at least one selected from the group consisting of ethanol, n-methyl-2-pyrrolidone (NMP), N,N-dimethylacetamide (DMAc), dipropylene glycol (DPG), ethylene glycol (EG), propylene glycol (PG), and isopropyl alcohol (IPA). The content of the organic solvent may be the remainder of the ionomer coating composition excluding the content of the anion exchange ionomer.

[0049] In addition, according to one embodiment of the present invention, in the step (S30), the coating layer may be formed to have a thickness of 1.0 μm or more and 10.0 μm or less. For example, the thickness of the coating layer may be 1.0 μm or more, 2.0 μm or more, 3.0 μm or more, or 4.0 μm or more, and 10.0 μm or less, 9.0 μm or less, 8.0 μm or less, 7.0 μm or less, 6.0 μm or less, or 5.0 μm or less. Specifically, the thickness of the coating layer may be 1.0 μm or more and 5.0 μm or less, and when the coating layer satisfies the thickness, the material of the anion exchange ionomer may not be impregnated into the pores of the porous substrate, but may be contained only in the coating layer.

[0050] In addition, according to one embodiment of the present invention, a coating method for forming the coating layer may be performed by a method such as bar coating, dip coating, spin coating, and spray coating, and preferably may be performed by a bar coating method. The bar coating may be performed by applying the coating composition onto one surface of the porous substrate using various methods such as a Meyer bar, a doctor blade, a slot die, a comma bar, or a spin coating.

[0051] In addition, according to one embodiment of the present invention, through the step (S13) of drying the coating layer to prepare the separation membrane, the remaining organic solvent can be removed to form a solid coating layer. Specifically, the drying step can be performed at 50°C to 150°C for 30 minutes to 8 hours. If the drying step is performed at a temperature of less than 50°C or for less than 30 minutes, the organic solvent may not be sufficiently removed, which may affect the properties of the coating layer. In addition, if the drying step is performed at a temperature of more than 150°C or for more than 8 hours, the porous substrate may be deformed, which may result in a deterioration of the properties of the separation membrane.

[0052] Hereinafter, examples of the present invention will be described in detail so that those skilled in the art can easily implement the present invention. However, the present invention may be embodied in a variety of forms and is not limited to the examples described herein.

<Manufacture and Use of Separation Membrane>

Example 1

[0053] A porous filter (pore size: 200 nm, thickness: 150 μm) made of polyethersulfone(PES) was placed on a bar coater, and a Sustainion dispersion solution (5 wt%, EtOH) was coated only on the surface facing the cathode among both surfaces of the porous filter using a 200 μm bar to form a coating layer thereon. Thereafter, the ethanol was dried for 10 minutes under conditions of 50 °C, and further, the coated porous filter was placed in a circulation oven and further dried at 80°C for 1 to 8 hours to prepare a separation membrane.

Example 2

[0054] A separation membrane was manufactured in the same manner as in Example 1, except that a porous filter (pore size: 100 nm, thickness: 150 μm) made of polyethersulfone(PES) was used.

Comparative Example 1

[0055] The same porous filter as in Example 1 was used as the separation membrane without coating.

Comparative Example 2

[0056] A separation membrane was manufactured in the same manner as in Example 1, except that only the surface facing the anode among both surfaces of the porous filter identical as in Example 1 was coated.

Comparative Example 3

[0057] The same porous filter as in Example 2 was used as the separation membrane without coating.

Comparative Example 4

[0058] A separation membrane was manufactured in the same manner as in Example 1, except that only the surface facing the anode among both surfaces of the porous filter identical as in Example 2 was coated.

Comparative Example 5

[0059] A SustainionX37-50 Grade RT anion exchange separation membrane from Dioxide Materials was purchased, and the anion exchange separation membrane was used after being immersed in a 1 M KOH aqueous solution for 1 day.

Comparative Example 6

[0060] A separation membrane was manufactured in the same manner as in Example 1, except that Nafion dispersion solution (5 wt%, EtOH) was used instead of Sustainion dispersion solution (5 wt%, EtOH) in Example 1.

Comparative Example 7

[0061] A separation membrane was manufactured in the same manner as in Example 1, except that Sustainion dispersion solution (15 wt%, EtOH) was used instead of Sustainion dispersion solution (5 wt%, EtOH) in Example 1.

Comparative Example 8

[0062] A separation membrane was manufactured in the same manner as in Example 1, except that Nafion dispersion solution (15 wt%, EtOH) was used instead of Sustainion dispersion solution (5 wt%, EtOH) in Example 1.

Comparative Example 9

[0063] A porous filter made of the same polyethersulfone(PES) as in Example 1 was used as the separation membrane without coating.

[0064] However, instead of forming a coating layer on the porous filter, a coating layer was formed directly on the gas diffusion layer coated with an Ag catalyst applied as a cathode. Specifically, the gas diffusion layer (GDL) coated with an Ag catalyst applied as a cathode was placed on a bar coater, and a Nafion dispersion solution (15 wt%, EtOH) was coated only on the surface facing the separation membrane using a 200 μm bar to form a coating layer thereon. Thereafter, the ethanol was dried for 10 minutes under conditions of 50 °C, and further, the coated gas diffusion layer was placed in a circulation oven and further dried at 80°C for 1 to 8 hours to prepare a gas diffusion layer. The gas diffusion layer and the separation membrane were used in the experimental examples below.

Experimental Example

[0065] A carbon dioxide electrolysis unit cell including a zero-gap structure membrane electrode assembly in which an anode, an anode electrolyte, a separation membrane manufactured by examples and comparative examples, a cathode, and a gas diffusion layer are sequentially stacked was operated under the operating conditions described below.

Reaction current density: 100 mA/cm^2, 200 mA/cm^2, 300 mA/cm^2, 400 mA/cm^2 (constant current operation)
Reaction voltage: 1~4 V
Reaction temperature: 40°C
Reaction pressure: 1 atm (normal pressure)
Anode catalyst: IrO_2 on Ti mesh
Cathode catalyst: Ag powder

Electrode area: 25 cm^2
Gas diffusion layer: Sigracet 39BB, JNTG
Anode electrolyte: 0.25 M Cs_2CO_3 (25 ml/min)
Cathode reactant: 40°C Humidified CO_2 gas (25 ccm)

[0066] Electrolysis was performed under the above operating conditions using the above carbon dioxide electrolysis unit cell, and the conversion rate of carbon monoxide (%), carbon monoxide (CO) Faraday efficiency (%), and hydrogen (H_2) Faraday efficiency (%), voltage and impedance were measured. The measured results are shown in Table 1.

Measurement Method

(1) Conversion rate of carbon monoxide (%)

[0067] The conversion rate (%) was calculated as a ratio of carbon monoxide (CO) generated to the amount of carbon dioxide (CO_2) gas input per hour.

(2) Carbon Monoxide (CO) Faraday Efficiency (%)

[0068] The composition of the gas discharged outside the carbon dioxide electrolysis device was measured through gas-chromatography (GC) analysis. In addition, the Faraday efficiency was calculated using the following equation:

[Mathematical Equation 1]

$$FE_{product}(\%) = \frac{i_{product}}{i_{total}} \times 100 = \frac{V_{product} \times Q \times \frac{2F_p}{RT}}{i_{total}} \times 100$$

wherein Q is a flow rate in the path through which the product is discharged outside the carbon dioxide electrolysis device, F is a Faraday constant, p is a pressure, T is a measurement temperature, and R is an ideal gas constant. The total current (i_{total}) is a value of the total current applied over time, and the current for the product ($i_{product}$) is a value calculated from the volume of gas ($V_{product}$) measured through GC analysis.

(3) Hydrogen (H_2) Faraday Efficiency (%)

[0069] The hydrogen Faraday efficiency was measured and calculated in the same way as in (2) carbon monoxide Faraday efficiency above.

(4) Voltage (V)

[0070] Current application and voltage measurement were performed through the VSP potentiostat from BioLogic. A booster of 80 A was mounted, and a current corresponding to a large area was applied. The current was applied stepwise at 100 mA/cm^2, 200 mA/cm^2, 300 mA/cm^2, and 400 mA/cm^2 and maintained for a certain period of time, and then the voltage was recorded after 30 minutes have elapsed. Gas-chromatography (GC) analysis was also performed simultaneously.

(5) Impedance (mΩ)

[0071] Ohmic resistance was measured at 0.2 V and a frequency of 100 KHz-10 Hz using a VSP potentiostat from BioLogic.

[Table 1]

Division		Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9
Porous substrate type / Pore size (nm)		PES/200	PES/100	PES/200	PES/200	PES/100	PES/100	Sustainion X37-50	PES/200	PES/200	PES/200	PES/200
Coating material		Sustainion (5 wt%, EtOH)	Sustainion (5 wt%, EtOH)	None	Sustainion (5 wt%, EtOH)	None	Sustainion (5 wt%, EtOH)	None	Nafion (5 wt%, EtOH)	Sustainion (15 wt%, EtOH)	Nafion (15 wt%, EtOH)	Nafion (15 wt%, EtOH)
Coating location (One surface facing a specific electrode among both surfaces of the separation membrane)		Cathode	Cathode	-	Anode	-	Anode	-	Cathode	Cathode	Cathode	Coated directly on the cathode
Thickness (μm)	Porous substrate	150	125	150	150	125	150	50	150	150	150	150
Thickness (μm)	Coating layer	3	3	-	4	-	2	-	3	>10	>10	5
Current density 100 mA/cm^2	Voltage (V)	-2.792	-2.857	-2.901	-2.883	-2.840	-2.666	-3.022	-3.471	N.A	-4.0	-2.932
Current density 100 mA/cm^2	CO Faraday efficiency (%)	100.00	99.74	100.00	100.00	99.00	98.00	95.8	84.93	N.A	N.A	97.32
Current density 100 mA/cm^2	H_2 Faraday efficiency (%)	0.33	0.37	0.38	0.43	0.25	0.38	-	-	N.A	N.A	0.67

(continued)

Division		Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9
Current density 100 mA/cm^2	Conversion rate of carbon dioxide (%)	9.83	9.54	9.84	9.84	9.96	9.70	9.16	8.17	N.A	N.A	9.21
Current density 200 mA/cm^2	Voltage (V)	-3.105	-3.094	-3.180	-3.154	-3.111	-3.032	-3.297	-3.749	N.A	N.A	-3.190
Current density 200 mA/cm^2	CO Faraday efficiency (%)	96.16	97.66	95.36	95.22	95.46	94.44	93.2	78.44	N.A	N.A	90.82
Current density 200 mA/cm^2	H_2 Faraday efficiency (%)	0.28	0.32	0.39	0.42	0.23	0.36	-	-	N.A	N.A	0.56
Current density 200 mA/cm^2	Conversion rate of carbon dioxide (%)	18.81	18.69	18.66	18.74	19.22	18.69	17.83	15.09	N.A	N.A	17.19
Current density 300 mA/cm^2	Voltage (V)	-3.304	-3.264	-3.387	-3.355	-3.301	-3.232	-3.473	-3.812	N.A	N.A	-3.348
Current density 300 mA/cm^2	CO Faraday efficiency (%)	91.87	93.22	90.42	90.06	92.55	91.40	88.78	70.73	N.A	N.A	84.49

(continued)

Division		Example 1	Example 2	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7	Comparative Example 8	Comparative Example 9
Current density 300 mA/cm^2	H_2 Faraday efficiency (%)	0.33	0.31	1.30	1.48	0.36	0.36	-	-	N.A	N.A	0.65
Current density 300 mA/cm^2	Conversion rate of carbon dioxide (%)	26.96	26.75	26.54	26.58	27.95	27.13	25.48	20.41	N.A	N.A	23.99
Current density 400 mA/cm^2	Voltage (V)	-3.460	-3.413	-3.571	-3.496	-3.465	-3.367	-3.65	-4.050	N.A	N.A	-3.560
Current density 400 mA/cm^2	CO Faraday efficiency (%)	87.86	88.65	83.94	84.27	89.86	85.72	81.21	42.76	N.A	N.A	82.27
Current density 400 mA/cm^2	H_2 Faraday efficiency (%)	0.51	1.65	2.84	2.68	0.64	2.08	-	-	N.A	N.A	1.75
Current density 400 mA/cm^2	Conversion rate of carbon dioxide (%)	34.38	33.93	32.84	33.16	36.18	33.92	31.08	20.57	N.A	N.A	33.50

[0072] Referring to Table 1 above, in the case of Example 1 in which Sustainion (5 wt%, EtOH) was coated on the surface facing the cathode of the PES porous substrate (200 nm), it can be confirmed that the overvoltage, carbon monoxide Faraday efficiency, hydrogen Faraday efficiency, and carbon dioxide conversion rate are at excellent levels overall compared to Comparative Examples 1 and 2 in which no coating was applied or the coating was applied on the surface facing the anode. In particular, it can be confirmed that the performance difference becomes greater as the current density increases to 300 mA/cm2 and 400 mA/cm2.

[0073] In addition, in the case of Example 2 in which Sustainion (5 wt%, EtOH) was coated on the surface facing the cathode of the PES porous substrate (100 nm), it can be confirmed that the overvoltage, carbon monoxide Faraday efficiency, hydrogen Faraday efficiency, and carbon dioxide conversion rate are also at excellent levels overall compared to Comparative Examples 3 and 4 in which no coating was applied or the coating was applied on the surface facing the anode. Likewise, it can also be confirmed that the performance difference becomes greater as the current density increases to 300 mA/cm^2 and 400 mA/cm^2.

[0074] In addition, in the case of Comparative Example 5 using SustainionX37-50 as the existing anion exchange separation membrane, it can be confirmed that all electrolysis efficiencies are inferior to those of the examples, and in the case of Comparative Example 6 using a cationic ionomer, it can be confirmed that the overvoltage is very inferior.

[0075] In addition, Comparative Example 7 used Sustainion (15%, EtOH) as the coating material. In this case, a coating layer thickness of about 10 μm or more was formed, but Sustainion itself cracked and crumbled during the drying step, making it impossible to manufacture the membrane itself.

[0076] In addition, Comparative Example 8 performed the coating using Nafion (15 wt%, EtOH) in a powder form. In this case, the surface pores were immediately blocked, and when evaluating the performance, the overvoltage exceeded -4.0 V at a current density of 100 mA/cm^2, making it impossible to measure the performance. The surface SEM image of the membrane manufactured in Comparative Example 8 is shown in FIG. 2. FIG. 2 is an SEM photograph of the surface showing that the pores of a porous substrate are blocked by a coating layer of Comparative Example 8.

[0077] In addition, in Comparative Example 9, the Nafion (15 wt%, EtOH) was not coated on the porous substrate, but a coating layer was directly formed on the cathode. In Examples 1 and 2, the Nafion ionomer coating layer is coated on the PES porous substrate in a porous form, so there is no problem in material movement. On the other hand, in the case of Comparative Example 9, the coating is formed in the form of a film by directly coating on the cathode, which makes it difficult for ions and substances such as H_2O of the electrolyte required for carbon dioxide conversion to come into contact with the catalyst, so it can be confirmed that the electrical resistance and overvoltage are at a high level compared to the example, and thus the electrical efficiency is inferior.

Claims

1. An electrolysis cell including:

a gas diffusion layer, a cathode, an anode, an electrolyte, and a separation membrane positioned between the cathode and the anode,
wherein the separation membrane includes a porous substrate and a coating layer disposed on at least one surface of the porous substrate,
wherein the coating layer includes an anion exchange ionomer, and
the anion exchange ionomer is not included inside the pores of the porous substrate.

2. The electrolysis cell according to claim 1, wherein the coating layer is disposed on a surface facing the cathode among both surfaces of the porous substrate.

3. The electrolysis cell according to claim 1, wherein the porous substrate comprises at least one selected from the group consisting of polyethersulfone, polyvinylidene difluoride, cellulose acetate, polytetrafluoroethylene, and polyimide.

4. The electrolysis cell according to claim 1, wherein the anion exchange ionomer is a hydrocarbon-based ionomer or a perfluorinated ionomer.

5. The electrolysis cell according to claim 1, wherein the electrolysis cell is a zero-gap membrane electrode assembly cell in which the gas diffusion layer, the cathode, the separation membrane, and the anode having an anolyte path formed therein are sequentially stacked without gaps.

6. The electrolysis cell according to claim 1, wherein the ratio of the thickness of the coating layer to the thickness of the porous substrate is 1:10 to 200.

7. The electrolysis cell according to claim 1, wherein the thickness of the coating layer is 1.0 μm or more and 10.0 μm or less.

8. The electrolysis cell according to claim 1, wherein the thickness of the porous substrate is 5.0 μm or more and 250.0 μm or less.

9. The electrolysis cell according to claim 1, wherein the average pore size of the pores of the porous substrate is 10.0 nm or more and 450.0 nm or less.

10. The electrolysis cell according to claim 1, wherein the electrolysis cell electrolyzes carbon dioxide.

11. The electrolysis cell according to claim 1, wherein the electrolysis cell generates at least one product selected from the group consisting of carbon monoxide, ethylene, methane, formic acid, hydrocarbon, aldehyde, and alcohol.

12. A method for manufacturing an electrolysis cell, the method including the steps of:

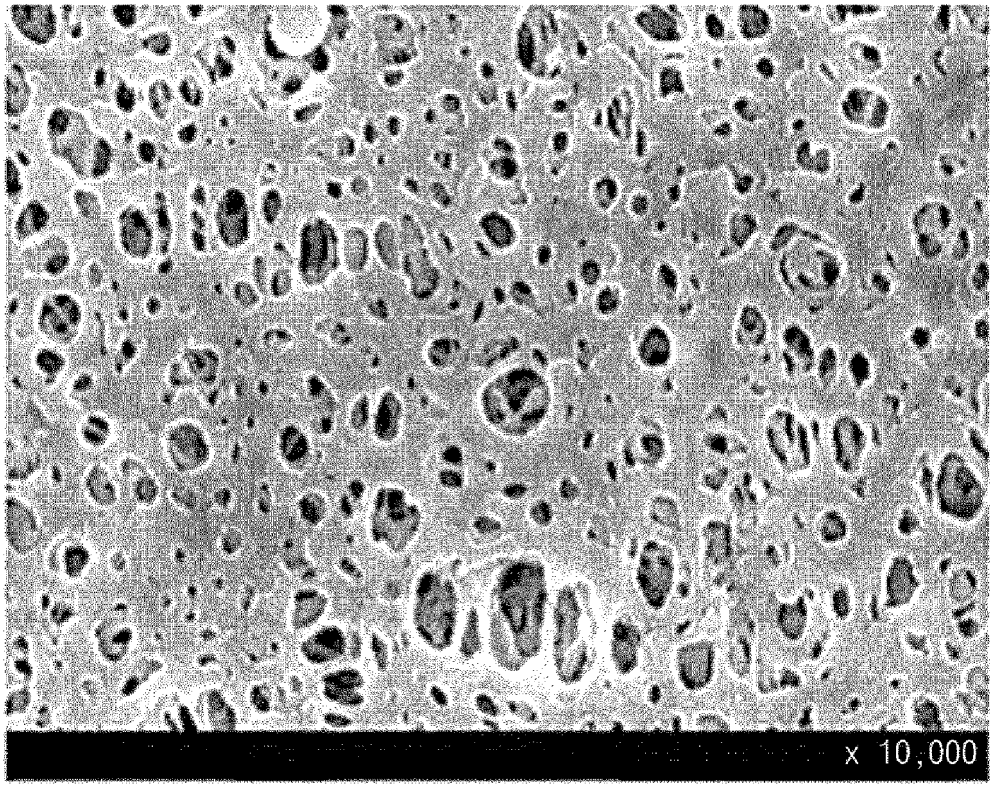
manufacturing a separation membrane having a coating layer disposed on one surface (S10);
installing a cathode on one surface of the separation membrane having the coating layer disposed and installing an anode on the other surface of both surfaces of the separation membrane (S20); and
installing a bipolar plate on the outside of each of the cathode and the anode (S30),
wherein the step (S10) of manufacturing the separation membrane includes the steps of:

preparing a coating composition comprising an anion exchange ionomer and an organic solvent, and a porous substrate (S1);
applying the coating composition on one surface of the porous substrate to form a coating layer (S2); and
drying the coating layer to manufacture the separation membrane (S3).

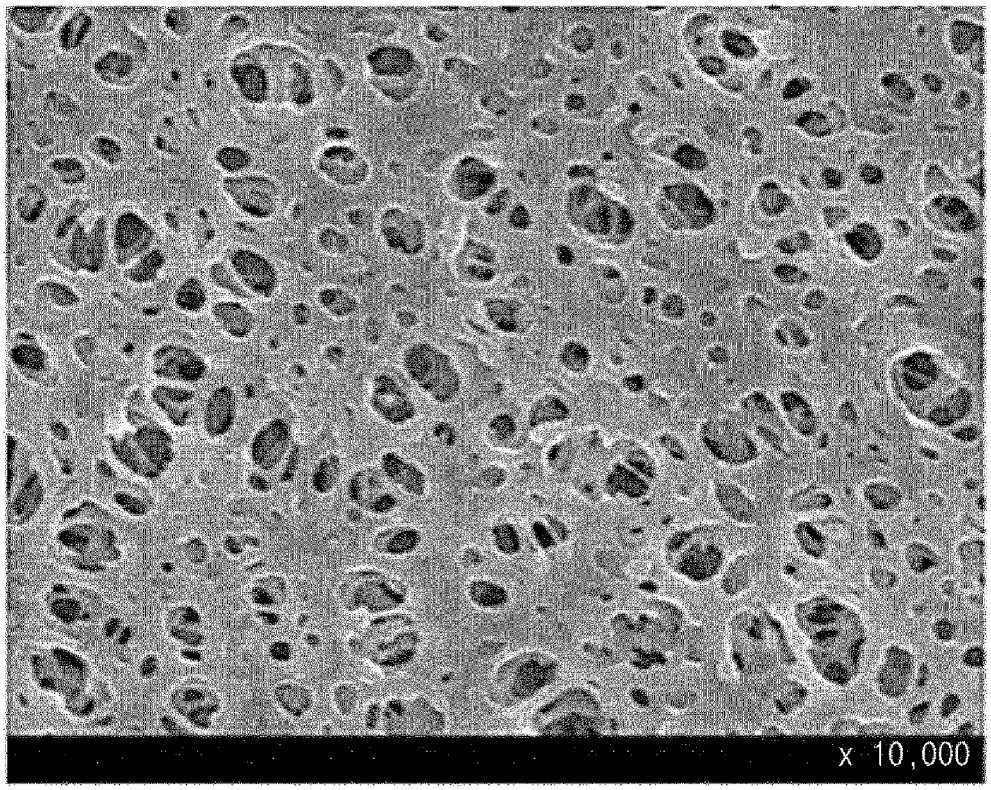
13. The method for manufacturing an electrolysis cell according to claim 12, wherein the coating composition includes 1 wt% or more and 10 wt% or less of the anion exchange ionomer.

14. The method for manufacturing an electrolysis cell according to claim 12, wherein in the step (S30), the coating layer is formed to have a thickness of 1.0 μm or more and 10.0 μm or less.

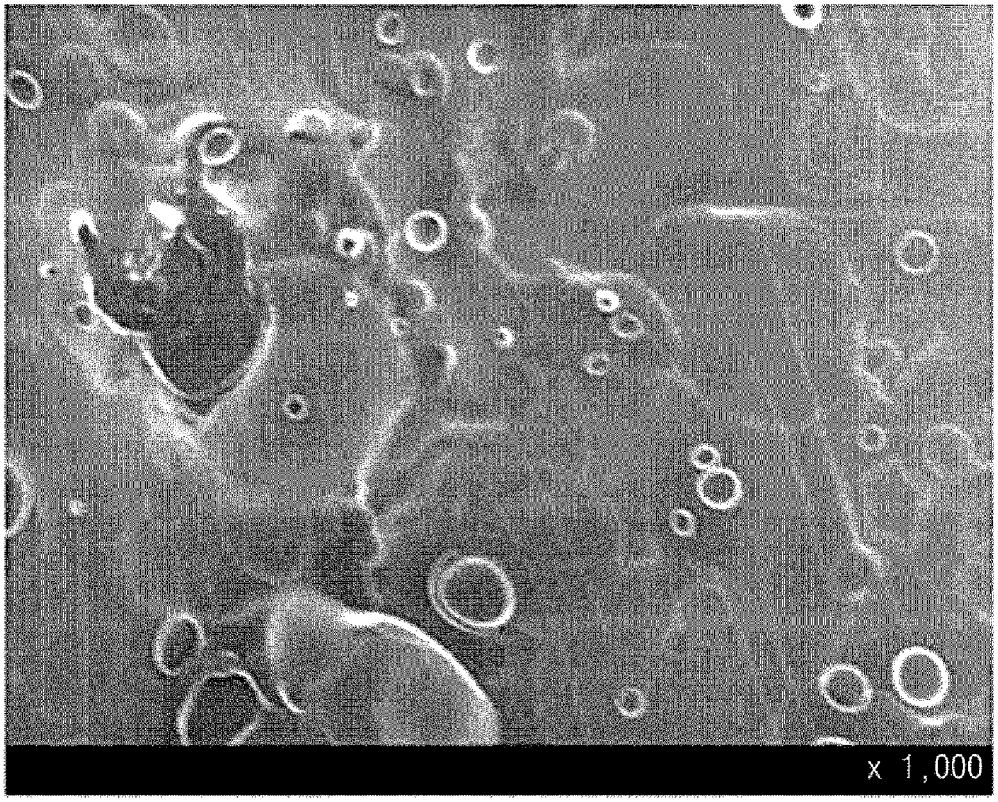
[FIG. 1a]



[FIG. 1b]



[FIG. 2]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/012868

A. CLASSIFICATION OF SUBJECT MATTER

C25B 9/23(2021.01)i; **C25B 13/02**(2006.01)i; **C25B 13/08**(2006.01)i; **C25B 3/26**(2021.01)i; **C25B 3/03**(2021.01)i; **C25B 3/07**(2021.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C25B 9/23(2021.01); C08J 5/22(2006.01); C25B 1/04(2006.01); C25B 1/22(2006.01); C25B 1/23(2021.01); H01M 4/86(2006.01); H01M 4/88(2006.01)

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

Korean utility models and applications for utility models: IPC as above
Japanese utility models and applications for utility models: IPC as above

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

eKOMPASS (KIPO internal) & keywords: 전기분해 셀(electrolysis cell), 분리막(separator), 다공성 기재(porous substrate), 코팅층(coating layer), 음이온 교환 이오노머(anion-exchange ionomer)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2021-0148910 A (DANKOOK UNIVERSITY CHEONAN CAMPUS INDUSTRY ACADEMIC COOPERATION FOUNDATION) 08 December 2021 (2021-12-08) See claims 1-5, 7-9 and 11-14; paragraphs [0003], [0017], [0028], [0046]-[0048], [0050], [0051] and [0060]; and figures 1 and 2.	1-14
Y	KR 10-2023-0042313 A (SZEGEDI TUDOMANYEGYETEM et al.) 28 March 2023 (2023-03-28) See claims 1 and 31; and paragraphs [0003] and [0058].	1-14
Y	KR 10-2021-0132887 A (KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY) 05 November 2021 (2021-11-05) See abstract; and claims 1, 4, 9, 10 and 17.	12-14
A	KR 10-2005-0045878 A (NEC TOKIN CORPORATION) 17 May 2005 (2005-05-17) See abstract; and claims 1-13.	1-14

☑ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 December 2024	**10 December 2024**
Name and mailing address of the ISA/KR **Korean Intellectual Property Office** **Government Complex-Daejeon Building 4, 189 Cheongsa-ro, Seo-gu, Daejeon 35208** Facsimile No. **+82-42-481-8578**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR2024/012868

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 07-258436 A (ASAHI GLASS CO., LTD.) 09 October 1995 (1995-10-09) See abstract; and claims 1-7.	1-14

Form PCT/ISA/210 (second sheet) (July 2022)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR2024/012868

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2021-0148910 A	08 December 2021	KR 10-2544968 B1	20 June 2023
KR 10-2023-0042313 A	28 March 2023	CN 116194621 A	30 May 2023
		EP 4182493 A1	24 May 2023
		EP 4182493 B1	29 May 2024
		US 2024-0209534 A1	27 June 2024
		WO 2022-013583 A1	20 January 2022
KR 10-2021-0132887 A	05 November 2021	KR 10-2415739 B1	05 July 2022
		US 11649551 B2	16 May 2023
		US 2021-0332486 A1	28 October 2021
KR 10-2005-0045878 A	17 May 2005	CN 100617378 A	18 May 2005
		JP 2005-149727 A	09 June 2005
		US 2005-0100778 A1	12 May 2005
JP 07-258436 A	09 October 1995	None	

Form PCT/ISA/210 (patent family annex) (July 2022)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- KR 1020230112690 **[0001]**
- KR 20190125822 A **[0007]**