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Electric power generation by a submersible microbial fuel cell equipped with a membrane electrode assembly

Booki Min [a,b,*], Finn Willy Poulsen [c], Anders Thygesen [d], Irini Angelidaki [b]

[a] Department of Environmental Science and Engineering, Kyung Hee University, 1 Seocheon-dong, Yongin-si, Gyeonggi-do 446-701, Republic of Korea
[b] Department of Environmental Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark
[c] Fuel Cell and Solid State Chemistry Department, National Laboratory for Sustainable Energy, Technical University of Denmark P.O. Box 49, DK-4000 Roskilde, Denmark
[d] Center for BioProcess Engineering, Department of Chemical and Biochemical Engineering, Technical University of Denmark P.O. Box 49, DK-4000 Roskilde, Denmark

HIGHLIGHTS

- ▶ Membrane electrode assembly (MEA) was connected in parallel for SMFC operation.
- ▶ Various impedance contributions in SMFC were characterized by EIS analysis.
- ▶ The internal resistance of different electrode combinations was characterized.
- ▶ Optimum conditions for SMFC operation was proposed for high power generation.

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ABSTRACT

Membrane electrode assemblies (MEAs) were incorporated into the cathode chamber of a submersible microbial fuel cell (SMFC). A close contact of the electrodes could produce high power output from SMFC in which anode and cathode electrodes were connected in parallel. In polarization test, the maximum power density was 631 mW/m^2 at current density of 1772 mA/m^2 at 82 Ω. With 180-Ω external resistance, one set of the electrodes on the same side could generate more power density of 832 ± 4 mW/m^2 with current generation of 1923 ± 4 mA/m^2. The anode, inclusive a biofilm behaved ohmic, whereas a Tafel type behavior was observed for the oxygen reduction. The various impedance contributions from electrodes, electrolyte and membrane were analyzed and identified by electrochemical impedance spectroscopy. Air flow rate to the cathode chamber affected microbial voltage generation, and higher power generation was obtained at relatively low air flow less than 2 mL/min.

1. Introduction

Renewable energy production and wastewater treatment are indispensable requirements for sustainable human society. Global warming, energy supply security and risk of depletion of fossil fuels has emerged a strong interest in renewable energy sources (HaoYu et al., 2007). In addition, wastewater production is increasing as human and livestock population is increasing. Wastewater treatment is an essential component for the protection of human health and the environment, but the process requires considerable amount of energy supply. On the other hand wastewaters often contain many kinds of organic chemicals which with advantage could be utilized for renewable energy production (Logan, 2008).

A promising energy technology, utilizing the microbial fuel cell (MFC), has been proposed for solving energy supply and simultaneous treatment of wastewater containing organic compounds and even toxic chemicals (Logan, 2004; Lovley, 2006; Rittmann, 2006; Zhang et al., 2012a,b). In MFC technology, microorganisms use redox enzymes to transfer electrons from organic chemicals to a solid electrode in an anode chamber, and then the electrons are transported through the external load for electricity generation. For a complete circuit, a reduction process (oxygen to water) occurs at appropriate potential in the cathode chamber (Allen and Bennetto, 1993; Min and Logan, 2004). An MFC is operated in a similar way to a typical chemical fuel cell, but it uses microorganisms as biocatalyst, for the oxidation of diverse organic and inorganic substrates as the fuels. Since microorganisms are used in the system, there are several restrictions in operation such as maintaining neutral pH, optimum temperature, and proper salt and electrolyte concentration (Liu et al., 2005; Logan et al., 2006). When MFC technology is applied for field operation, scaling

* Corresponding author at: Department of Environmental Science and Engineering, Kyung Hee University, 1 Seocheon-dong, Yongin-si, Gyeonggi-do 446-701, Republic of Korea. Tel.: +82 31 201 2463.
E-mail address: bkmin@khu.ac.kr (B. Min).

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