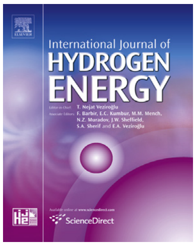
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–6

Available online at www.sciencedirect.com

ScienceDirect

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



Dynamic power response of microbial fuel cells under external electrical exciting

Chin-Tsan Wang [a],*, Yan-Ming Chen [b], Zi-Yang Hu [a], Wen-Tong Chong [c]

[a] Department of Mechanical and Electro-Mechanical Engineering, National I-Lan University, No.1, Sec. 1, Shennong Rd., 26047 I Lan, Taiwan

[b] Institute of Materials Science and Engineering, National Taipei University of Technology, No.1, Sec. 3, Zhongxiao E. Rd., 106 Taipei, Taiwan

[c] Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 25 November 2016
Received in revised form
25 January 2017
Accepted 9 February 2017
Available online xxx

Keywords:
Wastewater
Microbial fuel cells
Electric impact
Bacteria
Power
Dynamic response

ABSTRACT

More related studies of microbial fuel cells (MFCs) have been noted recently because of the feature that MFCs could use bacteria to convert organic matter from wastewater into electricity. But facing the slow dynamic response and low power density of MFCs, a technique using external physical exciting with an electrical force, with an intensity ranging from 0 to 8.8 kV/m, was applied in this study to ascertain the bioelectrochemical dynamic response of MFCs. Results show that the rise time of MFCs under external electric impact, regardless of electrical intensity, was shorter than in a case of without electric impacting. Evidence shows that external electric impact gives a significant positive impact on the dynamic performance of MFCs. The dynamic power response of a system under cases of electric impacting is better than in cases of without (i.e., $MFC_{original}$). In addition, a maximum electric charge of 358.9×10^{-3}C in a system whose Oxidation-Reduction Potential (ORP) was −219 mV was obtained in the case of $MFC_{E\text{-}4.8}$ and was 4.07 times that of the $MFC_{original}$. These findings will be useful to the application of micro-MFCs, especially for those electrically impacting wastewater environments.

Introduction

As for the feature that MFCs have bioreactors that use microbes to direct organic matter into electricity [1,2], it is not only possible to apply them to wastewater treatment [3,4] and bio-sensors [5,6], but also to apply them to micro-electronic devices for energy supply [7]. Currently, a lengthy study should be undertaken and improved on for the purpose of making MFCs commercialized [8,9] because of their slow dynamic response and low power density.

In MFCs, the electron production in the system mainly relates to the biofilm where bacteria is attached on the surface of the anodic electrode and is not related to drifting or floating bacteria, archaea, algae and protozoa. Two reasons for this can be explained as follows. First, the electron kinetic transfer process of microbes will often occur by way of taking the direct electron transfer and solid conductive matrix. It is easier to react to than in a pathway utilizing electron mediators [10]. Conversely, planktonic electrochemically active bacterial strains in the reactor of MFCs would be carried away along with the effluent [11]. Hence, this would result in an

---

* Corresponding author.
E-mail address: ctwang@niu.edu.tw (C.-T. Wang).

http://dx.doi.org/10.1016/j.ijhydene.2017.02.064
0360-3199/© 2017 Hydrogen Energy Publications LLC. Published by Elsevier Ltd. All rights reserved.

Please cite this article in press as: Wang C-T, et al., Dynamic power response of microbial fuel cells under external electrical exciting, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.02.064

uneven biofilm on the system electrodes and also even induce a low power output and unsteady overshooting state in the power performance of MFCs [12]. Therefore, controlling the biofilm of the electrode surface in the system seems to be important for treating wastewater effectively [13].

As for the dynamic response of MFCs, this would also significantly affect the start-up time of MFCs [14]. Lu et al. indicated that the start-up time required for MFCs in a case of without biofilm was 9 days, but only about 10 min [14] in the case of with one. Therefore, how to enhance the interaction between microbes and electrodes seems to be worthy of studying in this work [15].

Facing the related reports, several studies on the property of electrode material were executed for enhancing the interaction between parts of microbes and electrodes. Karra et al. [16] reported that the activated carbon nanofibers (ACNF) of anodes utilized would enhance biofilm growth because a higher surface area of electrodes was occupied, then the power density (PD) of 3.50 ± 0.46 W/m^3 obtained was higher than in the case of using a carbon cloth electrode with a PD $= 1.10 \pm 0.21$ W/m^3. Additionally the COD removal of $85 \pm 4\%$ found by utilizing ACNF was higher than in the case of electrodes with carbon cloth by about 15%. Zhang et al. [17] also indicated that the mesoporous carbon modified anode not only increased the anode surface area, but also enhanced the electron transfer. The maximum power density obtained was 81% higher and the startup time of the system appeared 68% shorter than in the case of using bare carbon paper anodes [17].

Another method of ammonia-treatment was undertaken by Cheng et al. [18] to impose on the bacterial attachment of the carbon cloth during the start-up period in MFCs. Results show that the first stage time of maximum power was shorter than in the case of untreated carbon cloth, being at about 90 h, and the start-up time was also reduced by 50% [18]. Similarly, MFCs with a shorter start-up time would be utilized by using carbon paper with an anode electrode of low Polytetrafluoroethene (PTFE) whose content is about 0–20 wt% [19]. The formation of biofilm would change the surface feature of the electrode surface from hydrophobic into hydrophilic because the biofilm formation would greatly decrease the contact angle of the electrode surface. Finally, Santoro et al. [20] addressed that a batch type of MFC with a fifteen day start-up time would be obtained by utilizing $\text{-N(CH}_3)^{3+}$ modified gold electrodes because of it having a better attachment and growth of biofilm [20].

However, modified anode electrode material in MFCs would reinforce the adhesion ability of microbes on the electrode, but the development of the biofilm upon the electrode still deeply relied on a natural process because the microbes closely approached the surface, with the environmental condition near the part of the electrode surface being simultaneously rich in nutrients [21]. Hence, how to shorten the approach time of plankton microbes moving to the electrode surface would be important and worthy of investigation in this study.

Nowadays, several studies have shown that the surface of most microbial cells including *Escherichia coli* would occupy a negative charge [22–24]. Therefore, a technique of electric force applied in MFCs to enhance the dynamic and power performance of the system would be workable because all the microbes would be forced to move and accumulate onto the region of the electrode surface undertaking a suitable operation of using external electric impacting. Similarly, results showed that a positive effect on enhancing the electricity and shortening the start-up time of a MFC would be found [25] under a condition of DC electric voltages (±1 V, −3 V). Now, a new method, different to the one previously reported [25], will be utilized in this study. Here, a continuous external electric force will be synchronized with the electrical discharge reaction of MFCs when ascertaining the external electric impact on the performance of the system, especially for the dynamic power response.

Materials and methods

MFC setup

In this study, two kinds of MFC apparatus were designed with corresponding aims, respectively. The first kind is a dual chamber MFC whose main elements, shown in Fig. 1, are electrodes, a membrane and external electric plate. They would be mounted on a slide glass (72 mm × 20 mm × 1 mm) to clearly observe the motion of bacteria in the MFC chamber on the metallographic microscope. In this study the working volume of each anode and cathode chamber was 15 ml. And Nafion 117 (Dupont Co., USA), with an effective area of 14 mm^2 (1 mm × 14 mm), was used as the proton exchange membrane (PEM) for separating the anode and cathode chambers.

Another kind of a dual chamber MFC (not shown) was addressed as follows. On setting the external DC electric force, this MFC was assembled by two cubic-shaped chambers whose dimensions were 4.4 mm × 22 mm × 2 mm and the working volume was 5 ml. It would be made up of Polymethylmethacrylate (PMMA) and separated by Nafion 117 with an area of 48 mm^2 (2 mm × 24 mm). And carbon cloth with 300 mm^2 (20 mm × 15 mm) was utilized as the anode and cathode electrode in MFCs.

For impacting effectiveness of the external electrical force on the bacteria within these two kinds of MFCs, an external

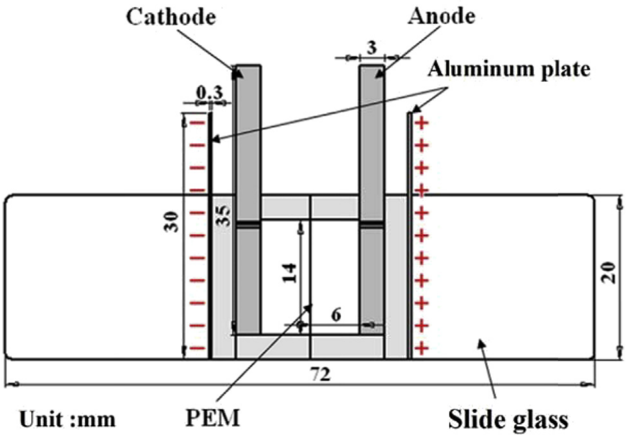


Fig. 1 – Schematic diagram of a dual chamber MFC mounted on a slide glass.

Please cite this article in press as: Wang C-T, et al., Dynamic power response of microbial fuel cells under external electrical exciting, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.02.064