A MINIATURIZED MICROBIAL FUEL CELL

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ABSTRACT

This paper presents a miniaturized microbial fuel cell as an energy source for MEMS. A microorganism, *Saccharomyces cerevisiae*, is used to catalyse glucose and electricity is produced by the overall redox reaction. The fabricated miniaturized microbial fuel cell has an electrode area of 0.07 cm^2 . The bio-electrical responses of the miniaturized microbial fuel cell are characterized. The open-circuit potential is measured as 300 mV and lasts for 2 hours. The current density is measured as 286 nA/cm^2 and lasts for 30 minutes under a 100 ohm load.

INTRODUCTION

Miniaturized, portable power sources are important for the realization of MEMS. Previous approaches including micro turbine engines and micro batteries[1, 2] have been proposed. In this paper, we have demonstrated the feasibility of a miniaturized microbial fuel cell as an energy source for MEMS.

Figure 1 shows the operation principle of a microbial fuel cell. In the anode compartment, microorganisms, such as *Saccharomyces cerevisiae*, are put into a buffer solution. Glucose is fed to the microorganisms and the hydrogen protons, electrons and carbon dioxide are generated during the fermentation process[3]. The electrons are transferred to the electrode and protons are diffused through a proton-exchange membrane(PEM). In order to increase the electron transfer efficiency, an electron transfer *mediator* is needed in the anolyte suspension[4]. In the cathode compartment, oxidizing materials such as potassium ferricyanide can be used to accept the electrons and reduce to ferrocyanide. The reduced ferrocyanide is oxidized by oxygen and returns to ferricyanide and water. The wastes produced in the microbial fuel cell are carbon dioxide and water.

FABRICATION PROCESSES

Figure 2(a) shows the close-up diagram of the PEM with Cr/Au electrode. Filter papers with $0.2 \mu\text{m}$ porosity are used as the electrode support and Cr/Au is thermal evaporated on to the support. After the electrodes with porous supports are fabricated, they are thermal compression bonded to the PEM, Dupont Nafion-117. Figure 2(b) shows

Figure 1: Operational principle of a microbial fuel cell.

the exploded diagram of the miniaturized microbial fuel cell. The electrode area is 0.07 cm^2 and the fluid ports are made of plastic with o-ring seal to minimize leakage. In the final assembly step, the fluid ports and the electrode/PEM assembly are glued together and ready for testing.

EXPERIMENTAL PROCEDURES AND RESULTS

The anolyte is prepared as the following: microorganism culture (*Saccharomyces cerevisiae*) is mixed with glucose in a 0.1 M phosphate buffer(pH 7.0). An electron transfer mediator, methylene blue of 0.01 M is then added in to promote the bio-electrical reaction efficiency. Moreover, a sufficient aeration is provided to enhance the fermentation process. On the cathode side, a 0.02 M potassium ferricyanide solution is prepared in a 0.1 M phosphate buffer(pH 7.0). The bio-electrical responses are measured by dropping a drop(volume 0.16 c.c.) of each corresponding solutions into the anode and cathode compartments and the electrical signals are measured chronically. Figure 3 shows the measurement results of the open-circuit voltage response of a microbial fuel cell. The voltage goes up to 300 mV and lasts for more than 2 hours. The final voltage drop after 2 hours is identified as solution dried out in air. The fuel cell discharge experiment is also carried out and the result is shown in Fig. 4 for two loading conditions. In the first loading condition, a bare conduction wire with resistance of 0.18 ohm is used. As shown in Fig. 4, the voltage goes up

(a)

(b)

Figure 2: Design of a miniaturized microbial fuel cell. (a): A close-up schematic diagram of the PEM, Cr/Au electrodes and porous support. (b): Final assembly of the fuel cell.

Figure 3: Open-circuit voltage measurement results.

to 13 μV in 10 minutes. In the second loading condition, a resistor of 100 ohm is used, the voltage maintains at 2 μV for 30 minutes. The current density of 286 nA/cm^2 is then calculated by dividing the current with the electrode area.

Figure 4: Microbial fuel cell discharge measurement results.

CONCLUSIONS

In this paper, we have demonstrated a miniaturized microbial fuel cell as a power source for MEMS. *Saccharomyces cerevisiae* is used to catalyse glucose and generate electricity. The wastes in the fuel cell are water and carbon dioxide. The fuel cell electrode area is 0.07 cm^2 and the current density is measured as 286 nA/cm^2 under 100 ohm and remains stable for 30 minutes. The open-circuit voltage goes up to 300 mV and lasts for 2 hours.

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