Technical Note

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Nafion as a nanoproton conductor in microbial fuel cells*

Mostafa RAHIMNEJAD, Tahereh JAFARY, Fahimeh HAGHPARAST, Ghasem D. NAJAFPOUR, Ali Asghar GHOREYSHI
[1]*Biotechnology Research Lab., Faculty of Chemical Engineering, Noshirvani University of Technology, Babol-IRAN*
e-mails: rahimnejad_mostafa@yahoo.com

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Abstract

Nafion, a sulfonated tetrafluoroethylene copolymer, consists of a hydrophobic fluorocarbon backbone (–CF2–CF2–) to which hydrophilic sulfonate groups (SO_3^-) are attached. The presence of negatively charged sulfonate groups in a nanomembrane brings about a high level of proton conductivity. In this study, *Saccharomyces cerevisiae* was used for production of bioelectricity in a 2-chambered microbial fuel cell (MFC). We selected 9- cm^2 Nafion 117 and Nafion 112 as nanomembranes to transport the produced proton from the anode chamber to the cathode compartment at ambient temperature and pressure. Initial glucose concentration was 30 g/L. The maximum obtained voltage, current, and power density for Nafion 117 were 668 mV, 60.28 mA/m^2, and 9.95 mW/m^2, respectively. For Nafion 112, those results were 670 mV, 150.6 mA/m^2, and 31.32 mW/m^2, respectively.

Key Words: Nanomembrane, MFC, Nafion, bioelectricity, *Saccharomyces cerevisiae*

Introduction

Microorganisms serve as biocatalysts and convert the energy stored in chemical bonds of bioconvertible substrates into electricity under ambient temperatures and pressures in microbial fuel cells (MFCs) (Chaudhuri and Lovely, 2003). The biopotential developed between the bacterial metabolic activity [reduction reaction generating electrons (e-) and protons (H+)] and the electron acceptor conditions, separated by a membrane, leads to the generation of bioelectricity in MFCs (Cheng et al., 2006; Aelterman et al., 2008). Nafion is one of the extensively studied ionomer membranes due to its high electrical conductivity, remarkable permselectivity, and excellent thermal and chemical stability. The chemical structure of the Nafion 117 membrane consists of a polytetrafluoroethylene backbone and a regularly spaced, long perfluorovinyl ether pendant side chain terminated by a sulfonate ionic group (Heitner-Wirguin, 1996).

The main objective of this study was to evaluate Nafion as a nanomembrane in a 2-chambered microbial fuel cell.

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Materials and Methods

Saccharomyces cerevisiae PTCC 5269 was supplied by the Iranian Research Organization for Science and Technology, Tehran, Iran. The microorganisms were grown in an anaerobic jar.

The fabricated cells, in laboratory scale, were made of glass (Pyrex) material. The volume of each chamber (anode and cathode chambers) was 800 mL, with a working volume of 600 mL. The sample port was provided for the anode chamber, wire point inputs, and inlet port. The selected electrodes in the MFC were graphite, with a size of $30 \times 55 \times 2\ mm$. A proton exchange membrane (PEM; Nafion 117 and 112, Sigma-Aldrich) was used to separate the 2 compartments. A photograph of the fabricated MFC cell is shown in Figure 1.

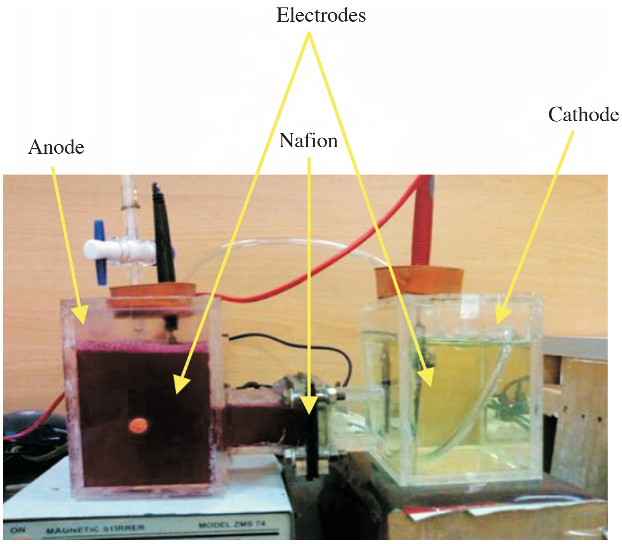

Figure 1. Two-chamber MFC used in this experiment.

Results and Discussion

After inoculation of 30 g/L of glucose in the anode chamber with *Saccharomyces cerevisiae* as electrically active bacteria, a data logger was set to obtain data in the form of open circuit voltage until the reaching of the steady state condition. The initial voltages for both systems, one with Nafion 117 as the membrane and the other with Nafion 112 (hereafter labeled as MFC1 and MFC2, respectively), were 300 and 320 mV, which was expected due to the same substrate of the 2 systems. Gradual generation of electrons and protons as the substrate was consumed by the biocatalyst led to bioelectricity production. Figure 2 shows improvement in the open circuit voltage curve results, along with MFC performances after inoculation. This procedure took about 30 h. Steady voltage was increased to around 690 and 680 mV for MFC1 and MFC2, respectively.

In a batch cycle, once the MFCs stabilized at the maximum steady voltage, the polarization curve was obtained, recording the voltage by varying the external resistance. Figure 3 demonstrates the voltage and power density versus the current density. At maximum condition, which is the peak point of the polarization curve, voltage, current density, and resistance, set to obtain a polarization curve, versus voltage and current density, respectively, Figures 4a and 4b were obtained. Figure 4 shows the behavior of the 2 MFCs in the form of voltage and current density when constant resistance was used to result in polarization curves.

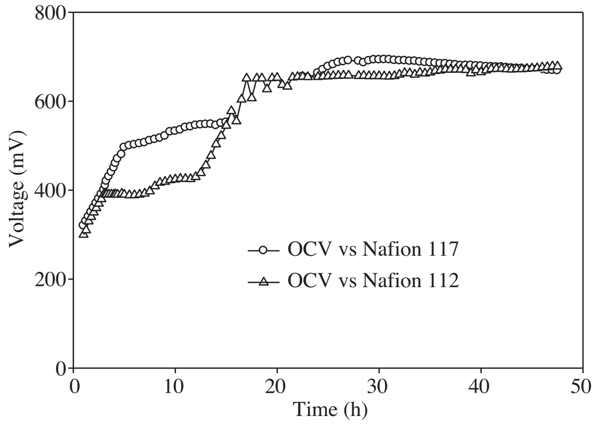

Figure 2. Open circuit voltage (OCV) curves of MFC1 and MFC2.

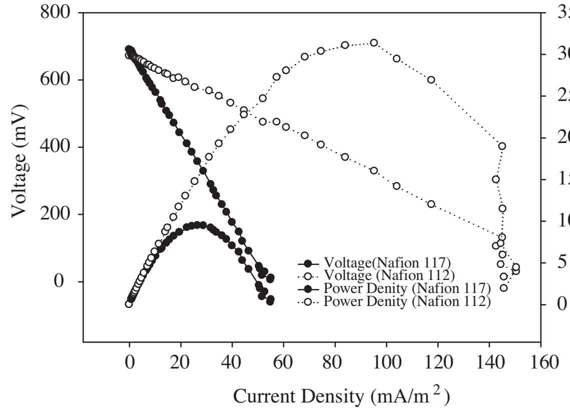

Figure 3. Polarization curve of MFC1 and MFC2 at steady OCV.

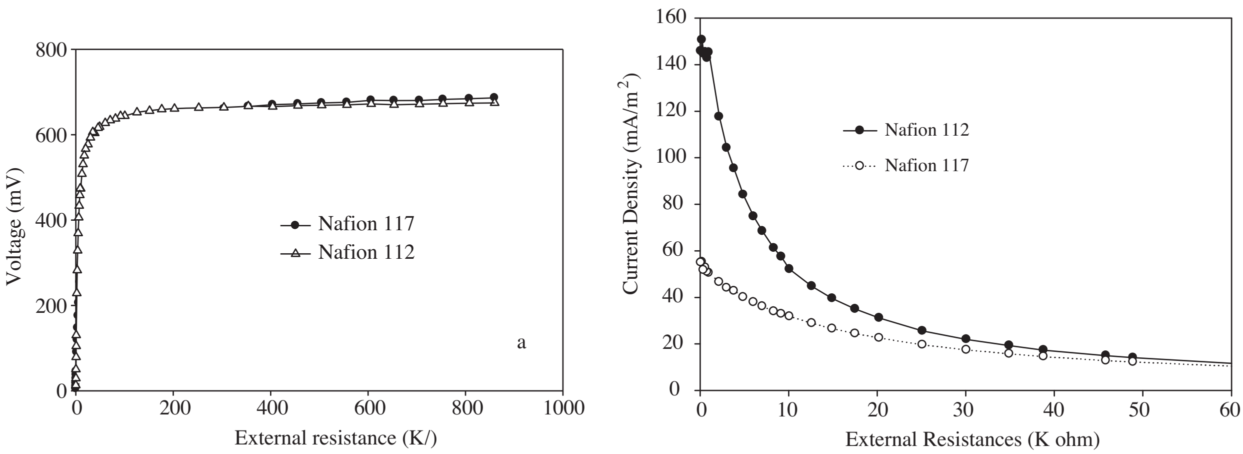

Figure 4. a) Voltage obtained in a Ω-definite range of external resistance at steady conditions, and b) voltage obtained in a definite range of external resistance at steady conditions.

Conclusion

The obtained data showed that this nanomembrane has good conductivity for production of bioelectricity in MFCs. Nafion 112 and 117, different in thickness, were tested in this study. The results showed showed better performance for Nafion 112, but the stability of both nanomembranes should be considered.

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