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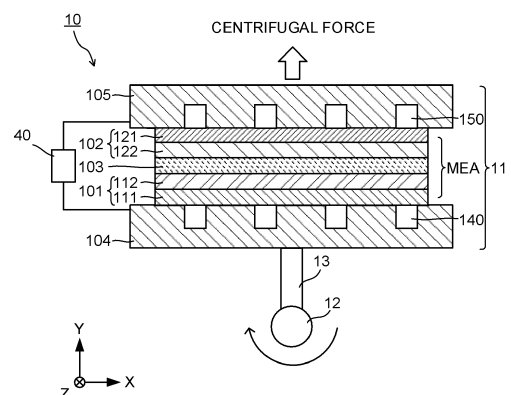
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(54) **ELECTROLYSIS SYSTEM AND METHOD OF DRIVING ELECTROLYSIS SYSTEM**

(57) An electrolysis system includes: an electrolysis cell having an anode to oxidize an oxidizable material to produce an anode product, a cathode to reduce a reducible material to produce a cathode product, a diaphragm between the anode and the cathode, a first flow path plate having an anode flow path facing on the anode and through which an anode fluid containing the oxidizable material flows, and a second flow path plate having a cathode flow path facing on the cathode and through which a cathode fluid containing the reducible material flows, the anode, the cathode, the diaphragm, the first flow path, and the second flow path being stacked in a first direction; a rotary shaft disposed on the opposite side of the cathode from the diaphragm and extending along a second direction; and a driving device to rotate the electrolysis cell around the rotary shaft.

FIG. 2



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Description

FIELD

5 **[0001]** Arrangements relate to an electrolysis system.

BACKGROUND

10 **[0002]** In recent years, sustainably available renewable energy have been increasingly expected in view of the depletion of fossil fuels such as petroleum and coal. The renewable energy can be generated by energy generation technologies such as a photovoltaics and wind power generation. These technologies have a problem of difficulty in stably supplying the power because their power generation amount depends on weather and nature conditions. To solve this problem, an attempt of the energy generation technologies store the power generated from the renewable energy into a storage battery to stabilize the power. However, storing the power has problems of the cost of the storage battery and the occurrence of loss during the power storage.

15 **[0003]** Alternatively, an attracting example of the energy generation technologies reduces a reducible material such as water (H_2O), carbon dioxide (CO_2), or nitrogen (N_2) using power generated from renewable energy to convert it into a chemical substance (chemical energy) such as a carbon compound or a nitrogen compound. Storing these chemical substances in a cylinder or a tank has the advantages of being lower in energy storage cost and smaller in storage loss than storing the power (electric energy) in the storage battery.

RELEVANT REFERENCES

Patent Reference

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[0004]

Reference 1: JP 2013-159503 A

Reference 2: WO 2019/176141 A1

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BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

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FIG. 1 is a block diagram illustrating an example configuration of an electrolysis system.

FIG. 2 is a schematic view illustrating a first example structure of an electrolysis unit 10.

FIG. 3 is a schematic view illustrating the first example structure of the electrolysis unit 10.

FIG. 4 is a schematic view illustrating an example structure of an electrolysis cell stack.

FIG. 5 is a schematic view illustrating a second example structure of the electrolysis unit 10.

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FIG. 6 is a schematic view illustrating a further arrangement of the electrolysis unit 10.

DETAILED DESCRIPTION

[0006] A problem to be solved by arrangements is to reduce electrolysis efficiency degradation.

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[0007] An electrolysis system of an arrangement includes: an electrolysis cell having an anode configured to oxidize an oxidizable material to produce an anode product, a cathode configured to reduce a reducible material to produce a cathode product, a diaphragm provided between the anode and the cathode, a first flow path plate having an anode flow path facing on the anode and through which an anode fluid containing the oxidizable material flows, and a second flow path plate having a cathode flow path facing on the cathode and through which a cathode fluid containing the reducible material flows, the anode, the cathode, the diaphragm, the first flow path plate, and the second flow path plate being stacked in a first direction; a rotary shaft disposed on the opposite side of the cathode from the diaphragm and extending along a second direction intersecting with the first direction; and a driving device configured to rotate the electrolysis cell around the rotary shaft.

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[0008] Arrangements will be hereinafter described with reference to the drawings. In the drawings, the relationship between the thickness and planar dimension of each constituent element, a thickness ratio among constituent elements, and so on may be different from actual ones. An up-down direction may differ from the up-down direction according to the gravitational acceleration. In the arrangements, substantially the same constituent elements are denoted by the same reference signs and a description thereof will be omitted when appropriate.

[0009] In this specification, "connecting" not only includes physically connecting but also electrically connecting and includes not only directly connecting but also indirectly connecting unless specified.

[0010] FIG. 1 is a block diagram illustrating an example configuration of an electrolysis system. The electrolysis system 1 includes an electrolysis unit 10 that performs electrolysis, a rotation driving unit 20 connected to the electrolysis unit 10, and a control unit 30 connected to the electrolysis unit 10 and the rotation driving unit 20.

(First Example Structure of Electrolysis Unit 10)

[0011] FIG. 2 and FIG. 3 are schematic views illustrating a first example structure of the electrolysis unit 10. In FIG. 2 and FIG. 3, an X-axis, a Y-axis orthogonal to the X-axis, and a Z-axis orthogonal to the X-axis and the Y-axis are indicated. FIG. 2 illustrates part of its X-Y section. FIG. 3 illustrates part of its X-Z section.

[0012] The electrolysis unit 10 has an electrolysis cell 11, a rotary shaft 12, and a fixed shaft 13.

[0013] The electrolysis cell 11 has an anode 101, a cathode 102, a diaphragm 103, a flow path plate 104, and a flow path plate 105. For example, the anode 101, the cathode 102, the diaphragm 103, the flow path plate 104, and the flow path plate 105 extend in the X-axis direction and are stacked in the Y-axis direction.

[0014] The anode 101 is capable of oxidizing an oxidizable material (a material to be oxidized) to produce an anode product. Examples of the oxidizable material include water. Examples of the anode product include oxygen (O_2) and hydrogen ions (H^+). The anode 101 is connected to a positive (+) terminal of a power source 40 so that an oxidation reaction occurs in the anode 101. The anode 101 can have any of various forms such as a plate form, a mesh form, a wire form, a granular form, a porous form, a thin film form, and an island form.

[0015] The anode 101 has an anode conductor 111 and an anode catalyst 112.

[0016] The anode conductor 111 is electrically connected to the power source 40 and has a function as an electrode of the anode 101. The anode conductor 111 has a supporting member having a structure allowing liquid and ions to move therethrough between the diaphragm 103 and the anode 101, for example, a porous structure such as a mesh material, a punched material, a porous member, or a sintered metal fiber. The supporting member may be formed of a metal material such as a metal such titanium (Ti), nickel (Ni), or iron (Fe) or an alloy (for example, SUS) containing at least one of these metals, or may be formed of a later-described oxidation catalyst material. In the case where an oxide is used as the oxidation catalyst material, it is preferable to form a catalyst layer by bonding or stacking the oxidation catalyst material on the surface of the supporting member formed of the aforesaid metal material. The oxidation catalyst material preferably has nanoparticles, a nanostructure, a nanowire, or the like to promote the oxidation reaction. The nanostructure is a structure in which nanoscale irregularities are formed on the surface of the catalyst material.

[0017] The anode catalyst 112 is preferably formed of a material (oxidation catalyst material) capable of oxidizing the oxidizable material to produce the anode product and capable of decreasing an overvoltage of such a reaction. Examples of the oxidation catalyst material include metals such as platinum (Pt), palladium (Pd), and nickel (Ni), alloys and inter-metallic compounds containing these metals, binary metal oxides such as manganese oxide (Mn-O), iridium oxide (Ir-O), nickel oxide (Ni-O), cobalt oxide (Co-O), iron oxide (Fe-O), tin oxide (Sn-O), indium oxide (In-O), and ruthenium oxide (Ru-O), ternary metal oxides such as Ni-Co-O, Ni-Fe-O, La-Co-O, Ni-La-O, and Sr-Fe-O, quaternary metal oxides such as Pb-Ru-Ir-O and La-Sr-Co-O, and metal complexes such as a Ru complex and an Fe complex. A composite electrode in which any of these materials is stacked on the supporting member may also be employed as the anode 101.

[0018] The cathode 102 is capable of reducing a reducible material (a material to be reduced) to produce a cathode product. Examples of the reducible material include water, carbon dioxide, and nitrogen. Examples of the cathode product include hydrogen, a carbon compound, and a nitrogen compound. Examples of the reducible material may include hydrogen, a carbon compound, and a nitrogen compound which are obtained through the reduction reaction. The cathode 102 is connected to a negative (-) terminal of the power source 40 so that a reduction reaction occurs in the cathode 102. The cathode 102 has, in at least part thereof, a site capable of electrically reducing water, carbon dioxide, or nitrogen (hereinafter, referred to as a reducing site).

[0019] Examples of the carbon compound include carbon monoxide (CO), formic acid (HCOOH), methane (CH_4), methanol (CH_3OH), acetic acid (CH_3COOH), ethane (C_2H_6), ethylene (C_2H_4), ethanol (C_2H_5OH), formaldehyde (HCHO), acetaldehyde (CH_3CHO), ethylene glycol ($HOCH_2CH_2OH$), 1-propanol ($CH_3CH_2CH_2OH$), isopropanol ($CH_3CHOHCH_3$), acetylene (C_2H_2), glycerol ($C_3H_8O_3$), dihydroxyacetone ($C_3H_6O_3$), hydroxypyruvic acid ($C_3H_4O_4$), mesoxalic acid ($C_3H_2O_5$), oxalic acid ($C_2H_2O_4$), glyceraldehyde ($C_3H_6O_3$), glyceric acid ($C_3H_6O_4$), tartaric acid ($C_4H_4O_5$), glycolic acid ($C_2H_4O_3$), glyoxal ($C_2H_2O_2$), glycolaldehyde ($C_2H_4O_2$), and glyoxylic acid ($C_2H_2O_3$).

[0020] Examples of the nitrogen compound include ammonia, urea, uric acid, and amino acid.

[0021] The cathode 102 may be immersed in an electrolytic solution or may be in contact with the electrolytic solution. The cathode 102 may be in contact with water vapor, a carbon dioxide gas, or a nitrogen gas. The cathode 102 may be in contact with the water vapor, the carbon dioxide gas, or the nitrogen gas dissolved in the electrolytic solution.

[0022] The cathode 102 has a cathode conductor 121 and a cathode catalyst 122.

[0023] The cathode conductor 121 is electrically connected to the power source 40 and has a function as an electrode

of the cathode 102. FIG. 2 illustrates a state in which the cathode conductor 121 is connected directly to the cathode catalyst 122, but the form of the cathode conductor 121 is not limited to this. The cathode conductor 121 may be physically separated from the cathode catalyst 122 as well as electrically connected to the cathode catalyst 122. The cathode conductor 121 only needs to be capable of passing a current supplied from the power source 40 to the cathode catalyst 122. In the case where the cathode catalyst 122 itself has the conductivity that the electrode requires, the cathode catalyst 122 may function also as the cathode conductor 121 without the cathode conductor 121 being provided.

[0024] The cathode conductor 121 can be formed using a metal material containing at least one metal element selected from gold (Au), silver (Ag), copper (Cu), platinum (Pt), nickel (Ni), zinc (Zn), palladium (Pd), aluminum (Al), iron (Fe), manganese (Mn), titanium (Ti), tin (Sn), indium (In), gallium (Ga), and bismuth (Bi). The metal material may be an element metal of any of the aforesaid metal elements or may be an alloy containing the aforesaid metal elements, for example, an alloy such as SUS, or an intermetallic compound. Further, the cathode conductor 121 may be formed using, for example, a light-transmissive and conductive metal oxide such as ITO (Indium Tin Oxide), ZnO (Zinc Oxide), FTO (Fluorine-doped Tin Oxide), AZO (Aluminum-doped Zinc Oxide), or ATO (Antimony-doped Tin Oxide), a semiconductor such as silicon or germanium, a conductive resin, or a conductive ion exchange membrane. The cathode conductor 121 may be formed using a carbon material such as carbon black, carbon nanotube, or fullerene. The cathode conductor 121 may be, for example, a stack including a metal material layer and another conductive material layer or a stack including a conductive material layer other than the metal material layer and another conductive material layer.

[0025] The cathode conductor 121 may have a porous structure having pores or a structure having through holes that allows the electrolytic solution to pass therethrough. The through holes each may be a structure continuing from the cathode conductor 121 up to the cathode catalyst 122. The porous structure can be obtained by, for example, a method of forming the pores by etching a member, a method using a porous material, or the like. The cathode conductor 121 having the porous structure preferably has the distribution of the pores of not less than 1 mm nor more than 20 mm, for instance. The through holes can be formed by the etching of the cathode conductor 121, for instance. In the cathode conductor 121 having the porous structure, the pores communicating with one another can be regarded as a through hole. The cathode conductor 121 having the porous structure or the through holes achieves the high diffusibility of ions and a reactant through the pores or the through holes while having high conductivity and a wide surface area of an active surface.

[0026] The cathode catalyst 122 has a site (reducing site) capable of reducing the reducible material. The cathode catalyst 122 only needs to have the reducing site at least on its surface, but the reducing site is preferably present up to the inside of the porous member. It is possible to form the cathode catalyst 122 having the reducing site using, for example, a reduction catalyst material, that is, a material that decreases activation energy for reducing the reducible material, in other words, a material that lowers an overvoltage at the time of producing hydrogen, a carbon compound, or a nitrogen compound through the reduction reaction (material forming the reducing site/reduction catalyst material). The cathode catalyst 122 is preferably formed of the material forming the reducing site (reduction catalyst material).

[0027] In the case where the cathode catalyst 122 is formed of the reduction catalyst material, examples of the reduction catalyst material include a metal material containing at least one metal element selected from gold (Au), silver (Ag), copper (Cu), platinum (Pt), nickel (Ni), zinc (Zn), and palladium (Pd). The metal material as the reduction catalyst material may be an element metal of any of the aforesaid metal elements or may be an alloy containing the aforesaid metal elements.

[0028] The cathode catalyst 122 is not limited to a structure entirely formed of the reduction catalyst material. The cathode catalyst 122 having the reducing site may have a configuration in which the cathode catalyst 122 is formed of a metal material other than the reduction catalyst material and the reduction catalyst material is present on its surface. The reduction catalyst material may also be present inside the cathode catalyst 122. Examples of a method of making the reduction catalyst material present in the cathode catalyst 122 include a method of coating the cathode catalyst 122 with a material such as particulates (nanoparticles), a dispersion liquid, or a solution of the reduction catalyst material, but the method is not limited to this. In such a case, in addition to the aforesaid metal material (Au, Ag, Cu, Pt, Ni, Zn, Pd), a carbon material such as carbon, graphene, carbon nanotube, fullerene, or ketjen black or a metal complex such as a Ru complex or a Re complex may be used as the reduction catalyst material. Further, the reduction catalyst material may be a composite material containing at least two or more of the aforesaid metal material, carbon material, and metal complex or may contain organic molecules.

[0029] The cathode catalyst 122 may be made of a reduction catalyst material capable of reducing nitrogen to produce ammonia. Examples of such a material include a molybdenum complex. Examples thereof include the following molybdenum complexes (A) to (D).

[0030] A first example includes (A) a molybdenum complex having, as a PCP ligand, N,N-bis(dialkyl-phosphinomethyl)dihydrobenzoimidazolidine (where the two alkyl groups may be identical or different, and at least one hydrogen atom of the benzene ring may be replaced by an alkyl group, an alkoxy group, or a halogen atom).

[0031] A second example includes (B) a molybdenum complex having, as a PNP ligand, 2,6-bis(dialkyl-phosphinomethyl)pyridine (where the two alkyl groups may be identical or different, and at least one hydrogen atom of the pyridine

ring may be replaced by an alkyl group, an alkoxy group, or a halogen atom).

[0032] A third example includes (C) a molybdenum complex having, as a PPP ligand, bis(dialkyl-phosphinomethyl)aryl-phosphine (where the two alkyl groups may be identical or different).

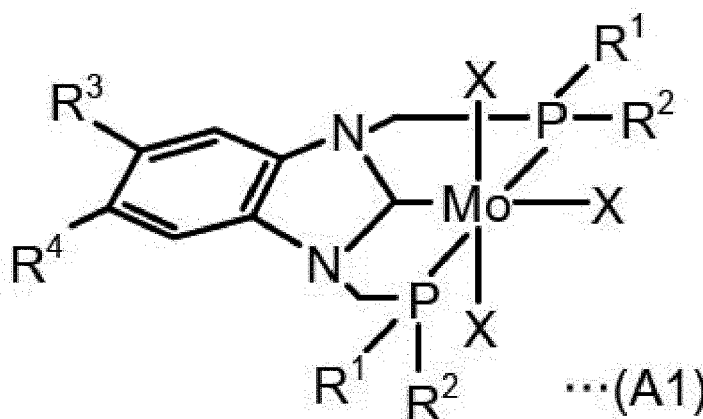
[0033] A fourth example includes (D) a molybdenum complex represented by $\text{trans-Mo}(\text{N}_2)_2(\text{R}^1\text{R}^2\text{R}^3\text{P})_4$ (where R^1 , R^2 , and R^3 are alkyl groups or aryl groups that may be identical or different, and the two R^3 s may be connected to form an alkylene chain).

[0034] In the aforesaid molybdenum complexes, examples of the alkyl group may include a methyl group, an ethyl group, a propyl group, a butyl group, a pentyl group, a hexyl group, and straight-chain or branched alkyl groups such as structural isomers of these, and may include cyclic alkyl groups such as a cyclopropyl group, a cyclobutyl group, a cyclopentyl group, and a cyclohexyl group. The carbon number of the alkyl group is preferably 1 to 12, and more preferably 1 to 6. Examples of the alkoxy group may include a methoxy group, an ethoxy group, a propoxy group, a butoxy group, a pentoxy group, a hexyloxy group, and straight-chain or branched alkoxy groups such as structural isomers of these, and may include cyclic alkoxy groups such as a cyclopropoxy group, a cyclobutoxy group, a cyclopentoxy group, and a cyclohexyloxy group. The carbon number of the alkoxy group is preferably 1 to 12, and is more preferably 1 to 6.

Examples of the halogen atom include a fluorine atom, a chlorine atom, a bromine atom, and an iodine atom.

[0035] Examples of (A) the molybdenum complex include a molybdenum complex represented by the following formula (A1).

[Chem. 1]

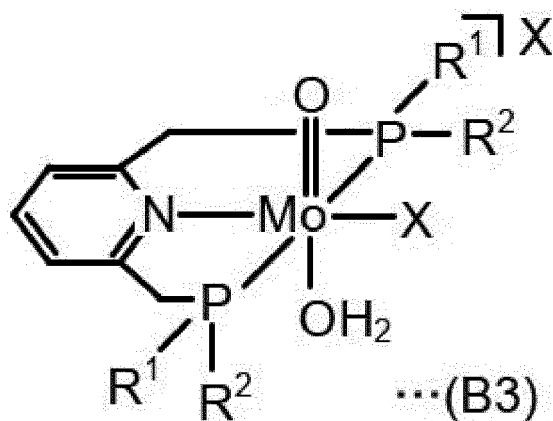
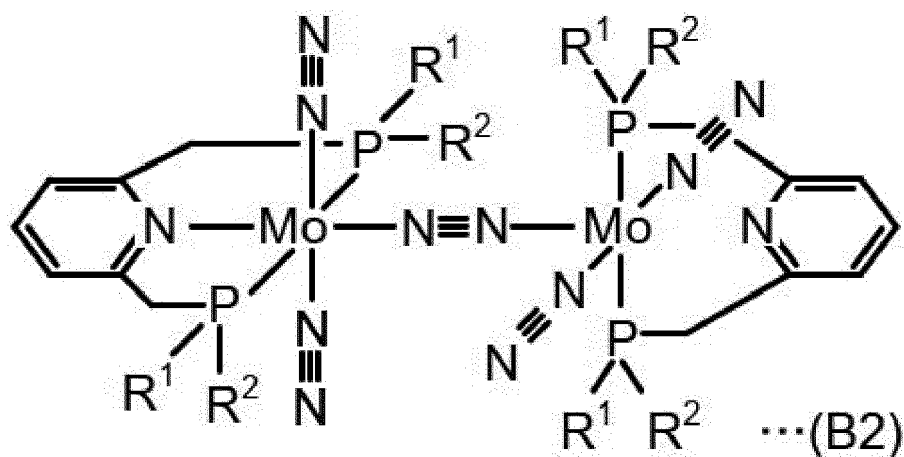
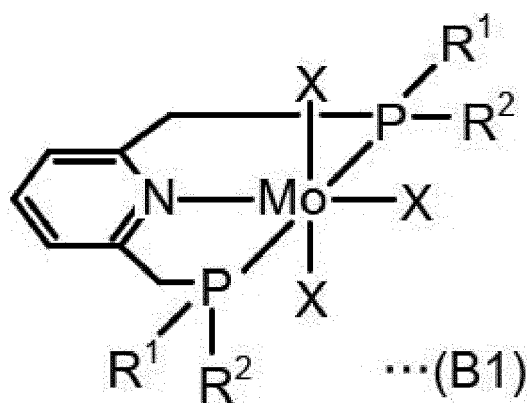


(where R^1 and R^2 are alkyl groups that may be identical or different, X is an iodine atom, a bromine atom, or a chlorine atom, and at least one hydrogen atom on the benzene ring may be replaced by an alkyl group, an alkoxy group, or a halogen atom).

[0036] Examples of the alkyl group, the alkoxy group, and the halogen atom include the same functional groups and atoms as the functional groups and the atoms previously mentioned as examples. R^1 and R^2 are preferably bulky alkyl groups (for example, tert-butyl groups or isopropyl groups). Preferably, on the benzene ring, hydrogen atoms are not replaced, or hydrogen atoms in position 5 and position 6 are replaced by chain, cyclic, or branched alkyl groups whose carbon numbers are 1 to 12.

[0037] Examples of (B) the molybdenum complex include molybdenum complexes represented by the following formula (B 1), formula (B2), and formula (B3).

[Chem. 2]

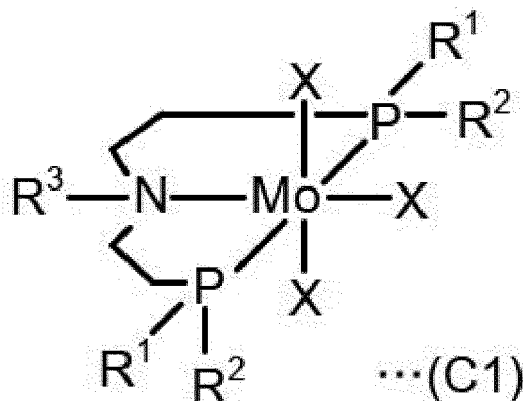


(where R¹ and R² are alkyl groups that may be identical or different, X is an iodine atom, a bromine atom, or a chlorine atom, and at least one hydrogen atom on the pyridine ring may be replaced by an alkyl group, an alkoxy group, or a halogen atom).

[0038] Examples of the alkyl group, the alkoxy group, and the halogen atom include the same functional groups and atoms as the functional groups and the atoms previously mentioned as examples. R¹ and R² are preferably bulky alkyl groups (for example, tert-butyl groups or isopropyl groups). Preferably, on the pyridine ring, hydrogen atoms are not replaced, or a hydrogen atom in position 4 is replaced by a chain, cyclic, or branched alkyl group whose carbon number is 1 to 12.

[0039] Examples of (C) the molybdenum complex include a molybdenum complex represented by the following formula (C1).

[Chem. 3]

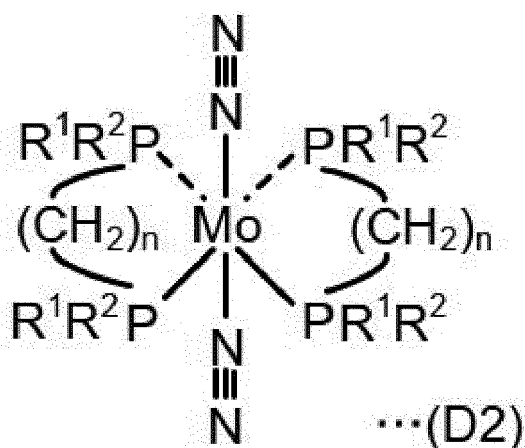
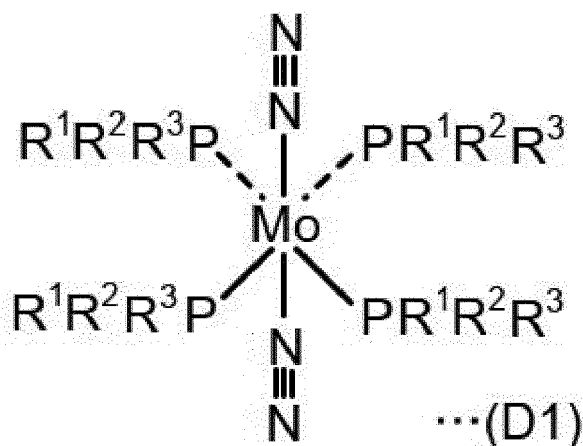


(where R¹ and R² are alkyl groups that may be identical or different, R³ is an aryl group, and X is an iodine atom, a bromine atom, or a chlorine atom).

[0040] Examples of the alkyl group include the same functional groups as the functional groups previously mentioned as examples. Examples of the aryl group include a phenyl group, a tolyl group, a xylyl group, a naphthyl group, and a functional group in which at least one of cyclic hydrogen atoms of these is replaced by an alkyl group or a halogen atom. Examples of the alkyl group and the halogen atom include the same functional groups and atoms as the functional groups and the atoms previously mentioned as examples. R¹ and R² are preferably bulky alkyl groups (for example, tert-butyl groups or isopropyl groups). Preferably, R³ is a phenyl group.

[0041] Examples of (D) the molybdenum complex include molybdenum complexes represented by the following formula (D1) and formula (D2).

[Chem. 4]



(where R¹, R², and R³ are alkyl groups or aryl groups that may be identical or different, and N is 2 or 3).

[0042] Examples of the alkyl group and the aryl group include the same functional groups as the functional groups previously mentioned as examples. In formula (D), preferably, R¹ and R² are aryl groups (for example, phenyl groups) and R³ is an alkyl group (for example, a methyl group) whose carbon number is 1 to 4, or R¹ and R² are alkyl groups (for example, methyl groups) whose carbon numbers are 1 to 4 and R³ is an aryl group (for example, a phenyl group). In formula (D2), preferably, R¹ and R² are aryl groups (for example, phenyl groups) and N is 2.

[0043] The diaphragm 103 is provided between the anode 101 and the cathode 102. The diaphragm 103 is constituted by an ion exchange membrane or the like that allows ions to move therethrough between the anode 101 and the cathode 102 and is capable of separating the anode 101 and the cathode 102. Examples of the ion exchange membrane include cation exchange membranes such as Nafion and Flemion and anion exchange membranes such as Neosepta and Selemion. Besides these, any material that allows ions to move therethrough between the anode 101 and the cathode 102 is usable as the diaphragm 103.

[0044] The anode 101, the cathode 102, and the diaphragm 103 form a membrane electrode assembly MEA. The membrane electrode assembly MEA has a conductive structure when a voltage is applied between the anode 101 and the cathode 102 through the diaphragm 103 or the electrolytic solution, or through both of these, and has an insulative structure when the voltage is not applied.

[0045] The flow path plate 104 has an anode flow path 140. The anode flow path 140 faces on the anode 101 and faces on the anode conductor 111. The anode flow path 140 allows an anode fluid containing the oxidizable material to flow. The anode fluid contains a solution containing at least water. The inlet of the anode flow path 140 may be connected to an anode supply source that supplies the oxidizable material. The outlet of the anode flow path 140 may be connected to an anode fluid collector that collects the anode fluid. The shape of the anode flow path 140 is not limited, but for example, they may have a strip shape or a serpentine shape in their X-Z sections, for instance. Fig. 2 shows a plurality of the anode flow paths 140.

[0046] Examples of the water-containing solution include an electrolytic solution containing an optional electrolyte. This solution is preferably an aqueous solution that promotes the oxidation reaction of water. Examples of the electrolytic solution include aqueous solutions containing ions such as phosphate ions (PO_4^{2-}), borate ions (BO_3^{3-}), hydrogen carbonate ions (HCO_3^-), sodium ions (Na^+), potassium ions (K^+), calcium ions (Ca^{2+}), lithium ions (Li^+), cesium ions (Cs^+), magnesium ions (Mg^{2+}), chloride ions (Cl^-), bromide ions (Br^-), and iodide ions (I^-).

[0047] The solution containing H_2O and CO_2 preferably has high H_2O and CO_2 absorptance, and examples thereof include aqueous solutions of LiHCO_3 , NaHCO_3 , KHCO_3 , and CSHCO_3 . The solution containing H_2O and CO_2 may be alcohols such as methanol, ethanol, and acetone. Preferably, the solution containing H_2O , CO_2 , and N_2 is a solution that lowers the reduction potentials of H_2O , CO_2 , and N_2 , has high ion conductivity, and contains an H_2O , CO_2 , and N_2 absorbent that absorbs H_2O , CO_2 , and N_2 . As such a solution, an ionic liquid that is composed of a salt of cations such as imidazolium ions and pyridinium ions and anions such as BF_4^- and PF_6^- and is in a liquid form in a wide temperature range may be used or an aqueous solution thereof may be used. Other examples of the solution include solutions of amines such as ethanolamine, imidazole, and pyridine and aqueous solutions thereof. The amine may be any of primary amine, secondary amine, and tertiary amine.

[0048] The flow path plate 105 has a cathode flow path 150. The cathode flow path 150 faces on the cathode 102 and faces on the cathode conductor 121. The cathode flow path 150 allows a cathode fluid containing the reducible material to flow. The cathode fluid contains the reducible material such as water, carbon dioxide, or nitrogen. The inlet of the cathode flow path 150 may be connected to a cathode supply source that supplies the reducible material. The outlet of the cathode flow path 150 may be connected to a cathode fluid collector that collects the cathode fluid. The shape of the cathode flow path 150 is not limited, but they may have a strip shape or a serpentine shape in their X-Z sections, for instance. Fig. 2 shows a plurality of the cathode flow paths 150.

[0049] The power source 40 is not limited to a typical system power supply or a battery, but examples thereof may include power sources that supply power generated by renewable energy, such as a photovoltaics and wind power generation. The power source 40 may further have a power controller that adjusts an output of the power source to control the voltage between the anode 101 and the cathode 102. The power source 40 may be provided outside the electrolysis unit 10. The power source 40 may supply the power to the anode 101 and the cathode 102 through the flow path plate 104 and the flow path plate 105 respectively. A conductive member may be provided between the anode 101 and the flow path plate 104 or between the cathode 102 and the flow path plate 105.

[0050] The rotary shaft 12 is rotatable in, for example, the X-Y plane. The rotary shaft 12 is connected to the electrolysis cell 11 via the fixed shaft 13. The fixed shaft 13 is connected to, for example, the flow path plate 104, on the opposite side of the anode flow path 140. The rotary shaft 12 has the rotation center in the Z-axis direction. The rotary shaft 12 is provided on the opposite side of the diaphragm 103 from the anode 101. The rotary shaft 12 may be included in or separated from the flow path plate 104. The rotary shaft 12 preferably extends along the direction of gravitational force.

[0051] The rotation driving unit 20 is connected to the rotary shaft 12 and is capable of rotating the electrolysis cell 11 around the rotary shaft 12. The rotation driving unit 20 has a rotation driving device that rotates the electrolysis cell 11 in response to a control signal from the control unit 30, for instance.

[0052] The control unit 30 can control the rotation driving device to control the rotation operation caused by the rotation driving unit 20. The control unit 30 can control the electrolysis unit 10 to control the electrolysis operation of the electrolysis cell 11. The control unit 30 may be constituted using hardware that uses a processor or the like, for instance. These operations may be stored as an operating program in a computer-readable recording medium such as a memory, and the operations may be executed by the hardware reading the operating program stored in the recording medium when required.

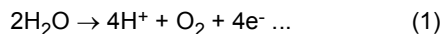
[0053] The electrolysis unit 10 may have a stack of a plurality of the electrolysis cells 11. FIG. 4 is a schematic view illustrating an example structure of the electrolysis cell stack. The electrolysis cell stack illustrated in FIG. 4 has the plurality of electrolysis cells 11, and the electrolysis cells 11 are stacked in the Y-axis direction. Between the plurality of membrane electrode assemblies MEA, the electrolysis cell stack may have a flow path plate 106 instead of the flow path plate 104 or the flow path plate 105. The flow path plate 106 has a first surface having the anode flow path 140 facing on the anode 101 and a second surface having the cathode flow path 150 facing on the cathode 102. The number of the stacked electrolysis cells 11 is not limited to the number illustrated in FIG. 4. For the other description of the electrolysis cell stack, the description of FIG. 2 and FIG. 3 can be referred to as required.

[0054] Next, an example method of driving the electrolysis system 1 will be described. The example method includes supplying the oxidizable material to the anode flow path 140, supplying the reducible material to the cathode flow path 150, and applying a voltage between the anode 101 and the cathode 102 from the power source 40 to supply a current between the anode 101 and the cathode 102. Consequently, the electrolysis cell 11 performs electrolysis.

[0055] Passing the current to the anode 101 and the cathode 102 causes the following oxidation reaction near the anode 101 and the following reduction reaction near the cathode 102. The description here is of the case where carbon monoxide (CO) which is an anode product is produced through the reduction of carbon dioxide which is the reducible material, but the anode product is not limited to carbon monoxide and may be the other carbon compound or nitrogen

compound previously described such as an organic compound. Known examples of a reaction process by the electrolysis cell include a reaction process of producing mainly hydrogen ions (H^+) and a reaction process of producing mainly hydroxide ions (OH^-), but the reaction process is not limited to these reaction processes.

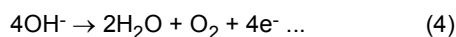
[0056] The reaction process of mainly producing hydrogen ions (H^+) by oxidizing water (H_2O) will be described. Supplying the current between the anode 101 and the cathode 102 causes the oxidation reaction of water in the anode 101 in contact with the oxidizable material flowing in the anode flow path 140. Specifically, as represented by the following formula (1), water contained in the anode fluid is oxidized, resulting in the production of oxygen (O_2) and hydrogen ions (H^+).



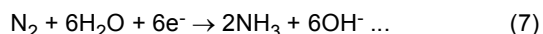
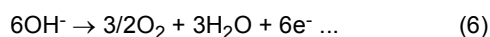
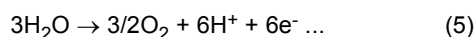
[0057] H^+ produced in the anode 101 moves in the cathode fluid in the cathode flow path 150 through the anode 101 and the diaphragm 103 to reach the vicinity of the cathode 102. With electrons (e^-) based on the current supplied to the cathode 102 from the power source 40 and H^+ which has moved to the vicinity of the cathode 102, the reduction reaction of carbon oxide occurs. Specifically, as represented by the following formula (2), carbon dioxide contained in the reducible material supplied to the cathode 102 from the cathode flow path 150 is reduced, resulting in the production of carbon monoxide.



[0058] Next, the reaction process of mainly producing hydroxide ions (OH^-) by reducing carbon dioxide (CO_2) will be described. When the current is supplied between the anode 101 and the cathode 102, water (H_2O) and carbon dioxide (CO_2) are reduced in the vicinity of the cathode 102, resulting in the production of carbon monoxide (CO) and hydroxide ions (OH^-) as represented by the following formula (3). The hydroxide ions (OH^-) diffuse to the vicinity of the anode 101, and the hydroxide ions (OH^-) are oxidized, resulting in the production of oxygen (O_2) as represented by the following formula (4).



[0059] In the case where ammonia (NH_3) which is the anode product is produced through the reduction of nitrogen (N_2) which is the reducible material, in the vicinity of the anode 101, water or hydroxide ions are electrochemically oxidized based on the following formula (5) or formula (6), resulting in the production of oxygen. In the vicinity of the cathode 102, nitrogen is reduced based on the following formula (7) or formula (8), resulting in the production of ammonia.



[0060] The cathode fluid containing the cathode product is discharged from the outlet of the cathode flow path 150 and is separated into a cathode discharge gas and a cathode discharge liquid using a gas/liquid separator. The cathode discharge gas and the cathode discharge liquid may be further separated into compounds using another separating device. This enables the collection of the cathode product. However, the cathode product, if having a high viscosity in an operating temperature range of the electrolysis cell 11, may adhere to the cathode 102 to be difficult to detach. The operating temperature range of the electrolysis cell 11 is, for example, not lower than 25°C nor higher than 200°C.

[0061] To activate the reduction reaction, a microstructure of the cathode catalyst 122 is preferably formed. Examples thereof include a cathode having, in an electrode member, a nanoparticle catalyst exhibiting high activity to the reduction reaction of carbon dioxide. It is possible to increase reaction active sites of the reduction reaction by increasing the amount of the loaded catalyst. However, some cathode product has a problem of difficulty in detaching from the cathode 102 because of its high viscosity, and thus inhibits the progress of sequential catalytic reactions. This will be a cause of electrolysis efficiency degradation. Examples of the cathode product having a high viscosity include ethylene glycol.

[0062] The anode fluid containing the anode product is discharged from the outlet of the anode flow path 140 and is separated into an anode discharge gas and an anode discharge liquid using a gas/liquid separator. The anode discharge

gas and the anode discharge liquid may be further separated into compounds using another separating device. This enables the collection of the anode product. However, in the case where the anode product contains gas, an increase in the amount of the gas prevents a liquid contained in the oxidizable material from reaching the anode 101. This causes electrolysis efficiency degradation.

[0063] In contrast, the electrolysis system of the arrangement includes that the control unit 30 controls the rotation driving unit 20 to rotate the electrolysis cell 11 around the rotary shaft 12. The rotation of the electrolysis cell 11 generates centrifugal force toward the outer side of the electrolysis cell 11 (to the opposite side of the rotary shaft 12 from the electrolysis cell 11). The arrow indicates the direction of the centrifugal force.

[0064] The centrifugal separation enables the cathode product to easily detach from the cathode 102 and the detached cathode product to easily flow through the cathode flow path 150. This enables the efficient collection of the cathode product. In the case where the cathode product contains gas and is smaller in molecular weight than the reducible material such as carbon dioxide or nitrogen, the centrifugal separation does not hinder the collection of the cathode product. On the other hand, in the case where the cathode product contains gas and is larger in molecular weight than the reducible material such as carbon dioxide or nitrogen, adjusting the size and the centrifugal separation speed can assist the collection of the cathode product. Therefore, it is possible to reduce electrolysis efficiency degradation.

[0065] The centrifugal separation facilitates the movement of the oxidizable material to a more outer side than the anode product and facilitates the movement of the anode product to a more inner side than the oxidizable material. This is because the oxidizable material is larger in specific gravity than the anode product. This can efficiently supply the oxidizable material to the anode 101 to cause the oxidation reaction and also to collect the anode product. Therefore, it is possible to reduce electrolysis efficiency degradation.

[0066] The rotation operation may be performed after stopping or finishing the electrolytic reaction or may be concurrent with the electrolytic reaction. For example, the rotation of the electrolysis cell 11 can be performed with the application of the voltage between the anode 101 and the cathode 102 by forming a structure in which a first electrode that can be in contact with the flow path plate 104 and a second electrode that can be in contact with the flow path plate 105 are provided on the Z-axis-direction lower part and upper part of the flow path plate 104 and the flow path plate 105, connecting the first electrode and the second electrode to the power source 40, and rotating the electrolysis cell 11 on the first electrode and the second electrode. In the case where the rotation operation is performed after stopping or finishing the electrolysis reaction, the rotation operation may be performed after the supply of the oxidizable material, the supply of the reducible material, and the supply of the current to the anode 101 and the cathode 102 are stopped.

[0067] The cathode fluid may contain a gaseous substance involved in neither the oxidization nor the reduction. The supply of the gaseous substance can be performed by supplying a mixed gas containing the reducible material and the gaseous substance to the cathode flow path 150, for instance. The gaseous substance can dissolve the cathode product. The gaseous substance may preferably have a viscosity lower than the viscosity of the cathode product in the operating temperature range of the electrolysis cell 11. Examples of the gaseous substance include water vapor, acidic compounds such as hydrogen chloride and nitric acid, basic compounds such as ammonia and hydrazine, and organic solvents such as methanol, ethanol, propanol, hexane, and chloroform. The use of the gaseous product enables the efficient collection of even a cathode product with a high viscosity since the cathode product is soluble in the gaseous substance. Preferably, the gaseous substance does not liquefy after being introduced to the cathode flow path 150. This is because due to the centrifugal separation, the liquefied gaseous substance stays on the flow path plate 105 side and is difficult to move toward the cathode 102. However, if it is possible to block the supply of the reducible material by intentionally introducing and liquefying a large amount of the gaseous substance, the gaseous substance is prevented from staying in the flow path plate 105 due to the centrifugal separation and can reach the cathode 102, making it possible to dissolve the high-viscosity cathode product and collect it.

(Second Example Structure of Electrolysis Unit 10)

[0068] FIG. 5 is a schematic view illustrating a second example structure of the electrolysis unit 10. In FIG. 5, an X-axis, a Y-axis orthogonal to the X-axis, and a Z-axis orthogonal to the X-axis and the Y-axis are indicated. FIG. 5 illustrates part of the outer appearance view.

[0069] The second example structure of the electrolysis unit 10 differs from the first example structure in its configuration in which the electrolysis cell 11 has a cylindrical shape (a columnar shape) extending in the Z-axis direction. In the following, parts different from those of the first example structure will be described, and for the other parts, the description of the first example structure can be referred to as required.

[0070] Fig. 5 shows that a membrane electrode assembly MEA surrounds a flow path plate 104 and is surrounded by a flow path plate 105. In this case, an anode 101, a cathode 102, and a diaphragm 103 each have a cylindrical shape extending in the Z-axis direction. An anode conductor 111 may surround the flow path plate 104. An anode catalyst 112 may surround the anode conductor 111. The diaphragm 103 may surround the anode catalyst 112. A cathode catalyst 122 may surround the diaphragm 103. A cathode conductor 121 may surround the cathode catalyst 122. The flow path

plate 105 may surround the cathode conductor 121.

[0071] The anode flow path 140 and cathode flow path 150 each preferably have a strip shape extending in the Z-axis direction. In this case, the anode flow path 140 and the cathode flow path 150 may penetrate through the flow path plate 104 and the flow path plate 105 respectively in the Z-axis direction. The anode flow path 140 is provided along the inner periphery of the membrane electrode assembly MEA. The cathode flow path 150 are provided along the outer periphery of the membrane electrode assembly MEA. Fig. 5 shows a plurality of the anode flow paths 140 and a plurality of the cathode flow paths 150.

[0072] A rotary shaft 12 extends in the Z-axis direction and, for example, along the center of the flow path plate 104. The rotary shaft 12 is preferably along the direction of gravitational force.

[0073] In an electrolysis system of the second arrangement, as in the first arrangement, the control unit 30 controls the rotation driving unit 20 to rotate an electrolysis cell 11 around the rotary shaft 12. The rotation of the electrolysis cell 11 generates centrifugal force toward the outer side of the electrolysis cell 11 (to the opposite side of the rotary shaft 12 from the electrolysis cell 11 (to the opposite side of MEA from the flow path plate 105). The arrows indicate the directions of the centrifugal force.

[0074] The centrifugal separation enables a cathode product to easily detach from the cathode 102 and enables the detached cathode product to flow through the cathode flow path 150. This enables the efficient collection of the cathode product. In the case where the cathode product contains gas and is smaller in molecular weight than a reducible material such as carbon dioxide or nitrogen, the centrifugal separation does not hinder the collection of the cathode product. On the other hand, in the case where the cathode product contains gas and is larger in molecular weight than the reducible material such as carbon dioxide or nitrogen, adjusting the size and the centrifugal separation speed can assist the collection of the cathode product. Therefore, it is possible to reduce electrolysis efficiency degradation.

[0075] The centrifugal separation enables an oxidizable material to easily move to a more outer side than an anode product and enables the anode product to easily move to a more inner side than the oxidizable material. This is because the oxidizable material is larger in specific gravity than the anode product. This can efficiently supply the oxidizable material to the anode 101 to cause an oxidation reaction and to collect the anode product. Therefore, it is possible to reduce electrolysis efficiency degradation.

[0076] The rotation operation may be performed after stopping or finishing the electrolytic reaction or may be concurrent with the electrolytic reaction. For example, The application of the voltage between the anode 101 and the cathode 102 with the rotation of the electrolysis cell 11 by forming a structure in which a first electrode that can be in contact with the flow path plate 104 and a second electrode that can be in contact with the flow path plate 105 are provided on the Z-axis-direction upper parts or lower parts of the flow path plate 104 and the flow path plate 105, connecting the first electrode and the second electrode to the power source 40, and rotating the electrolysis cell 11 on the first electrode and the second electrode.

[0077] The cathode product may be moved downward by gravity. On the other hand, in the case where the reducible material is supplied to the cathode 102 from a lower side of the electrolysis cell 11, it is possible to collect an unreacted residue of the reducible material from the upper part of the cathode flow path 150, enabling the efficient reuse of the unreacted residue.

[0078] Since centrifugal force is proportional to the square of an angular velocity and is proportional to a radius of rotation, the higher the rotation speed of the electrolysis cell 11, the more preferable, and the longer the distance from the rotary shaft 12 to the anode 101 and the distance from the rotary shaft 12 to the cathode 102, the more preferable.

(Further Arrangement of Electrolysis Unit 10)

[0079] FIG. 6 is a schematic view illustrating a further arrangement of the electrolysis unit 10. The electrolysis unit 10 illustrated in FIG. 6 is different from that of the first example structure in its configuration further having an anode supply system 200 and a cathode supply system 300 in addition to the first example structure. The anode supply system 200 and the cathode supply system 300 may be controlled by the control unit 30. In the following, parts different from those of the first example structure will be described, and for the other parts, the description of the first example structure can be referred to as required. Not only the first example structure but also the second example structure may be employed.

[0080] The anode supply system 200 has an anode supply source 201, an anode fluid collector 202, an anode supply flow path P1, an anode discharge flow path P2, and an anode circulation flow path P3, and is configured such that an oxidizable material circulates in the anode flow path 140. The anode supply flow path P1 is connected to the inlet of the anode flow path 140. The anode discharge flow path P2 is connected to the outlet of the anode flow path 140. The anode supply flow path P1 and the anode discharge flow path P2 are connected to the anode flow path 140 such that they do not hinder the rotation operation of the electrolysis cell 11. In the anode supply system 200, the anode supply flow path P1 and the anode discharge flow path P2 are connected through the anode circulation flow path P3. A valve or a pump may be formed in the middle of the anode supply flow path P1, the anode discharge flow path P2, or the anode circulation flow path P3 to control the pressure in the flow path and the flow rate of the fluid flowing in the flow path.

[0081] The anode supply source 201 supplies the oxidizable material to the inlet of the anode flow path 140. The oxidizable material is introduced to the anode flow path 140 through the anode supply flow path P1. A pressure controller may be provided in the middle of at least one of the anode supply flow path P1, the anode discharge flow path P2, and the anode circulation flow path P3 to control the pressure of the anode flow path 140. The anode fluid collector 202 has:

a tank that collects the anode fluid discharged from the outlet of the anode flow path 140 to pass through the anode discharge flow path P2; and a gas/liquid separator provided in the tank to separate the anode fluid into an anode discharge liquid containing the oxidizable material and an anode discharge gas containing the anode product.

[0082] In the further arrangement of the electrolysis unit 10, by providing the anode fluid collector 202 at the outlet of the anode flow path 140 to separate the anode product from the anode fluid, it is possible to collect the anode product. By separating the oxidizable material from the anode fluid and returning it to the anode supply source 201, it is possible to reuse an unreacted residue of the oxidizable material.

[0083] The cathode supply system 300 has a cathode supply source 301, a cathode fluid collector 302, a cathode supply flow path P4, a cathode discharge flow path P5, and a cathode circulation flow path P6 and is configured such that the reducible material circulates in the cathode flow path 150. The cathode supply flow path P4 is connected to the inlet of the cathode flow path 150. The cathode discharge flow path P5 is connected to the outlet of the cathode flow path 150. The cathode supply flow path P4 and the cathode discharge flow path P5 are connected to the cathode flow path 150 such that they do not hinder the rotation operation of the electrolysis cell 11. In the cathode supply system 300, the cathode supply flow path P4 and the cathode discharge flow path P5 are connected through the cathode circulation flow path P6. A valve or a pump may be formed in the middle of the cathode supply flow path P4, the cathode discharge flow path P5, or the cathode circulation flow path P6 to control the pressure in the flow path and the flow rate of the fluid flowing in the flow path.

[0084] The cathode supply source 301 can supply the reducible material to the inlet of the cathode flow path 150. The reducible material can be introduced to the cathode flow path 150 through the cathode supply flow path P4. A pressure controller may be provided in the middle of at least one of the cathode supply flow path P4, the cathode discharge flow path P5, and the cathode circulation flow path P6 to control the pressure of the cathode flow path 150. The cathode fluid collector 302 has: a tank that collects the cathode fluid discharged from the outlet of the cathode flow path 150 to pass through the cathode discharge flow path P5; and a gas/liquid separator provided in the tank to separate the cathode fluid into a cathode discharge liquid containing an unreacted residue of the reducible material and a cathode discharge gas containing the cathode product.

[0085] The further arrangement of the electrolysis unit 10 has the cathode fluid collector 302 to follow the outlet of the cathode flow path 150 to enable separating the cathode product from the cathode fluid, to collect the cathode product. The further arrangement of the electrolysis unit 10 can separate the reducible material from the cathode fluid and return (re-supply) it to the inlet of the cathode flow path 150 through the cathode supply source 301 to reuse the unreacted residue of the reducible material. The further arrangement of the electrolysis unit 10 can have the anode fluid collector 202 to follow the outlet of the anode flow path 140 to separate the anode product from the anode fluid, it is possible to collect the anode product. The further arrangement of the electrolysis unit 10 can separate the oxidizable material from the anode fluid and return (re-supply) it to the inlet of the anode flow path 140 through the anode supply source 201, to reuse the unreacted residue of the oxidizable material.

[0086] The configurations of the above-described arrangements can be employed in combination or can be partly replaced. While certain arrangements have been described, these arrangements have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel arrangements described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the arrangements described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

[0087] The arrangements can be summarized into the following clauses.

(Clause 1)

[0088] An electrolysis system comprising:

an electrolysis cell comprising

an anode configured to oxidize an oxidizable material to produce an anode product,
 a cathode configured to reduce a reducible material to produce a cathode product,
 a diaphragm provided between the anode and the cathode,
 a first flow path plate having an anode flow path facing on the anode and through which an anode fluid containing the oxidizable material flows, and

a second flow path plate having a cathode flow path facing on the cathode and through which a cathode fluid containing the reducible material flows,
the anode, the cathode, the diaphragm, the first flow path plate, and the second flow path plate being stacked in a first direction;

a rotary shaft disposed on the opposite side of the cathode from the diaphragm and extending along a second direction intersecting with the first direction; and
a driving device configured to rotate the electrolysis cell around the rotary shaft.

(Clause 2)

[0089] The system according to clause 1,

wherein the oxidizable material includes water, and
wherein the anode product includes oxygen.

(Clause 3)

[0090] The system according to clause 1 or clause 2,

wherein the reducible material includes carbon dioxide, and
wherein the cathode product includes a carbon compound.

(Clause 4)

[0091] The system according to clause 1 or clause 2,

wherein the reducible material includes nitrogen, and
wherein the cathode product includes a nitrogen compound.

(Clause 5)

[0092] The system according to any one of clause 1 to clause 4,
wherein the system comprises a plurality of the electrolysis cells.

(Clause 6)

[0093] The system according to any one of clause 1 to clause 5,

wherein the cathode fluid contains a gaseous substance involved in neither the oxidation nor the reduction, and
wherein the cathode product is soluble in the gaseous substance.

(Clause 7)

[0094] The system according to any one of clause 1 to clause 6,
wherein the second direction is along the direction of gravitational force.

(Clause 8)

[0095] The system according to any one of clause 1 to clause 7,
wherein the electrolysis cell is cylindrical.

(Clause 9)

[0096] The system according to any one of clause 1 to clause 8, further comprising
at least one collector selected from the group consisting of a cathode fluid collector and a anode fluid collector, the cathode fluid collector being connected to an outlet of the cathode flow path and being configured to collect the cathode fluid containing the cathode product, and the anode fluid collector being connected to an outlet of the anode flow path

and being configured to collect the anode fluid containing the anode product.

(Clause 10)

5 **[0097]** The system according to any one of clause 1 to clause 9, further comprising
at least one circulation flow path selected from the group consisting of a cathode circulation flow path and an anode
circulation flow path, the cathode circulation flow path being connected to an outlet of the cathode flow path and being
configured to re-supply an unreacted residue of the reducible material to an inlet of the cathode flow path, and the anode
10 circulation flow path being connected to an outlet of the anode flow path and being configured to re-supply an unreacted
residue of the oxidizable material to an inlet of the anode flow path.

(Clause 11)

15 **[0098]** A method of driving an electrolysis system comprising an electrolysis cell,
the electrolysis cell comprising:

an anode;
a cathode;
a diaphragm provided between the anode and the cathode;
20 a first flow path plate having an anode flow path facing on the anode and through which an anode fluid containing
an oxidizable material flows; and
a second flow path plate having a cathode flow path facing on the cathode and through which a cathode fluid
containing a reducible material flows,
the anode, the cathode, the diaphragm, the first flow path plate, and the second flow path plate being stacked in a
25 first direction, and
the method comprising:

supplying the oxidizable material to the anode, supplying the reducible material to the cathode, and applying a
voltage between the anode and the cathode, to oxidize the oxidizable material and thus produce an anode
30 product and to reduce the reducible material and thus produce a cathode product; and
rotating the electrolysis cell around a rotary shaft disposed on the opposite side of the cathode from the diaphragm
and extending in a second direction intersecting with the first direction.

(Clause 12)

35 **[0099]** The method according to clause 11,
wherein the electrolysis cell is rotated after the electrolysis cell stops producing the anode product and the cathode product.

(Clause 13)

40 **[0100]** The method according to clause 11,
wherein the electrolysis cell is rotated while the anode product and the cathode product are produced.

(Clause 14)

45 **[0101]** The method according to any one of clause 11 to clause 13,

wherein the reducible material includes carbon dioxide, and
wherein the cathode product includes a carbon compound.

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(Clause 15)

[0102] The method according to any one of clause 11 to clause 13,

55 wherein the reducible material includes nitrogen, and
wherein the cathode product includes a nitrogen compound.

(Clause 16)

[0103] The method according to any one of clause 11 to clause 15,

5 wherein the cathode fluid contains a gaseous substance involved in neither the oxidation nor the reduction, and wherein the cathode product is soluble in the gaseous substance.

(Clause 17)

10 **[0104]** The method according to any one of clause 11 to clause 16, wherein the second direction is along the direction of gravitational force.

(Clause 18)

15 **[0105]** The method according to any one of clause 11 to clause 17, wherein the electrolysis cell is cylindrical.

(Clause 19)

20 **[0106]** The method according to any one of clause 11 to clause 18,

wherein the system further comprises
at least one collector selected from the group consisting of a cathode fluid collector and an anode fluid collector,
the cathode fluid collector being connected to an outlet of the cathode flow path and being configured to collect the
25 cathode fluid containing the cathode product, and the anode fluid collector being connected to an outlet of the anode
flow path and being configured to collect the anode fluid containing the anode product.

(Clause 20)

30 **[0107]** The method according to any one of clause 11 to clause 19,

wherein the system further comprises
at least one circulation flow path selected from the group consisting of a cathode circulation flow path and an anode
circulation flow path, the cathode circulation flow path being connected to an outlet of the cathode flow path and
35 being configured to re-supply an unreacted residue of the reducible material to an inlet of the cathode flow path,
and the anode circulation flow path being connected to an outlet of the anode flow path and being configured to re-
supply an unreacted residue of the oxidizable material to an inlet of the anode flow path.

40 **Claims**

1. An electrolysis system comprising:

45 an electrolysis cell comprising

an anode configured to oxidize an oxidizable material to produce an anode product,
a cathode configured to reduce a reducible material to produce a cathode product,
a diaphragm provided between the anode and the cathode,
a first flow path plate having an anode flow path facing on the anode and through which an anode fluid
50 containing the oxidizable material flows, and
a second flow path plate having a cathode flow path facing on the cathode and through which a cathode
fluid containing the reducible material flows, and

the anode, the cathode, the diaphragm, the first flow path plate, and the second flow path plate being stacked
55 in a first direction;
a rotary shaft disposed on the opposite side of the cathode from the diaphragm and extending along a second
direction intersecting with the first direction; and
a driving device configured to rotate the electrolysis cell around the rotary shaft.

2. The system according to claim 1,

wherein the oxidizable material includes water, and
wherein the anode product includes oxygen.

3. The system according to claim 1 or claim 2,

wherein the reducible material includes carbon dioxide, and
wherein the cathode product includes a carbon compound.

4. The system according to claim 1 or claim 2,

wherein the reducible material includes nitrogen, and
wherein the cathode product includes a nitrogen compound.

5. The system according to any one of claim 1 to claim 4,
wherein the system comprises a plurality of the electrolysis cells.

6. The system according to any one of claim 1 to claim 5,

wherein the cathode fluid contains a gaseous substance involved in neither the oxidation nor the reduction, and
wherein the cathode product is soluble in the gaseous substance.

7. The system according to any one of claim 1 to claim 6,
wherein the second direction is along the direction of gravitational force.

8. The system according to any one of claim 1 to claim 7,
wherein the electrolysis cell is cylindrical.

9. The system according to any one of claim 1 to claim 8, further comprising
at least one collector selected from the group consisting of a cathode fluid collector and a anode fluid collector, the
cathode fluid collector being connected to an outlet of the cathode flow path and being configured to collect the
cathode fluid containing the cathode product, and the anode fluid collector being connected to an outlet of the anode
flow path and being configured to collect the anode fluid containing the anode product.

10. The system according to any one of claim 1 to claim 9, further comprising
at least one circulation flow path selected from the group consisting of a cathode circulation flow path and an anode
circulation flow path, the cathode circulation flow path being connected to an outlet of the cathode flow path and
being configured to re-supply an unreacted residue of the reducible material to an inlet of the cathode flow path,
and the anode circulation flow path being connected to an outlet of the anode flow path and being configured to re-
supply an unreacted residue of the oxidizable material to an inlet of the anode flow path.

11. A method of driving an electrolysis system comprising an electrolysis cell,
the electrolysis cell comprising:

an anode;
a cathode;
a diaphragm provided between the anode and the cathode;
a first flow path plate having an anode flow path facing on the anode and through which an anode fluid containing
an oxidizable material flows; and
a second flow path plate having a cathode flow path facing on the cathode and through which cathode fluid
containing a reducible material flows,
the anode, the cathode, the diaphragm, the first flow path plate, and the second flow path plate being stacked
in a first direction, and
the method comprising:

supplying the oxidizable material to the anode, supplying the reducible material to the cathode, and applying
a voltage between the anode and the cathode, to oxidize the oxidizable material and thus produce an anode

product and to reduce the reducible material and thus produce a cathode product; and rotating the electrolysis cell around a rotary shaft disposed on the opposite side of the cathode from the diaphragm and extending in a second direction intersecting with the first direction.

5 **12.** The method according to claim 11,
 wherein the electrolysis cell is rotated after the electrolysis cell stops producing the anode product and the cathode product.

10 **13.** The method according to claim 11,
 wherein the electrolysis cell is rotated while the electrolysis cell producing the anode product and the cathode product.

14. The method according to any one of claim 11 to claim 13,

 wherein the reducible material includes carbon dioxide, and
15 wherein the cathode product includes a carbon compound.

15. The method according to any one of claim 11 to claim 13,

 wherein the reducible material includes nitrogen, and
20 wherein the cathode product includes a nitrogen compound.

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FIG. 1

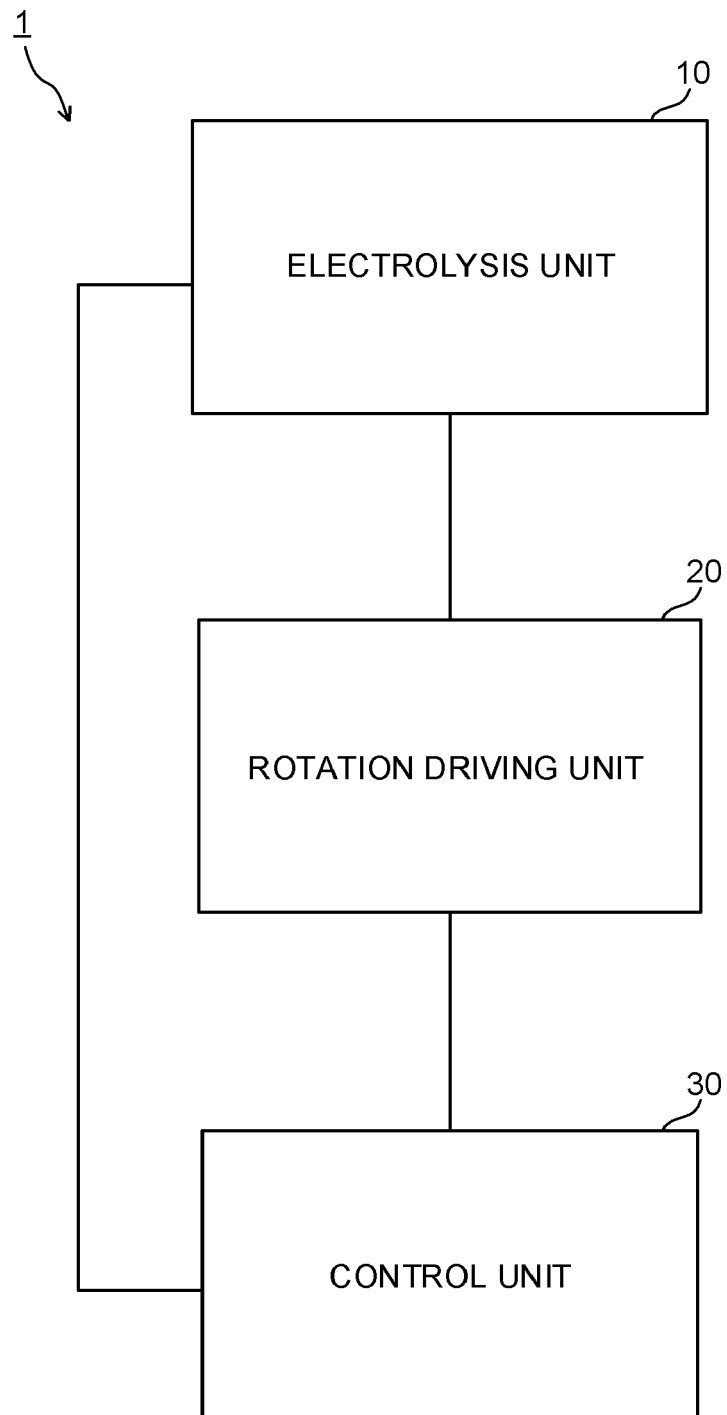


FIG. 2

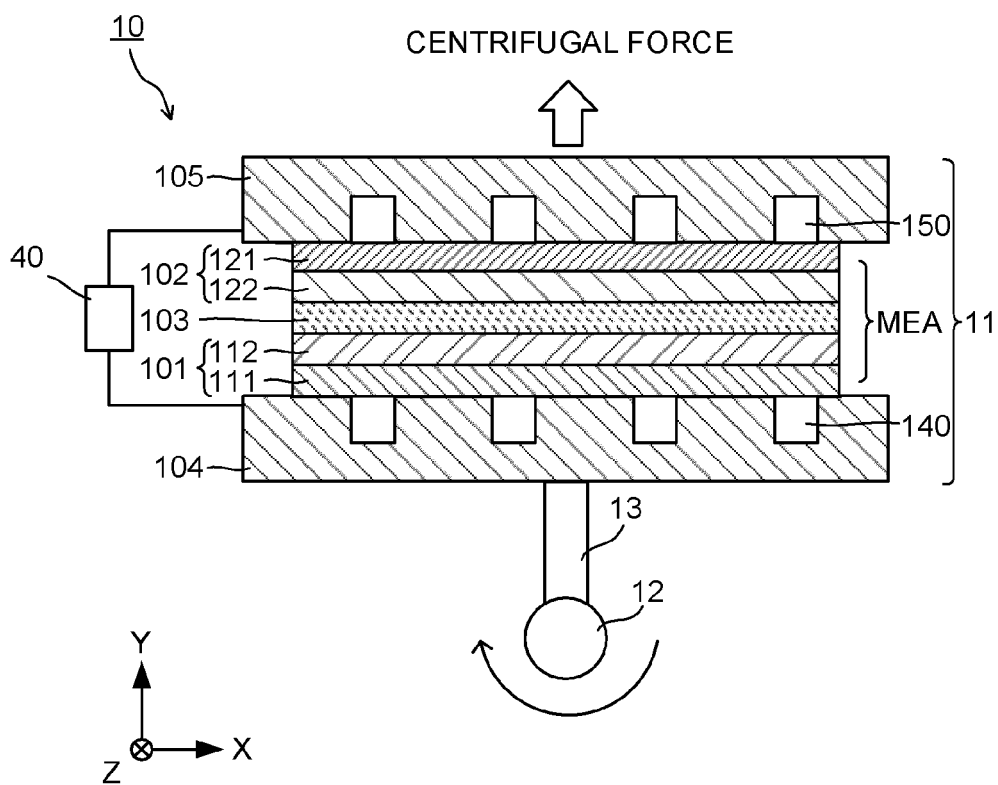


FIG. 3

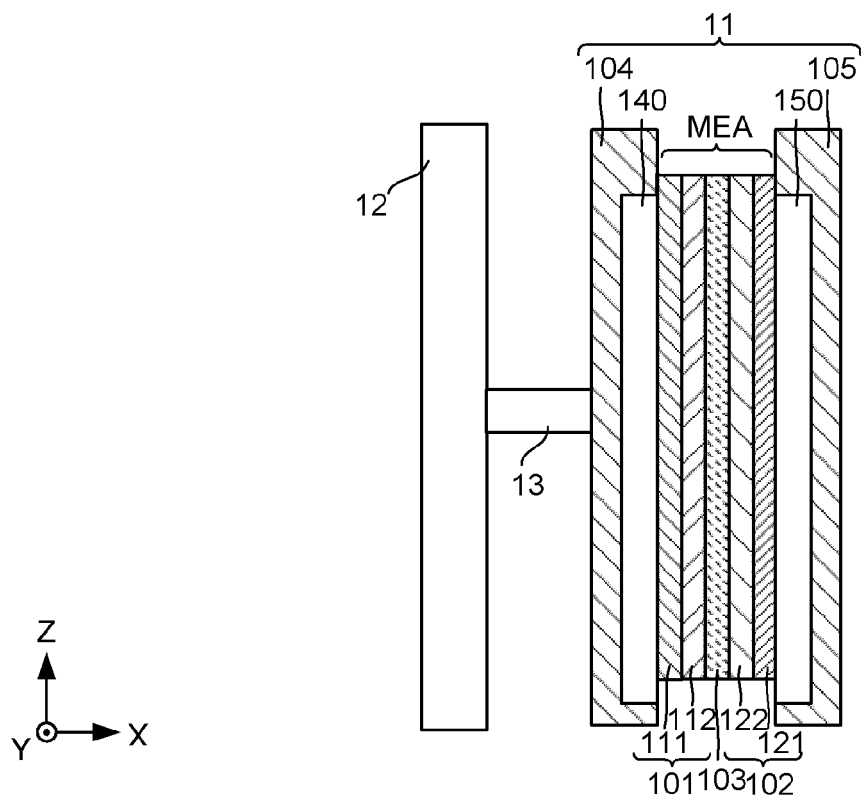


FIG. 4

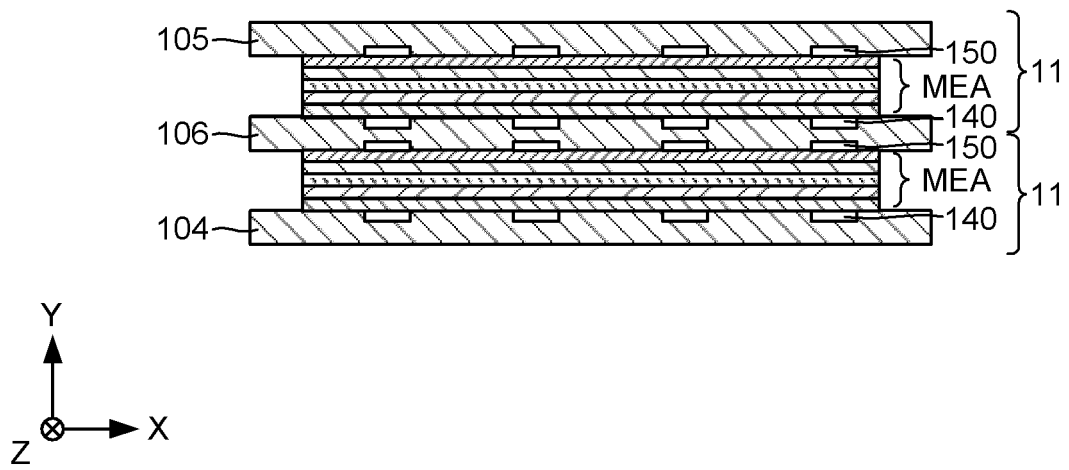


FIG. 5

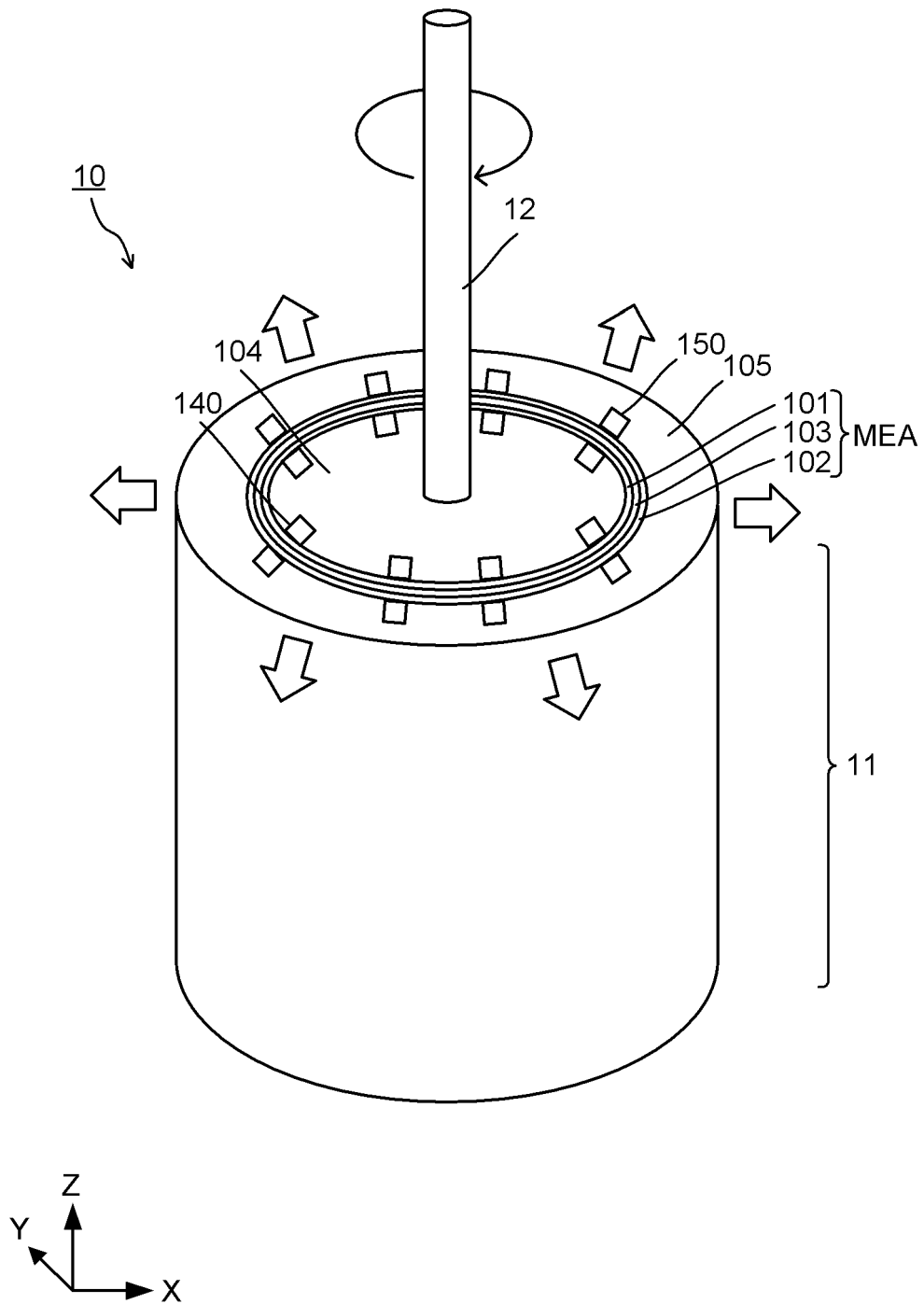
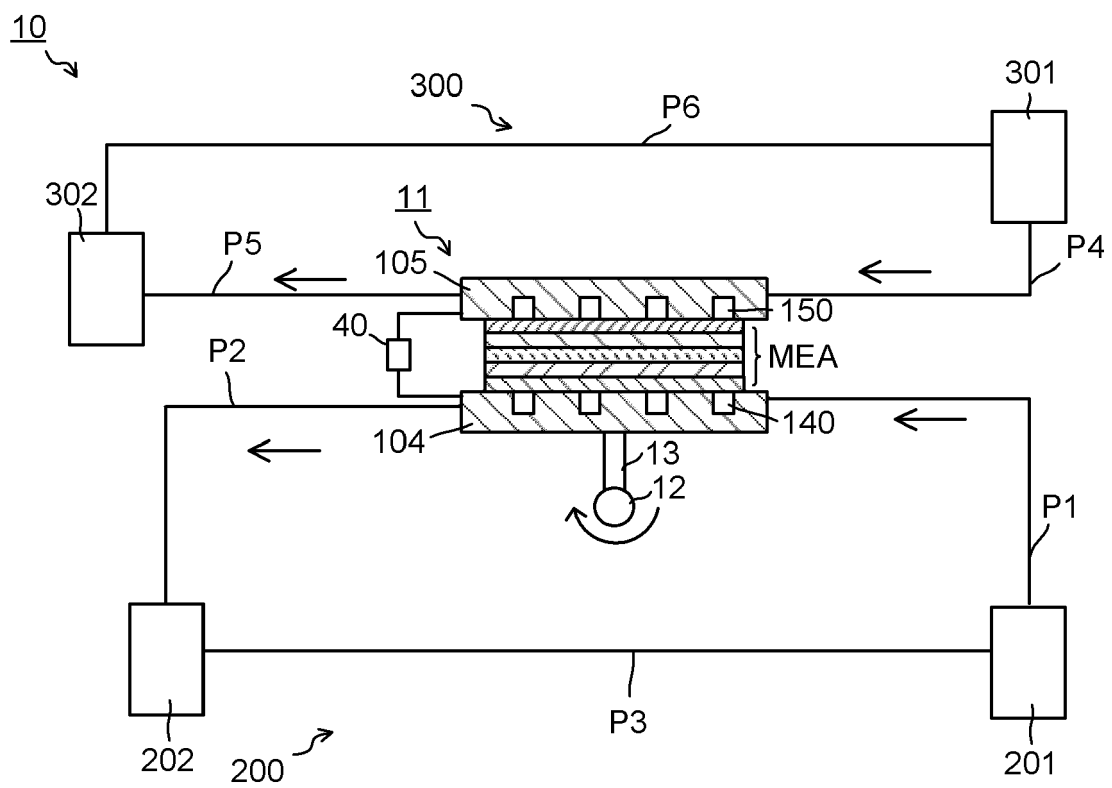


FIG. 6





EUROPEAN SEARCH REPORT

Application Number

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			C25B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		5 August 2024	De Porcellinis, D
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