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Mixing effect of biometric flow channel in microbial fuel cells

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HIGHLIGHTS

- ▶ Biometric mixer design was first applied to microbiological fuel cell.
- ▶ Power density reached was enhanced from that without mixer added for 28.9%.
- ▶ Mixer will contribute to the electricity improvement of microbiological fuel cell.

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ABSTRACT

Microbial fuel cell (MFC) technology can utilize microbiology to metabolize organic substance and transform the chemical energy into electrical energy, which can be widely applied to purify the environment and develop new energy. Now, a novel method of biometric mixer and biometric flow channel in MFC rarely utilized previously would be applied and investigated. Two parts of experiment related to biometric channel and biometric mixer experiment will be investigated respectively. Compared with common continuous MFC, the maximum power density of MFC with biometric channel can reach 91.81 mW/m^3, and the stable discharging voltage can retrain at 0.5 mV. Based on experiment (1), the biometric mixer is added and the effect is discussed. It is found that the average mixing efficiency of nutrient source and bacteria liquid reaches 98%, and the maximum power density reaches 118.34 mW/m^3, 28.9% higher than that of MFC without mixer. These results show that the biometric channel and biometric mixer can be useful to enhance the power performance and could be widely applied to all kinds of MFCs in the future.

1. Introduction

The rapid depletion of fossil fuels together with the uncertain global climate in the past decades has inevitably led to an increased commercial interest in renewable fuels [1]. The microbial fuel cell (MFC) technology has been attracting more and more researchers' attention in the field, as MFC technology provides a new opportunity for direct electricity generation from renewable and biodegradable materials [2].

Since the first successful MFC was set up by Potter [3] in 1911, MFC technology has developed and improved greatly, especially the recent few decades. However, MFC is still confronted with the problem of low power generating rate. Many efforts were devoted into the improvement of the MFC performance, especially on the electrode. Many materials has been tested and studied for MFC, such as graphite plate [4], graphite felt [5], carbon paper [6–8], and stainless steel mesh [9], carbon cloth [10–12] and so on. Besides, the electrode has also been modified, such as coating platinum and platinum mohr on electrode [13], and combining electron transferring mediator with the electrode [14].

In addition to above mentioned method, fluid dynamics could also be employed to improve the performance of MFC, wherein Heijne et al. [15] adopted parallel flow channel and power generating reached 2.3 μW/cm^2; Chiao et al. [16,17] applied parallel flow channel design to electrode, so that biological responses became closer to proton exchange membranes, which could make it easier for proton to penetrate through, and the open-circuit voltage of MFC was enhanced for 13.7 times.

Further, it is very important to maintain sufficient buffer liquid density in the system [18], because the electric power generated by MFC is through the released electron which is random motion from microbiological metabolizing reaction, therefore the mixing between buffer liquid and bacteria is very important. Hamid et al. [20] employed magnetite stirring method to enhance mixing of nutrient source and microbiology.

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However, the mechanical mixing will do harm to the bacteria, and the operation need extra energy input, which is a kind of energy waste. In previous literature, researches related to utilize the biometric mixer in MFC system were addressed rarely. Biometric mixer is a fluid component of low voltage resistance and high miscibility (mixing efficiency reaching 92%) [19]. In order to mix the nutrient source and bacteria homogeneously, a mixer designed according to the biometric concept can be applied to MFC, as well as biometric flow channel [11]. In the study, the biometric mixer and biometric flow channel are added to MFC separately, and the effect will be discussed.

2. Experimental design and method

2.1. Experiment model

In our body, the nutrient and the oxygen can be transferred to every place through blood vessels, as the diameter of the blood vessel changes with the body part. In order to fulfill the supply of nutrient and bacteria, the concept of biometric mixer (as shown in Fig. 1) was added into the design of MFC.

In traditional MFC, the transfer of electron and H^+ can be seen as the results of diffusion. Diffusion is random and uncertain, so the transfer efficiency is very low and the power performance is bad. But the addition of flow channel can utilize the characteristics of fluid to increase the probability of e^- and H^+ reaching the electrode. And the design of biometric flow channel (as shown in Fig. 2) can achieve the disturbance of anode, so the nutrient and bacteria can be mixed better and the movement of e^- and H^+ more violently [19].

In the study, a double chamber MFC was constructed. The material of MFC body was acryl, with 4.6 cm length, 4.7 cm width and 1.6 cm height, and the interior channel drawing was as shown in Fig. 2. The inner volume was 0.5 ml, and the width of inlet was 2 mm. The proton exchange membrane was Nafion-117. No. 304 stainless steel was chosen as the electrode material, with 2.5 cm length, 2.5 cm width, and electrode working area of 1.72 cm^2, the same cell body chose for the both chamber but cathode was without flow channel.

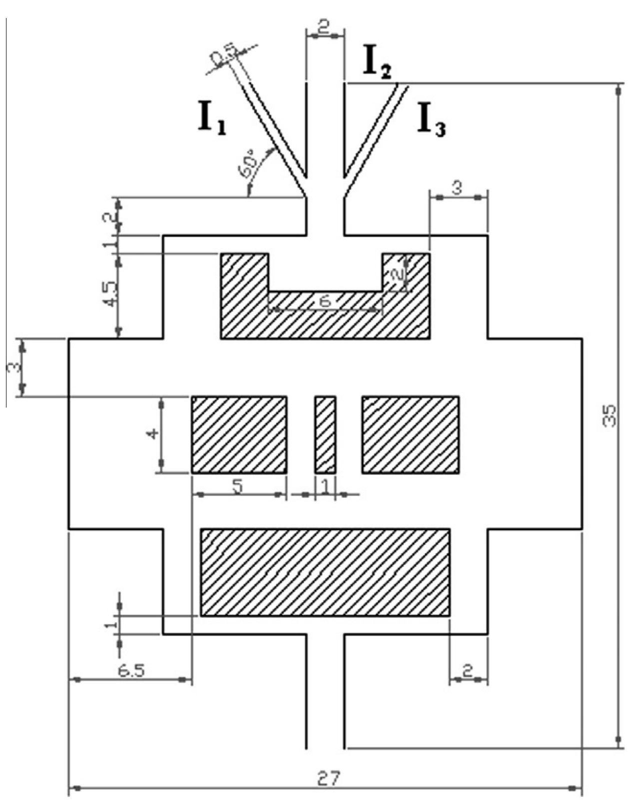

Fig. 1. Schematic diagram of biometric mixer (unit: mm) I_1, I_3: side inlet; I_2: major inlet.

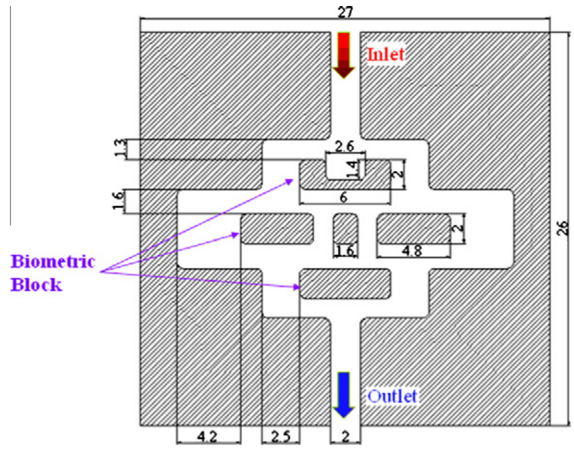

Fig. 2. Schematic diagram of biometric flow channel (unit: mm).

2.2. Bacteria

The adopted microbiology was *Escherichia coli* bacterial strain No. 51534 bought from Bioresource Collection and Research Center (BCRC). Quantitative culture method was employed; the related steps were as following:

1. Draw bacteria: Bring out minor bacteria liquid from frozen preserved bacteria liquid of *E. coli*, by flat crossed method; draw bacteria for 3 times then put into 37 °C incubator, and conduct cultivation for 12 h.
2. Select bacteria: From the third flat crossed line, select an applicable bacteria colony and put into culture solution mixed homogeneously, then put into 37 °C incubator and conduct cultivation with 200 rpm for 12 h.
3. Magnify: Bring out minor bacteria liquid from *E. coli* culture solution, and by quantitative method fetch required liquid volume and put into flask with culture solution, and leave at least 2/3 space for bacteria stirring space, finally put into 37 °C incubator and conduct cultivation with 200 rpm for 18 h.

2.3. Experiment framework

In order to study the effect of biometric mixer and biometric flow channel, two experiments were set up, as described as follows:

(1) Biometric flow channel experiment.

Based on the common continuous MFC, the biometric flow channel was added into the anode chamber, and the schematic diagram was shown in Fig. 3. When the nutrient and bacteria flow through the MFC, the existing block could change the movement of fluid and cause a disturbance. Then the disturbance could improve the mixing of nutrient and bacteria.

(2) Biometric mixer experiment.

As shown in Fig. 4, the biometric mixer was added ahead of the MFC. Before the nutrient and bacteria affluxes to the MFC, they