INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2014) 1–8

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Electricity generation with a sediment microbial fuel cell equipped with an air-cathode system using *photobacterium*

Dip Majumder [a], *Jyoti Prakash Maity* [b,1], *Chien-Yen Chen* [b,e,*,1], *Chien-Cheng Chen* [c], *Tsui-Chu Yang* [d], *Young-Fo Chang* [b,1], *Duen-Wei Hsu* [c], *Hau-Ren Chen* [a]

[a] *Department of Life Sciences, National Chung Cheng University, Minhsiung, Chiayi 621, Taiwan*

[b] *Department of Earth and Environmental Sciences, National Chung Cheng University, 168 University Road, Minhsiung, Chiayi 621, Taiwan*

[c] *National Kaohsiung Normal University, Department of Biotechnology, No. 62, Shenjhong Rd., Yanchao Township, Kaohsiung City 824, Taiwan*

[d] *Department of Hotel and Restaurant Management, Chia-Nan University of Pharmacy and Science, No. 60, Sec. 1, Erren Rd., Rende Dist., Tainan City 717, Taiwan*

[e] *Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Minhsiung, Chiayi 621, Taiwan*

ARTICLE INFO

Article history:
Received 29 October 2013
Received in revised form
11 August 2014
Accepted 2 September 2014
Available online xxx

Keywords:
Sediment microbial fuel cell
Cyclic voltammetry
Internal resistance
γ-Proteobacteria

ABSTRACT

The main purpose of this study is the characteristic and nature of current generation with a pure culture of single cell in a sediment microbial fuel cell. A sediment microbial fuel cell with an air-cathode system was studied for a prolonged period of time. The current maintained a steady increase throughout the entire time period and reached to its peak of 1.82 μA with power density of 29,024.65 μW/cm^2 at day 35. Water parameters such as salinity and pH were observed throughout the entire time period for better understanding. Operation of water parameter had been done after stabilization of current output for every measurement. The electron transfer pathway was assessed by cyclic voltammetry study. A low current density was observed due to profound internal resistance (141 Ω), and the reason for which was ohmic losses. A linear relationship was observed between current density and power density. Phylogenetic analysis was performed with 16S rRNA to identify the studied organism.

Introduction

It has have become main constraints to reduce the negative environmental impact in power generation and the use of energy for various heterogeneous applications, especially electrical energy. Freshwater and marine environments are rich in sediments that contain a high organic percentage, which could be used as a profuse inherent source of renewable energy for MFCs. Sediment microbial fuel cells (SMFCs)

* *Corresponding author*. Tel.: +886 5 2720411x66220; fax: +886 5 2720807.
E-mail addresses: chien-yen.chen@oriel.oxon.org, yen@eq.ccu.edu.tw, chieyeche@yahoo.com (C.-Y. Chen).
[1] Tel.: +886 5 2720411x66220.

http://dx.doi.org/10.1016/j.ijhydene.2014.09.005

are composed of a cathode that suspended in the aerobic sediment–water interface and an anode embedded in anaerobic marine or river sediment. They can be used to harvest electrical energy by the redox reactions. In water ecosystems, sediment of high organic content is perceived to be an environmentally undesirable solid waste due to contain of a range of pollutants, resulting in water-quality issues [1]. Tender et al. (2002) harvested power by oxidizing sediment organic matter with sea-water oxygen. In that study a naturally existing redox gradient has been used to span oxidant-rich sea water and reductant-rich sediment from millimeters to centimeters beneath the sediment surface [2–4]. Microorganisms plays a crucial role in these systems, including generation of electron-rich metabolites (e.g., sulfide ions), maintenance of the redox gradient, production of redox mediators and finally delivery of electrons to an electrode through direct electron transfer via a soluble electron shuttle [5]. Electrigenic bacteria in the sediment oxidize organic compounds of the sediment for their metabolic and respirational activity and harbor electrons to the anode, while oxygen is reduced in the water column by accepting electrons from the cathode electrode (Fig. 1) [5–9]. As a result, an electric current is generated.

A major aspect of the SMFCs is that these fuel cells depend on the natural voltage gradient and sources that are available in a marine or ocean and pond-like water ecosystem. Several ocean sensors require a low amount of energy in order to study oceanography, which makes sediment microbial fuel cells appropriate for this application. SMFCs could be applied for environmental monitoring, such as in biological oxygen demand (BOD) bio-sensors, and a dissolved oxygen (DO) sensor. As for practical application they could be applied for the removal of organic pollutants from sediment.

This study focused on a sediment microbial fuel cell consisting of an air cathode and an embedded anode for long operation at room temperature. This study was performed using a pure strain of a bacteria resembling *Photobacterium sp.* screened from ocean. The power production and the critical environmental parameters were measured for the assessment of the effects of on the performance of the sediment fuel cell.

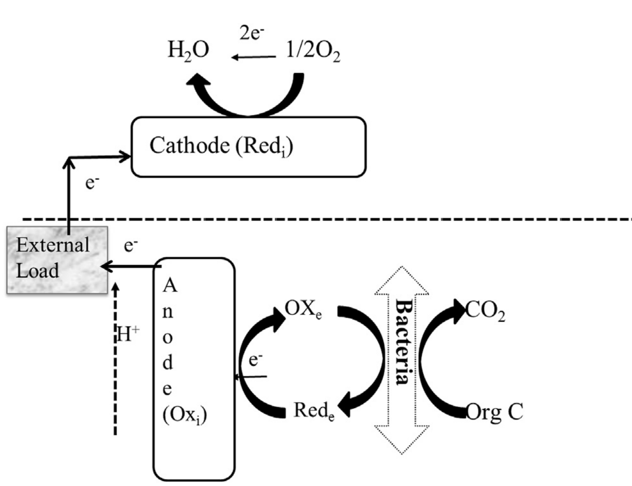

Fig. 1 – Schematic representation of working principle of mediator-less sediment microbial fuel cell.

Materials and methods

SMFC

The SMFC comprised a single chamber with a glass bridge on the lateral side equipped for the use of an air-cathode. The bioreactor was constructed from a 500-ml cylindrical flask with a three-electrode setup. The anode and cathode electrodes were made of carbon cloth, and the cathode was coated with 40% PTFE (Polytetraflouroetheylyene) diffusion layers to prevent water loss and diffusion of O_2, as described by Cheng et al., 2006 [10], without a platinum catalyst. For the anode and cathode electrodes (25 m^2/m^3), the volume and surface area were 128 cm^3 and 32 cm^2 respectively. The two electrodes were installed using the single chamber 180° to the horizontal plane for suitable electron transfer; copper wire was used to connect the circuit, and the fuel cell was placed under a constant load by connecting the anode and cathode to an external resistance of 150 KΩ.

Operational conditions

A wild-type bacterium screened from Taichung harbor, Taiwan was used for the production of electricity in SMFC. The bioreactor was operated at 33 ± 2 °C in a fed-batch mode for a month. The cylindrical flasks were converted to an SMFC by pouring sand up to a level to cover the cathode followed by gravel. Before use, the gravel was washed with acetone thrice and the sand was autoclaved. Then, the artificial sea water was poured off to create an artificial sediment environment. The artificial sea-water (35%) consisted of (per liter of deionized water) – NaCl-23.926 g, Na_2SO_4-4.008 g, KCl-0.677 g, $NaHCO_3$-0.196 g, KBr-0.098 g, H_3BO_3-0.026 g, NaF-0.003 g (Gravimetric salts), $MgCl_2 \cdot 6H_2O$-0.0532 g, and $CaCl_2 \cdot 2H_2O$-0.103 g (Volumetric salts). The bacteria were grown in a Marine Broth (Difco) overnight and inoculated to the reactor with

Table 1 – Marine broth composition.

Ingredients	Per liter
Peptone	5.0 g
Yeast Extract	1.0 g
Ferric Citrate	0.1 g
NaCl	19.45 g
$MgCl_2$	5.9 g
$MgSO_4$	3.24 g
$CaCl_2$	1.8 g
KCl	0.55 g
$NaHCO_3$	0.16 g
KBr	0.08 g
$SrCl_2$	34 mg
Boric acid	22 mg
Sodium silicate(Na_2SiO_3)	4 mg
Sodium fluoride(NaF)	2.4 mg
Ammonium nitrate(NH_4NO_3)	1.6 mg
Disodium phosphate(Na_2HPO_4)	8.0 mg

Please cite this article in press as: Majumder D, et al., Electricity generation with a sediment microbial fuel cell equipped with an air-cathode system using *photobacterium*, International Journal of Hydrogen Energy (2014), http://dx.doi.org/10.1016/j.ijhydene.2014.09.005