



(51) International Patent Classification:

C25B 11/069 (2021.01) G01N 27/30 (2006.01)
C25B 1/04 (2021.01) C25B 9/17 (2021.01)
C25B 11/03 (2021.01)

(21) International Application Number:

PCT/US2024/033807

(22) International Filing Date:

13 June 2024 (13.06.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/472,667 13 June 2023 (13.06.2023) US

(71) Applicant: TRUSTEES OF DARTMOUTH COLLEGE

[US/US]; 11 Rope Ferry Road, Room 6210, Hanover, NH 03755 (US).

(72) Inventors: SCHEIDELER, William, J. ; 27 Rio Vista, Unit 301, West Lebanon, NH 03784 (US). TIWARI, Anand, P. ; 20 Wolf Road, Apt. 122, Lebanon, NH 03766 (US).

(74) Agent: ALFANO, Gabriella R.; Hodgson Russ LLP, 140 Pearl Street, Suite 100, Buffalo, New York 14202-4040 (US).

(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, 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,

(54) Title: NANOPOROUS THREE-DIMENSIONAL TRANSITION METAL OXIDE AND CARBON COMPOSITE ELECTRODES FOR EFFICIENT ELECTROCATALYSIS

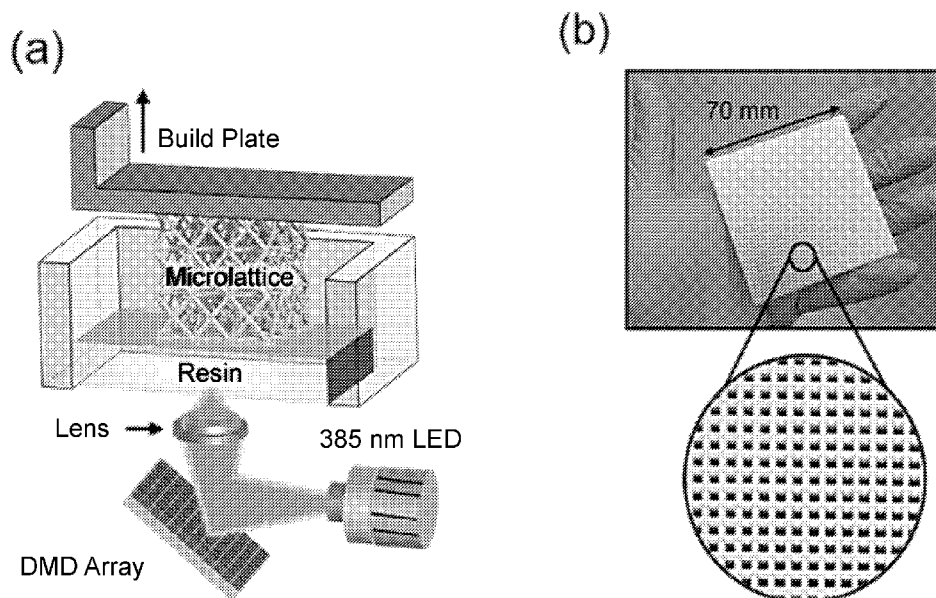


FIG. 8

(57) Abstract: An electrocatalyst electrode having a strut lattice structure fabricated of a polymer and a composite disposed on the strut lattice structure that includes at least one transition metal oxide, which may include copper oxide, cobalt oxide, or nickel oxide. The composite and the strut lattice structure are 3D and free-standing. The electrocatalyst electrode includes one or more pores that are vertically aligned to form channels and to facilitate bubble release. The composite is used for alkaline hydrogen evolution reaction (HER) and oxygen evolution reaction (OER).



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))*

(88) Date of publication of the international search report:

15 May 2025 (15.05.2025)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/033807

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. C25B 11/069; C25B 1/04; C25B 11/03; G01N 27/30 (2024.01)

ADD. C25B 9/17 (2024.01)

CPC - INV. C25B 11/069; C25B 1/04; C25B 11/03; G01N 27/30

ADD. C25B 9/17

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)
See Search History documentDocumentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History documentElectronic database consulted during the international search (name of database and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y --- A	Huddy et al. "Transforming 3D-printed mesostructures into multimodal sensors with nanoscale conductive metal oxides" Cellpressw; Article [online]. 16 September 2022 [retrieved 24 September 2024]. retrieved from the Internet: https://www.sciencedirect.com/science/article/pii/S2666386422000534	1-9 --- 10-11
Y --- A	US 2019/0103600 A1 (CALIFORNIA INSTITUTE OF TECHNOLOGY) 04 April 2019; Abstract, Paragraphs [0096], [0262]	1-9 --- 10-11
Y	US 2010/0116649 A1 (MAEKAWA, ET AL) 13 May 2010; Paragraph [0240]	6
Y --- A	US 2022/0056600 A1 (LNL - INTERNATIONAL IBERIAN NANOTECHNOLOGY LABORATORY et al.) 24 February 2022; Paragraphs [0029], [0070]	9 --- 10-11
A	US 2018/0280144 A1 (HD LIFESCIENCES LLC (WOBURN US)) 04 October 2018; Paragraphs [0056]-[0057], [0154]	1-11

☐ 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

25 September 2024 (25.09.2024)

Date of mailing of the international search report

DEC 05 2024

Name and mailing address of the ISA/

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents

P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-8300

Authorized officer

Shane Thomas

Telephone No. PCT Helpdesk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/033807

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:

-Please See Supplemental Page-

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 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.:

1-11

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/US2024/033807

-***-Continued From Box No. III: Observations where unity of invention is lacking-***-

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fee must be paid.

Group I: Claims 1-11 are directed toward an electrocatalyst electrode.

Group II: Claims 12-20 are directed toward a method.

The special technical features of Group I include at least a composite disposed on the strut lattice structure that includes at least one transition metal oxide, wherein the composite and the strut lattice structure are 3D and free-standing.

The special technical features of Group II include at least stereolithography 3D printing a free-standing strut lattice structure with a periodic pore structure; infusing the strut lattice structure with a metal salt by soaking the strut lattice structure in a concentrated solution of the metal salt dissolved in water; and annealing the strut lattice structure at a temperature from 400 °C to 700 °C.

The common technical features shared by Groups I & II are 3D printing a free-standing strut lattice structure; wherein the strut lattice structure is fabricated of a polymer. However, these common features are previously disclosed by US 2018/0280144 A1 to HD LifeSciences LLC. (hereinafter "HD"). HD discloses 3D printing a free-standing strut lattice structure (3d printing scaffolding for formation of a lattice with struts of unit cells; [0056-0057]); wherein the strut lattice structure is fabricated of a polymer (lattice is comprised of polyether ether ketone, a commonly used polymer; [0154]).

Since the common technical features are previously disclosed by the HD reference, these common features are not special and so Groups I-II lack unity.