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[Continued on next page]

(54) Title: MICROBIAL FUEL CELL

(57) Abstract: Disclosed is a high surface area electrode for use in a microbial fuel cell. In one embodiment the high surface area electrode has an electrode backing and villiated extensions attached to the backing. In one embodiment the villiated extensions and/or electrode backing are made of an electroconductive material such as, for example, graphite or graphite fibers. In one embodiment the electrode is an anode and the electrode backing is in the form of a mesh or woven structure. The electrodes offer superior removal of chemical oxygen demand (COD) and are thus useful in the remediation of wastewaters. The invention also provides microbial fuel cells that utilize the electrodes of the invention. In one embodiment the microbial fuel cells utilize an oxygen barrier and do not utilize a cation or anion or proton exchange membrane.

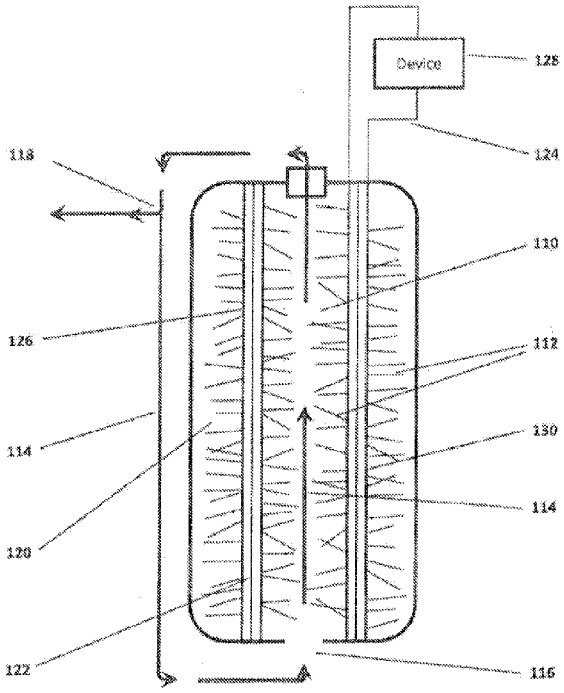

FIG. 1

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EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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:
16 January 2014

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/040655

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H01M 8/16 (2013.01)
USPC - 429/401
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)
IPC(8) - H01M 4/00, 4/72, 4/74, 4/96, 8/16 (2013.01)
USPC - 429/400, 401, 523; 977/702, 735, 742, 894, 925

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - H01M 4/133, 8/16; B82Y5/00 (2013.01)

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0068461 A1 (WALLACE et al) 18 March 2010 (18.03.2010) entire document	1-14
Y	US 2010/0092804 A1 (BOROLE) 15 April 2010 (15.04.2010) entire document	1-14
Y	US 4,118,305 A (OLOMAN et al) 03 October 1978 (03.10.1978) entire document	13-14
A	US 2010/0119920 A1 (LOGAN et al) 13 May 2010 (13.05.2010) entire document	1-14

☐ Further documents are listed in the continuation of Box C. ☐

* 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
17 October 2013	01 NOV 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/040655

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 extra 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 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.:
1-14

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/US2013/040655

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 fees must be paid.

Group I, claims 1-14, drawn to a high surface area electrode comprising an electrode lead and an electrode backing, the electrode backing comprises a mesh, wherein villiated extensions are attached to the backing.
Group II, claims 15-25, drawn to a microbial fuel cell comprising an oxygen barrier separating the anode chamber and the cathode chamber, wherein the oxygen barrier is not a cation or anion exchange membrane.
Group III, claims 26-31, drawn to a microbial fuel cell comprising a chemically-treated anode, a heat-treated cathode.

The inventions listed as Groups I, II and III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention:a high surface area electrode comprising an electrode lead and an electrode backing, the electrode backing comprises a mesh, wherein villiated extensions are attached to the backing as claimed therein is not present in the invention of Groups II and III. The special technical feature of the Group II invention: an oxygen barrier separating the anode chamber and the cathode chamber, wherein the oxygen barrier is not a cation or anion exchange membrane as claimed therein is not present in the invention of Groups I or III. The special technical feature of the Group III invention: a chemically-treated anode, a heat-treated cathode, as claimed therein is not present in the invention of Groups I or II.

Groups I, II and III lack unity of invention because even though the inventions of these groups require the technical feature of a microbial fuel cell comprising and anode and cathode, wherein the anode provides a surface area for supporting a population of microorganisms, the cathode, anode or electrode comprises an electroconductive material and receives electrons from the anode, an electrically conductive path connecting the anode to the cathode and allowing for an electrical current to pass between the anode and the cathode, this technical feature is not a special technical feature as it does not make a contribution over the prior art in view of US 2010/0092804 A1 (BOROLE) 15 April 2010 (15.04.2010). Borole teaches a microbial fuel cell (abstract) comprising an anode and cathode (paragraph 27, the microbial fuel cell (MFC) contains an anode and cathode), wherein the anode provides a surface area for supporting a population of microorganisms (paragraphs 12-13, establishing a biofilm of the microorganisms on and/or within the anode or electrode, and growing the microorganisms) the anode, cathode or electrode comprises an electroconductive material (the cathode is electrically conductive, paragraph 52; the anode is electrically conductive, paragraph 51; an electrode is either of the anode or cathode, thus is also electrically conductive), an electrically conductive path connecting the anode to the cathode and allowing for an electrical current to pass between the anode and the cathode (paragraphs 14, 27, The MFC contains an anode and a cathode that are in electrical connection, e.g., by a connecting Wire that is electrically conductive, such as a copper Wire; see also paragraph 4).

Since none of the special technical features of the Group I, II or III inventions are found in more than one of the inventions, unity of invention is lacking.