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(73) Octrooihouder(s):
Stichting Wetsus, European Centre of Excellence for Sustainable Water Technology te Leeuwarden.

(72) Uitvinder(s):
Sam Daniël Molenaar te Leeuwarden.
Tomas Hubertus Johannes Antonius Sleutels te Leeuwarden.
Annemiek van Apeldoorn-ter Heijne te Leeuwarden.
Hubertus Victor Marie Hamelers te Leeuwarden.
Cees Jan Nico Buisman te Leeuwarden.

(74) Gemachtigde:
ir. P.J. Hylarides c.s. te Den Haag.

(54) **Bioelectrochemical energy storage device and method for bioelectrochemical energy storage.**

(57) The invention relates to a bioelectrochemical energy storage device and method there for. The bioelectrochemical energy storage device according to the invention comprises:
- a housing having a first compartment and a second compartment;
- a reversible bio-electrode that is placed in the first compartment and comprises a microbial biosystem capable of performing in a charging state a charging operation involving a reduction reaction converting electrical energy into chemical energy, and performing in a discharging state a discharching operation involving an oxidation reaction converting chemical energy into electrical energy; and
- a counter electrode that is placed in the second compartment and is electrically connectable in a circuit with the reversible bio-electrode.

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BIOELECTROCHEMICAL ENERGY STORAGE DEVICE AND METHOD FOR BIOELECTROCHEMICAL ENERGY STORAGE

The present invention relates to a device for bioelectrochemical storage of energy, with the device being capable of charging and discharging energy.

Temporarily storage of energy is important to enable storage of energy in a time period of an energy surplus and to enable providing additional energy in a time period of a high energy demand. Examples of energy storage include storing wind energy in water (level) buffers, for example. Another conventional example of such energy storage devices are (car) batteries. This is not a very sustainable approach considering the materials required for the batteries.

These conventional devices and systems do not provide an effective energy storage device that is sustainable and could be implemented on a wide scale, for example including house holds.

The use of bioelectrochemical devices is known for being capable of oxidizing carbohydrates anaerobically to carbon dioxide involving anode respiring biofilms (ARBs) that can be used in microbial fuel cells (MFCs) and microbial electrolysis cells (MECs). These devices are not capable of storing (external) energy.

The present invention has for its object to provide an energy storage device, more particularly a bioelectrochemical energy storage device, capable of energy storage in time periods of an energy surplus and energy discharge in time periods of energy shortage.

This objective is achieved with the bioelectrochemical energy storage device according to the invention, the device comprising:

- a housing having a first compartment and a second compartment;
- a reversible bio-electrode that is placed in the first compartment and comprises a microbial biosystem capable of performing in a charging state a charging operation involving a reduction reaction converting electrical energy into chemical energy, and performing in a discharging state a discharching operation involving an oxidation reaction converting chemical energy into electrical energy; and
- a counter electrode that is placed in the second compartment and is electrically connectable in a circuit with the reversible bio-electrode.

The device according to the invention comprises a first and a second compartment. The first compartment is provided with a reversible bio-electrode. A counter electrode is placed in the second compartment. By providing a circuit the reversible bio-electrode and the counter electrode can be electrically connected. In a charging state of the device this circuit enables providing electrons at the reversible bio-electrode to perform a reduction reaction. For example, the reduction reaction may convert CO_2 electrochemically into organic molecules like methane and volatile fatty acids. Also, a combined electrochemical and biological reduction reaction/process is possible. For

example, an electrochemical conversion into hydrogen that in a biological conversion is converted with bicarbonate into acetate is capable of storing energy in accordance with the present invention. This embodiment enables providing the biomass independent of the electrode and in stead thereof, or in addition thereto, providing the biomass in the suspension using the dissolved components. This electrode with suspended biomass provides a reversible bio-electrode in a system configuration. The bio-electrode in the system according to the invention also comprises such bio-electrode system. In fact, in the different embodiments of the invention electrical energy is converted into chemical energy, for example storing the electrical energy in organic molecules.

In a discharging state of the device organic molecules can be oxidized to CO_2, protons, and electrons that can be transferred by the circuit, for example.

Therefore, the device according to the invention stores electrical energy by converting electrical energy into chemical energy and produces energy by converting chemical energy into electrical energy. This enables the bioelectrochemical energy storage device to act as a biobattery capable of storing and producing energy. More specifically, the storage of energy in a bioelectrochemical energy storage device according to the present invention enables higher specific energy densities and prolonged charge/discharge periods as compared to alternative conventional systems including capacitive systems.

As a further advantage the device according to the present invention provides an energy storage that is more safe and more cost effective as compared to many conventional devices. In addition, the device according to the invention can be regenerated, thereby enabling an effective use of the device under practical conditions. Furthermore, the device according to the invention is capable of being provided as a stand-alone application, in other words as an off-grid application, thereby also enabling effective energy storage in remote areas, for example.

The oxidation and reduction reactions are preferably performed with the use of electro-active biofilms (EABs) that interact with conductive surfaces of an electrode and catalyse reduction and/or oxidation reactions as part of the metabolism. In the discharging and/or charging states different components may react in the oxidation and reduction reactions including organic and anorganic components. For example, anodes respiring biofilms (ARBs) are capable to oxidize carbohydrates anaerobically with the conductive material in the electrode as electron acceptor. In the discharging reaction, with the reversible bio-electrode(s) being connected to a counter electrode, electrical power can be obtained. Charge neutrality is being maintained with the use of ionic exchange, for example.

The reversible bio electrode is preferably made of a biocompatible material to enable microorganisms to catalyze the reactions. The electrodes preferably have a sufficiently high electric conductivity. Possible materials include graphite, carbon, titanium etcetera. Optionally, additional use is made of a catalyst for conversion of CO_2 to organic material.

The counter electrode should be capable to switch between the different states. The counter electrode preferably comprises a material with a high capacity and/or a large surface area that cooperates with an electrolyte solution in the compartment. For example, the counter electrode may comprise Mn having Na^+ as counter ion. The use of other materials in the device according to the invention could also be envisaged. Alternatively, or in addition, a suitable reversible biological reaction can be performed at the counter electrode when the device according to the invention is in use.

Both electrodes should preferably be anodic and cathodic stable such that the electrodes do not react at the potential that is applied in the charging and/or discharging state of the bioelectrochemical energy storage device.

In a presently preferred embodiment of the invention oxidation and reduction of acetate is performed. In addition, or alternatively, butyrate, propionate and other components can be applied. In principle organic components can be used provided that they can be reversibly produced. Optionally, other processes, such as hydrolyses and fermentation, are used to convert longer chains into for example acetate that can be oxidized to electrons.

In the oxidation of an organic substrate a large amount of acid can be produced. For example, if acetate is oxidized, every mole of acetate produces 8 moles of protons that could significantly change the pH of the system. Preferably, buffer capacity in the system should be sufficiently high to compensate for the acid production, and/or compensation should be provided by adding or generating alkalinity, and/or by ion transport of protons through the membrane. In addition, or as an alternative thereto, extremophiles can be used on the reversible bio-electrodes that are capable of dealing with these pH changes.

It will be understood that the device according to the present invention may comprise more than two compartments with one or more electrodes and/or more than one electrode can be provided in one compartment. The specific configuration can be chosen dependent on required dimensions and/or amounts of energy that should be stored, for example.

Preferably, the bioelectrochemical energy storage device comprises an ion-exchange membrane separating the first and second compartment.

By providing an ion-exchange membrane charge neutrality in the housing is maintained by ionic exchange through the membrane. The ion-exchange membrane may comprise an anionic exchange membrane, a cation exchange membrane and/or a bipolar membrane comprising a cation and anion layer, for example. The use of such membrane provides an effective means to achieve charge neutrality in the housing and enable electricity generation in the discharging state and storage of chemical energy in a charging state of the bioelectrochemical energy storage device. For example, when applying acetate in the device according to the invention, the membrane is preferably a proton selective membrane to enhance the aforementioned compensating effect.

To enable transport of charge in the compartments an appropriate electrolyte is preferably applied in the compartment. For example, in a presently preferred embodiment of the invention the second compartment with the counter electrode is provided with Fe^{3+}/Fe^{2+}, Cu^{2+}/Cu, and/or Ag/AgCl.

In a presently preferred embodiment according to the invention the counter electrode comprises a capacitive electrode.

By providing a capacitive electrode a relatively simple counter electrode is achieved with a sufficient capacity. Preferably, the capacitive counter electrode is chosen in relation to the specific electrolyte composition in the second compartment. In such embodiment ions of the electrolyte may achieve a so-called double layer providing an overall capacity of the capacitive counter electrode.

In a presently preferred embodiment the first compartment comprises an organic material input.

By providing an organic material input organic material can be supplied to the first compartment. This enables increasing the capacity of the bioelectrochemical energy storage device during use and/or enables regeneration of the relevant components in the first compartment of the bioelectrochemical energy storage device. In one of the presently preferred embodiments the organic material comprises carbohydrates. It will be understood that other organic material could also be used in the system according to the invention, for example including protein and/of fats.

In a presently preferred embodiment according to the present invention the microbial biosystem comprises a unitary biosystem capable of performing both the oxidation and reduction reactions.

By providing a unitary biosystem it is possible to perform both the oxidation and reduction reactions in the charging and discharging state of the energy storing device. This has the advantage that only one biosystem is required.

In a further presently preferred embodiment according to the present invention the microbial biosystem comprises a multiple biosystem with a first bio-subsystem capable of performing the oxidation reaction and a second bio-subsystem, at least partly different from the first bio-subsystem, capable of performing the reduction reaction.

By providing at least two bio-subsystems the oxidation reaction and the reduction reactions can be optimized using specific microbial sub-systems that are dedicated to either the oxidation reaction or the reduction reaction. This optimizes the overall performance of the bioelectrochemical energy storage device according to the present invention.

In a further presently preferred embodiment according to the present invention the device is configured to store above 10 kWh/m^3, more preferably above 12.5 kWh/m^3, and most preferably above 15 kWh/m^3.

By providing a storage device capable of storing energy at a energy density of preferably above 15 kWh/m^3 an effective and efficient storage is provided. In one of the presently preferred embodiments according to the invention use is made of acetate in the device. In a device according to such preferred embodiment efficient energy storage is enabled with a biological conversion rate of acetate to electrons of about 25 A/m^2.

In a further presently preferred embodiment according to the present invention the first and/or second compartments are separated into an oxidation sub-compartment and a reduction sub-compartment.

By separating the consumption and production of electrons in different sub-compartments, including different (sub)-reactors, undesired competition of both reactions is prevented. Preferably, electrolyte is circulated over the sub-compartments.

The invention further relates to a method for bioelectrochemical energy storage, the method comprising the steps of:

- providing a bioelectrochemical energy storage device as mentioned above;
- performing a charging operation by providing electrons to the reversible bio-electrode to perform a reduction operation and converting electrical energy into chemical energy; and
- performing a discharging operation by extracting electrons from the reversible bio-electrode to perform an oxidation reaction and converting chemical energy into electrical energy.

The method provides the same effects and advantages as described for the device. The method enables storage of energy in a charging state, more specifically storage of energy as chemical energy in a time period of an energy surplus, and providing electrical energy in a discharging state by converting (chemical) components in a time period of energy shortage. This provides an effective means to store energy.

In a presently preferred embodiment the charging and discharging operations are performed under anaerobic conditions. This enables the use of anaerobic microorganisms in the anaerobic biosystem and/or bio-subsystems.

Preferably, the first compartment is provided with carbohydrates capable of anaerobic oxidation for converting chemical energy into electrical energy. It was shown that the use of carbohydrates enables an efficient storage of energy. Preferably, acetate is provided to the first compartment enabling efficient charging and discharging of the device. It will be understood that other components, preferably other organic material, can also be applied as mentioned in relation to the device.

In a presently preferred embodiment the method comprises the additional step of providing a first compartment with organic material to add additional energy to the system and/or recharge

the system. This provides an effective means to increase the overall capacity of the system and/or recharge or regenerate the system when in use. In a presently preferred embodiment, for recharging the system use is made of ethanol, including the use of bio-ethanol.

Preferably, the method is performed to enable local semi-off-grid or local off-grid energy storage without being dependent on the electricity grid. This provides a method and device capable of acting as a stand-alone device under a wide range of circumstances, including any household applications.

Further advantages, features and details of the invention are elucidated on the basis of preferred embodiments thereof, wherein reference is made to the accompanying drawings, in which:

- figure 1 shows a bioelectrochemical energy storage device according to the present invention; and
- figure 2 shows a schematic overview of components in a system with the bioelectrochemical energy storage device of figure 1.

The bioelectrochemical energy storage device 2 (figure 1) comprises tank or vessel 4 as a housing comprising first compartment 6 and second compartment 8. First compartment 6 comprises first reversible electrode 10 with biofilm 12. Second compartment 8 comprises counter electrode 14. Electrodes 10, 14 are connected through circuit 16. Circuit 16 comprises source/resistance 18.

In the illustrated embodiment first compartment 6 and second compartment 8 are separated with ion exchange membrane 20. First compartment 6 is provided with inlet 22 that is preferably configured to enable supply of organic material. First compartment 6 is further provided with outlet 24. Also second compartment 8 is provided with inlet 26 and outlet 28. It will be understood that an alternative configuration of inlets and outlets could be envisaged by a skilled person. Organic material including HCO_3^- 30 and further components 32, such as Ac^-, are provided in first compartment 6. In second compartment 8 material is converted in conversion reaction 34. In the illustrated embodiment conversion 34 involves converting Me^{2+} into Me^{3+} or vice versa, and an attraction effect 36 on Me^+ enabling a double layer 38 on counter electrode 14.

Energy system 40 comprises bioelectrochemical energy storage device 2 in a local system 42 that can be used in a house, for example. Energy source 44, such as a solar panel or wind turbine, is provided and consumer 46, such as an apparatus in the house of local system 42, uses energy. Energy is supplied through connection 48 from source 44 to user 46. In a time period of an energy surplus, energy is supplied through connection 50 from source 44 to device 2. In a time period of an energy shortage, energy is supplied from device 2 through connection 52, an optional convertor 54 and connection 56 to user 46. Optionally, an additional connection 58 to the electrical

grid or other network is provided to local system 42. Connection 58 may connect to source 44 and/or device 2 and/or user 46.

In a time period of energy surplus electricity is supplied to device 2. Electrons are provided at reversible bioelectrode 10 and a reduction reaction converts electrical energy into chemical energy with the use of biofilm 12. In a time period of an energy shortage the chemical components are converted into electrical energy with an oxidation reaction and energy is supplied from device 2 to a user 46.

Experiments have been performed with device 2. In one of these experiments acetate was used and it was shown that energy storage was possible with device 2. In theory, a maximum of 200 kWh/m^3 can be stored in device 2. The theoretical cell voltage is about 1.1 Volts depending on the potential of the counter reaction. The biological conversion of acetate to electrons is possible at a rate of 25 A/m^2, also depending on the counter reaction. It will be understood that the actual performance may depend on the design and materials used for device 2 that may chosen dependent on the intended use of device 2.

The present invention is by no means limited to the above described preferred embodiments thereof. The rights sought are defined by the following claims, within the scope of which many modifications can be envisaged.

Clauses

1. Bioelectrochemical energy storage device, comprising:
   - a housing having a first compartment and a second compartment;
   - a reversible bio-electrode that is placed in the first compartment and comprises a microbial biosystem capable of performing in a charging state a charging operation involving a reduction reaction converting electrical energy into chemical energy, and performing in a discharging state a discharching operation involving an oxidation reaction converting chemical energy into electrical energy; and
   - a counter electrode that is placed in the second compartment and is electrically connectable in a circuit with the reversible bio-electrode.

2. Bioelectrochemical energy storage device according to clause 1, further comprising an ion-exchange membrane separating the first and second compartment.

3. Bioelectrochemical energy storage device according to clause 2, wherein the ion-exchange membrane is a cation exchange membrane.

4. Bioelectrochemical energy storage device according to clause 3, wherein the cation-exchange membrane is a proton selective membrane.

5. Bioelectrochemical energy storage device according to one or more of the foregoing clauses, wherein the counter electrode comprises a capacitive electrode.

6. Bioelectrochemical energy storage device according to one or more of the foregoing clauses, wherein the first compartment comprises an organic material input.

7. Bioelectrochemical energy storage device according to one or more of the foregoing clauses, wherein the microbial biosystem comprises a unitary bio-system capable of performing both the oxidation and reduction reactions.

8. Bioelectrochemical energy storage device according to one or more of the foregoing clauses, wherein the microbial bio-system comprises a multiple bio-system with a first bio-subsystem capable of performing the oxidation reaction and a second bio-subsystem, at least partly different from the first bio-subsystem, capable of performing the reduction reaction.

9. Bioelectrochemical energy storage device according to one or more of the foregoing clauses, wherein the device is configured to store above 10 kWh/m^3, more preferably above 12.5 kWh/m^3, and most preferably above 15 kWh/m^3.

10. Bioelectrochemical energy storage device according to one or more of the foregoing clauses, wherein the first and/or second compartments are separated into an oxidation sub-compartment and a reduction sub-compartment.

11. Method for bioelectrochemical energy storage, comprising the steps of:
- providing a bioelectrochemical energy storage device according to one or more of the foregoing clauses;
- performing a charging operation by providing electrons to the reversible bio-electrode to perform a reduction operation and converting electrical energy into chemical energy; and
- performing a discharging operation by extracting electrons from the reversible bio-electrode to perform an oxidation reaction and converting chemical energy into electrical energy.

12. Method according to clauses 11, comprising the steps of performing the charging operation and/or discharging operations under anaerobic conditions.

13. Method according to clause 11 or 12, further comprising the step of providing the first compartment with carbohydrates capable of anaerobic oxidation for converting chemical energy into electrical energy.

14. Method according to clause 12, 13 or 14, comprising the step of providing the first compartment with acetate.

15. Method according to one or more of the clauses 11-14, further comprising the step of providing the first compartment with organic material to add additional energy to the system and/or recharge the system.

16. Method according to clause 15, wherein providing ethanol for recharging the system.

17. Method according to one or more of the clauses 11-16, wherein performing the charging step at a time period of energy surplus and performing the discharging step at a time period of energy shortage enabling local semi off-grid or off-grid energy storage.

CONCLUSIES

1. Bioelektrochemisch energieopslaginrichting, omvattende:
   - een behuizing voorzien van een eerste compartiment en een tweede compartiment;
   - een reversibele bio-electrode aangebracht in het eerste compartiment en omvattende een microbieel biosysteem geschikt voor het uitvoeren van een laadoperatie in een laadtoestand gebruikmakend van een reductiereactie voor het omzetten van elektrische energie in chemische energie, en het uitvoeren van een ontladingsoperatie in een ontladingstoestand gebruikmakend van een oxidatiereactie voor het omzetten van chemische energie in elektrische energie; en
   - een tegenelectrode die is aangebracht in het tweede compartiment en elektrisch verbindbaar is in een circuit met de reversibele bioelectrode.

2. Bioelektrochemisch energieopslaginrichting volgens conclusie 1, verder omvattende een ionuitwisselingsmembraan welke het eerste en tweede compartiment van elkaar scheidt.

3. Bioelektrochemisch energieopslaginrichting volgens conclusie 2, waarin het ionuitwisselingsmembraan een kationuitwisselingsmembraan is.

4. Bioelektrochemisch energieopslaginrichting volgens conclusie 3, waarin het ionuitwisselingsmembraan een protonselectief membraan is.

5. Bioelektrochemisch energieopslaginrichting volgens één van de voorgaande conclusies, waarin de tegenelectrode een capacitieve electrode omvat.

6. Bioelektrochemisch energieopslaginrichting volgens één van de voorgaande conclusies, waarin het eerste compartiment een organisch materiaalinlaat omvat.

7. Bioelektrochemisch energieopslaginrichting volgens één van de voorgaande conclusies, waarin het microbiële biosysteem een unitair biosysteem omvat geschikt voor het uitvoeren van zowel de oxidatie als reductiereacties.

8. Bioelektrochemisch energieopslaginrichting volgens één van de voorgaande conclusies, waarin het biosysteem een meervoudig biosysteem omvat met een eerste bio-subsysteem geschikt voor het uitvoeren van de oxidatiereactie en een tweede bio-subsysteem, ten minste gedeeltelijk verschillend van het eerste bio-subsysteem, geschikt voor het uitvoeren van de reductiereactie.

9. Bioelektrochemisch energieopslaginrichting volgens één van de voorgaande conclusies, waarin de inrichting is ingericht energie op te slaan met een dichtheid groter dan 10 kWh/m^3, bij voorkeur groter dan 12.5 kWh/m^3, en met de meeste voorkeur groter dan 15 kWh/m^3.

10. Bioelektrochemisch energieopslaginrichting volgens één of meer van de voorgaande conclusies, waarin het eerste en/of tweede compartiment is gescheiden in een oxidative sub-compartiment en een reductie sub-compartiment.

11. Werkwijze voor bioelektrochemisch energieopslag, omvattende de stappen:
- het voorzien van een bioelektrochemisch energieopslaginrichting volgens één of meer van de voorgaande conclusies,
- het uitvoeren van een laadoperatie door het voorzien van elektronen naar de reversibele bio-electrode voor het uitvoeren van een reductiereactie en het omzetten van elektrische energie in chemische energie; en
- het uitvoeren van een ontlaadoperatie door het extraheren van elektronen van de reversibele bio-elektrode bij het uitvoeren van een oxidatiereactie en het omzetten van chemische energie in elektrische energie.

12. Werkwijze volgens conclusie 11, omvattende de stappen van het uitvoeren van de laadoperatie en/of ontlaadoperatie onder anaerobe condities.

13. Werkwijze volgens conclusie 11 of 12, verder omvattende de stap van het voorzien van het eerste compartiment van koolhydraten geschikt voor anaerobe oxidatie voor het omzetten van chemische energie in elektrische energie.

14. Werkwijze volgens conclusie 11, 12 of 13, omvattende de stap van het voorzien van het eerste compartiment van acetaat.

15. Werkwijze volgens één van de conclusies 11-14, verder omvattende de stap van het voorzien van het eerste compartiment van organisch materiaal voor het toevoegen van additionele energie aan het systeem en/of het herladen van het systeem.

16. Werkwijze volgens conclusie 15, omvattende het voorzien van ethanol voor het herladen van het systeem.

17. Werkwijze volgens één van de conclusies 11-16, waarin het uitvoeren van de laadstap wordt uitgevoerd in een tijdsperiode van energie-overschot en het uitvoeren van de ontlaadstap wordt uitgevoerd in een tijdsperiode van energietekort daarmee locaal semi off-grid of off-grid energieopslag mogelijk makend.

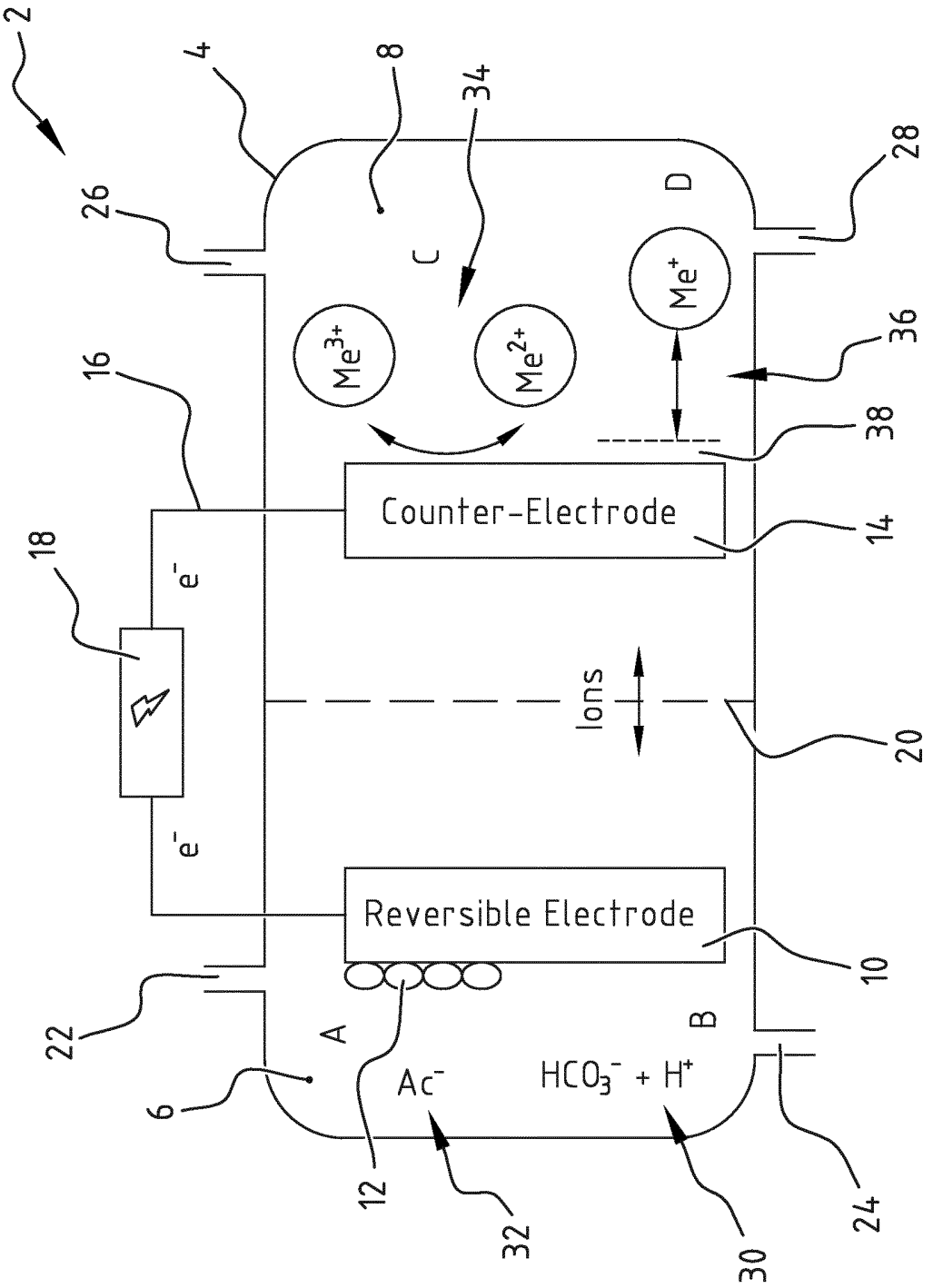
2
4
8
34
28
26
D
C
Me^{3+}
Me^{2+}
Me^{+}
36
16
38
Counter-Electrode
14
18
e^-
Ions
20
e^-
Reversible Electrode
10
22
A
B
6
Ac^-
$HCO_3^- + H^+$
12
32
30
24

FIG. 1

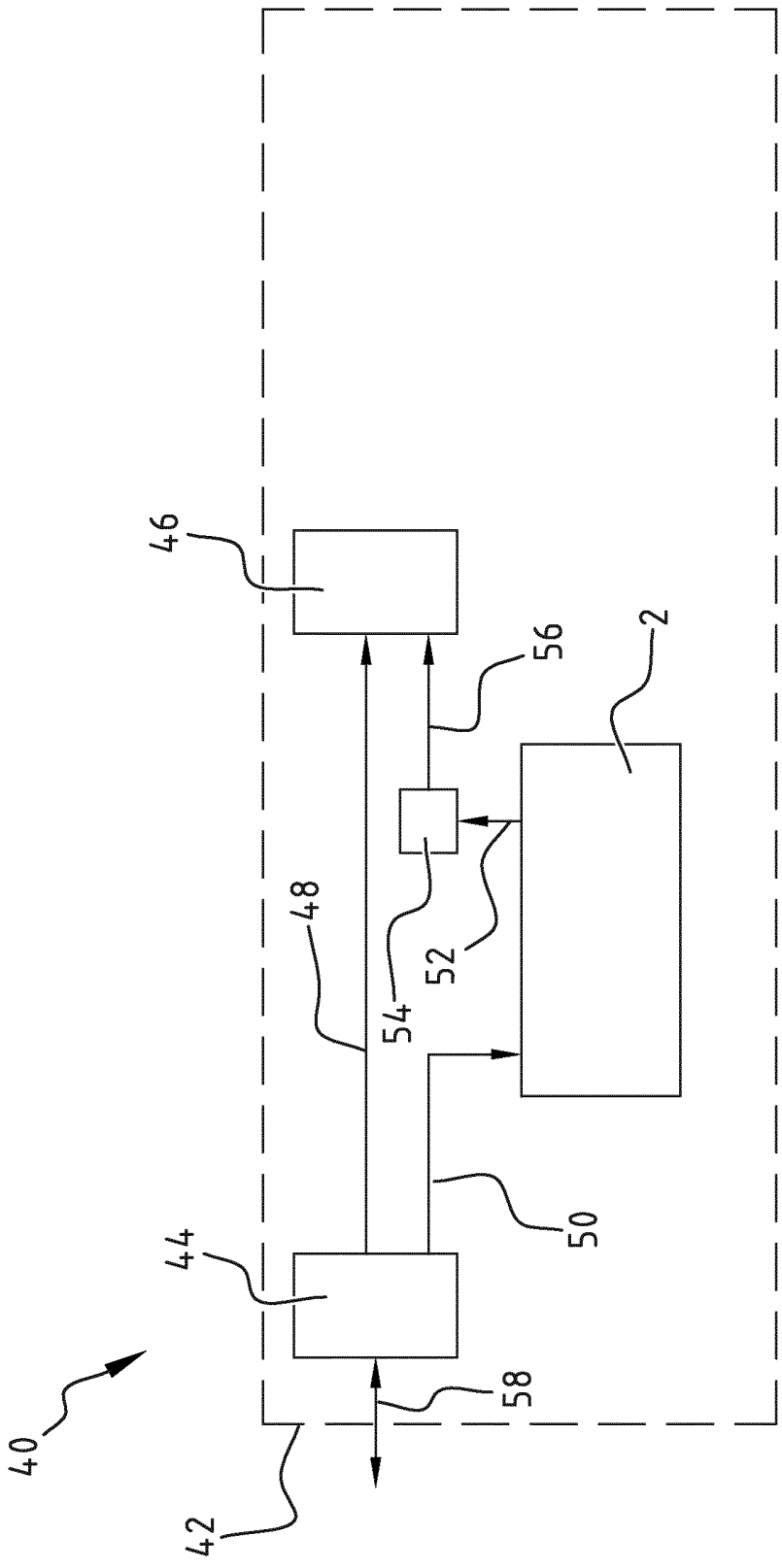

FIG. 2

ABSTRACT

The invention relates to a bioelectrochemical energy storage device and method there for. The bioelectrochemical energy storage device according to the invention comprises:

- a housing having a first compartment and a second compartment;
- a reversible bio-electrode that is placed in the first compartment and comprises a microbial biosystem capable of performing in a charging state a charging operation involving a reduction reaction converting electrical energy into chemical energy, and performing in a discharging state a discharching operation involving an oxidation reaction converting chemical energy into electrical energy; and
- a counter electrode that is placed in the second compartment and is electrically connectable in a circuit with the reversible bio-electrode.

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	2L/2QX38/MvD-65
Nederlands aanvraag nr. 2014248	Indieningsdatum 06-02-2015
	Ingeroepen voorrangsdatum

Aanvrager (Naam)

Stichting Wetsus, European Centre of Excellence for Sustainable Water Technology

Datum van het verzoek voor een onderzoek van internationaal type	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.
07-04-2015	SN 63878

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

H01M8/16 **H01M4/90** **H01M12/08**

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC	H01M

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III. ☐ GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)

IV. ☐ GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2014248

A. CLASSIFICATIE VAN HET ONDERWERP
INV. H01M8/16 H01M4/90 H01M12/08
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
H01M

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)
EPO-Internal

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	WO 2014/055671 A1 (UNIV LELAND STANFORD JUNIOR [US]) 10 april 2014 (2014-04-10) * het gehele document *	1-17
X	WANG YUN-HAI ET AL: "Electricity production from a bio-electrochemical cell for silver recovery in alkaline media", APPLIED ENERGY, deel 112, 4 februari 2013 (2013-02-04), bladzijden 1337-1341, XP028731620, ISSN: 0306-2619, DOI: 10.1016/J.APENERGY.2013.01.012 * het gehele document *	1-17

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[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

* Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvraag vermeld

"E" eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verhelderking van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
19 oktober 2015	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Koessler, Jean-Luc

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2014248

C (Vervolg) VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	SLEUTELS T H J A ET AL: "Effect of mass and charge transport speed and direction in porous anodes on microbial electrolysis cell performance", BIORESOURCE TECHNOLOGY, ELSEVIER BV, GB, deel 102, nr. 1, 8 juli 2010 (2010-07-08), bladzijden 399-403, XP027368505, ISSN: 0960-8524 [gevonden op 2010-07-08] * het gehele document *	1-17
X	US 2011/318610 A1 (RABAEY KORNEEL P H L A [BE] ET AL) 29 december 2011 (2011-12-29) * alinea [0056]; figuren 1, 2 *	1-3,5-17

1

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek: NL 2014248

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
WO 2014055671 A1	10-04-2014	US 2015214590 A1	30-07-2015
		WO 2014055671 A1	10-04-2014
US 2011318610 A1	29-12-2011	AU 2009304584 A1	22-04-2010
		CA 2739625 A1	22-04-2010
		CN 102224102 A	19-10-2011
		EP 2361219 A1	31-08-2011
		JP 2012505961 A	08-03-2012
		US 2011318610 A1	29-12-2011
		WO 2010042986 A1	22-04-2010

WRITTEN OPINION

File No.	Filing date (day/month/year)	Priority date (day/month/year)	Application No.
SN63878	06.02.2015		NL2014248

International Patent Classification (IPC)
INV. H01M8/16 H01M4/90 H01M12/08

Applicant
Stichting Wetsus, European Centre of Excellence for Sustainable Water Technology

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☒ Box No. VII Certain defects in the application
- ☒ Box No. VIII Certain observations on the application

Examiner
Koesslar, Jean-Luc

Application number

WRITTEN OPINION

NL2014248

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	11-17
	No:	Claims	1-10
Inventive step	Yes:	Claims	
	No:	Claims	1-17
Industrial applicability	Yes:	Claims	1-17
	No:	Claims	

2. Citations and explanations

see separate sheet

Application number
NL2014248

WRITTEN OPINION

Box No. VII Certain defects in the application

see separate sheet

Box No. VIII Certain observations on the application

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Prior Art

D1	WO 2014/055671
D2	WANG YUN-HAI ET AL: "Electricity production from a bio-electrochemical cell for silver recovery in alkaline media", APPLIED ENERGY, deel 112, 4 februari 2013 (2013-02-04), bladzijden 1337-1341, XP028731620, ISSN: 0306-2619, DOI: 10.1016/J.APENERGY.2013.01.012
D3	SLEUTELS T H J A ET AL: "Effect of mass and charge transport speed and direction in porous anodes on microbial electrolysis cell performance", BIORESOURCE TECHNOLOGY, ELSEVIER BV, GB, deel 102, nr. 1, 1 januari 2011 (2011-01-01), bladzijden 399-403, XP027368505, ISSN: 0960-8524 [gevonden op 2010-07-08]
D4	US 2011/318610

Novelty

D1 discloses a microbial battery comprising: an anode configured such that microbial activity at the anode provides electrons to an external circuit; a cathode configured to receive the electrons from the external circuit and change its composition from an oxidized cathode composition to a reduced cathode composition (claim 1). The microbial battery can operated without a membrane however the operation with a membrane is not excluded (p. 10 l. 15-18). The cathode comprises a redox couple selected from the group consisting of: Ag/AgO; Cu/Cu_2O; Cu/CuO; Fe_3O_4/Fe_2O_3; $Ni(OH)_2/Ni(OH)_3$;

oxides or hydroxides of X wherein X is selected from the group consisting of Ag, Cu, Fe, Ni, Mn, V, Zn or alloys thereof; cytochromes; conducting polymers; and Prussian blue analogues (claim 3).

This document is prejudicial to the novelty of claims 1, 2, 5-10.

D2 relates to a bioelectrochemical cell (paragraph 2.1, fig. 1) comprising two cylindrical chambers separated by a bipolar membrane, the anode is made of hydrophilic carbon cloth while the cathode is made of graphite. The bipolar membrane comprises a proton selective part. Both compartments comprise sampling holes.

This document is prejudicial to the novelty of claims 1-10.

D3 relates to a bioelectrochemical cell (paragraph 2.1) consisting of an anode and a cathode chamber separated by an anion exchange membrane. The anode is a carbon based felt and the cathode consists of a platinum coated titanium mesh. The anodic compartment comprises inlet and outlet holes (fig. 5).

This document is prejudicial to the novelty of claims 1, 2, 5-10.

D4 discloses a bioeletrichemical cell (paragraph 56) that consists of two parallel Perspex frames separated by a cation exchange membrane forming two chambers. The anode chamber is filled with granular graphite as the anode material and the cathode is formed of a carbon cloth electrically connected to a stainless steel frame. The anode and cathode chambers comprise inlet and outlet holes (fig. 1 and 2).

This document is prejudicial to the novelty of claims 1-3, 5-10

Inventive step

No opinion with respect to inventive step of the process claims 11-17 can be given for the time being in view of the unclear definition of the product claims which they depend thereon

Re Item VII

Certain defects in the application

The relevant background art disclosed inD1 is not mentioned in the description, nor is this document identified therein.

The features of the claims are not provided with reference signs placed in parentheses.

Re Item VIII

Certain observations on the application

Claims 1, 7, 8 do not meet the requirement of clarity especially with respect to the microbial biosystem, because the matter for which protection is sought is not clearly defined. The claim attempts to define the subject-matter in terms of the result to be achieved, which merely amounts to a statement of the underlying problem, without providing the technical features necessary for achieving this result.

There is no common technical definition for a capacitive electrode and as such claim 5 lacks clarity.

Claim 9 does not meet the requirement of clarity because the matter for which protection is sought is not clearly defined. The claim attempts to define the subject-matter in terms of the result to be achieved without providing the technical features necessary for achieving this result.

The feature of the apparatus claim 8 relate to a method of using the apparatus rather than clearly defining the apparatus in terms of its technical features espcially since the subject-matter of claim 10 is closely related to subject-matter of claim 8. The intended limitations are therefore not clear from this claim.