(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
10 May 2024 (10.05.2024)

WIPO | PCT

(10) International Publication Number
WO 2024/097216 A3

(51) International Patent Classification:
C25B 1/23 (2021.01) *C25B 15/027* (2021.01)
C25B 3/26 (2021.01) *C25B 15/08* (2006.01)
C25B 15/025 (2021.01)

(21) International Application Number:
PCT/US2023/036462

(22) International Filing Date:
31 October 2023 (31.10.2023)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
63/421,065 31 October 2022 (31.10.2022) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA,

(54) Title: CO2 ELECTROLYSIS PLANT

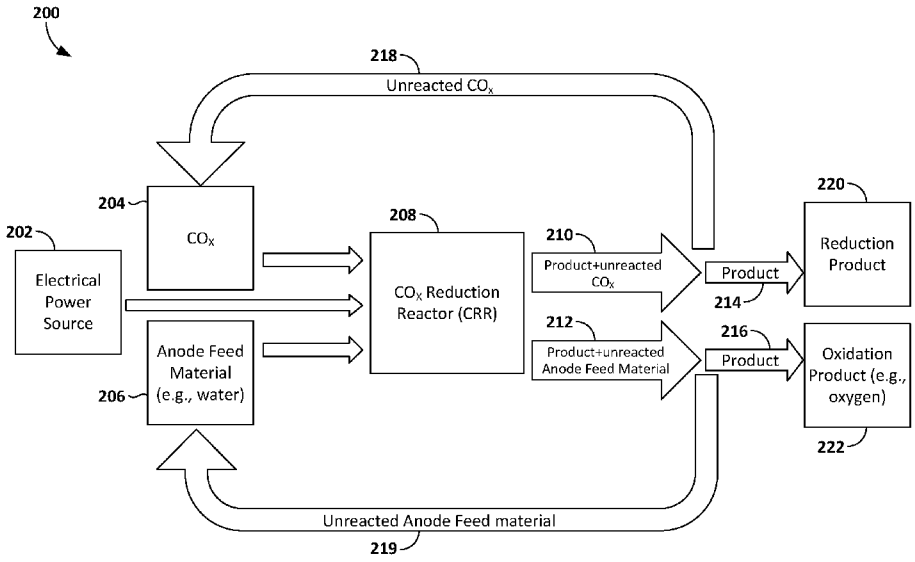

FIG. 2

(57) **Abstract:** Aspects of the present disclosure provide a system for a carbon oxide electrolysis plant incorporating advanced electrochemical reactors incorporating membrane electrode assemblies as well as control mechanisms. The system provides efficient transport and production rates while minimizing the competing hydrogen formation reaction. The system may use multiple electrochemical reactors, scaling up production with high energy efficiency, while providing flexibility in the types of chemical product outputs.

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[Continued on next page]

NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) **Date of publication of the international search report:**
11 July 2024 (11.07.2024)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
OPUSP028WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2023/036462	31 October 2023 (31-10-2023)	31 October 2022 (31-10-2022)
Applicant		
TWELVE BENEFIT CORPORATION		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 6 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language,** the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (See Box No. II)

3. ☒ **Unity of invention is lacking** (see Box No III)

4. With regard to the **title,**
   ☐ the text is approved as submitted by the applicant
   ☒ the text has been established by this Authority to read as follows:

   CO2 ELECTROLYSIS PLANT

5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings,**
   a. the figure of the **drawings** to be published with the abstract is Figure No. 2
      ☐ as suggested by the applicant
      ☐ as selected by this Authority, because the applicant failed to suggest a figure
      ☒ as selected by this Authority, because this figure better characterizes the invention
   b. ☐ none of the figures is to be published with the abstract

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2023/036462

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:
1-45

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/036462

A. CLASSIFICATION OF SUBJECT MATTER

INV. C25B1/23 C25B3/26 C25B15/025 C25B15/027 C25B15/08
ADD.

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 10 981 848 B2 (TOSHIBA KK [JP]) 20 April 2021 (2021-04-20)	1-3,7, 9-11, 13-15, 21,22
Y	abstract column 3, line 22 - column 6, line 48; figures 1, 2 column 7, line 18 - column 8, line 43 column 16, lines 45-49	4-6,8, 12, 16-20,23

X	US 2020/220185 A1 (MA SICHAO [US] ET AL) 9 July 2020 (2020-07-09)	24-45
Y	abstract paragraphs [0086], [0087]; figure 1 paragraph [0059]	4-6,8, 12, 16-20,23

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[X] Further documents are listed in the continuation of Box C.

[X] 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

"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
11 April 2024	11/06/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Desbois, Valérie

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/036462

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	MÖCKL MAXIMILIAN ET AL: "Proton exchange membrane water electrolysis at high current densities: Investigation of thermal limitations", INTERNATIONAL JOURNAL OF HYDROGEN ENERGY, ELSEVIER, AMSTERDAM, NL, vol. 45, no. 3, 18 December 2019 (2019-12-18), pages 1417-1428, XP085983086, ISSN: 0360-3199, DOI: 10.1016/J.IJHYDENE.2019.11.144 [retrieved on 2019-12-18] page 1426; figure 9	1-3,7,9, 13-15, 19,21
A	JANG DOHYUNG ET AL: "Numerical modeling and analysis of the temperature effect on the performance of an alkaline water electrolysis system", JOURNAL OF POWER SOURCES, ELSEVIER, AMSTERDAM, NL, vol. 506, 2 June 2021 (2021-06-02), XP086717924, ISSN: 0378-7753, DOI: 10.1016/J.JPOWSOUR.2021.230106 [retrieved on 2021-06-02] 3.2. Operational optimization; page 7 - page 8; figures 7, 8 4. Conclusions, point 5.; page 9 figure 1	1-3,7,9, 13-15, 19,21
A	HANCKE RAGNHILD ET AL: "The case for high-pressure PEM water electrolysis", ENERGY CONVERSION AND MANAGEMENT, ELSEVIER SCIENCE PUBLISHERS, OXFORD, GB, vol. 261, 25 April 2022 (2022-04-25), XP087047524, ISSN: 0196-8904, DOI: 10.1016/J.ENCONMAN.2022.115642 [retrieved on 2022-04-25] 2.1 Technical model; pages 3-4	1-23

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2023/036462

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 10981848 B2	20-04-2021	EP 3626858 A1	25-03-2020
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		US 2022393203 A1	08-12-2022
		US 2024145745 A1	02-05-2024
		WO 2020132064 A1	25-06-2020

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-45

A carbon oxide electrolyzer system comprising:
a carbon oxide reduction reactor configured to electrochemically reduce a gaseous carbon oxide to produce a molecular carbon-containing species;
a gas source configured to provide the gaseous carbon oxide to a cathode of the carbon oxide reduction reactor;
a power source configured to supply electrical power to the carbon oxide reduction reactor; and
an anolyte circulation system configured to provide anolyte solution to an anode of the carbon oxide reduction reactor, the anolyte circulation system comprising a temperature control system.

1.1. claims: 1-23

the temperature control system is operable to control a temperature differential of the anolyte solution across the anode.

1.2. claims: 24-45

the temperature control system is operable to maintain the anolyte solution provided to the anode within a predetermined temperature range.

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2. claims: 46-51

A system comprising:
a carbon oxide electrolyzer system having a programmable control system;
a computer storage media; and
a processing device, operatively coupled to the computer storage media and configured to:
control input, at a gas inlet of the carbon oxide electrolyzer system, of gaseous carbon dioxide;
control input, at a water inlet of the carbon oxide electrolyzer system, of water, the water provided by a water system incorporating an anolyte circulation system and an anolyte recirculation system and a catholyte circulation system;
monitor and control, at a power input of the carbon oxide electrolyzer system, electrical power; and
monitor and control electrolysis, by the carbon oxide electrolyzer, to output a molecular hydrogen and carbon-containing species in a selected hydrogen to carbon-containing species ratio range.
