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Performance evaluation of Disposable Microbial Fuel Cell Contained Drying Bacillus Subtilis in an Anodic Electrode

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Abstract: In this study, a simple microbial fuel cell (MFC) was created as a disposable electricity generator. By using multiwalled carbon nanotube instead of carbon sheet to make electrodes, we obtained high performance. MFC generated maximum power density of 0.64μW/cm2 and current density of 8μA/cm2 at external resistance of 10kΩ.

Key words: *Microbial Fuel Cell, MWCNT, Handmade Electrode, Bacillus subtilis*

INTRODUCTION

Nowadays, energy issues are more serious in the world. Limited producing fossil fuel countries intend to cut down the amount of export due to decreasing fossil fuel reserves. That may cause economic collapse and creating war. In addition, the increasing of consuming fossil fuel is the cause of increasing CO_2 ratio in the air inducing climate change phenomenon. So, an increasing CO_2 ratio gets the world into a vicious circle of environment.

Various electrical power generation methods existed in the world, including thermal power generation and nuclear generation, and which is the core of electrical energy all over the world. Thermal power generation is the most famous method with high efficiency, however, it needs to burn a lot of fuel to work the turbine. So, this method produces much amount of CO2 gases into the atmosphere. On the other hand, nuclear power generation is very high efficiency and low CO2 emission. However, it may cause a terrible disaster. An accident by a nuclear power plant is very dangerous that scatter much amount of dangerous radioactive substance.

Recently, renewable power generation method has been expected to shoulder the next generation. Water power generation, wind power generation, solar power generation and so forth are renewable energy generation methods. Although, these methods are low efficiency compared with thermal power generation and nuclear power generation, they are safe and environmental friendly. More recently, bio fuel cells have been receiving increasingly attention as new renewable energy [1-4]. It is a cell that produces electric power based on the reaction of hydrogen and oxygen, which has been used in a wide range of fields such as automobile manufacturing and space development. The distinctive features of it are ecological, quiet, and high-efficient in exhausting heat, so it is one of the crucial and utilizable technologies from now on. Microbial Fuel Cell (MFC) is one type of fuel cells, and it produces electric power by decomposing bio fuel by microorganism [2-4]. In other words, it makes possible to eliminate wasteful processing in waste disposal system and resolve social issue.

MFC has mainly two types: two chamber MFC and one chamber MFC [5-9]. A two chamber MFC is composed of an anodic chamber, a cathodic chamber, electrolyte and electrodes. In the anodic chamber, biofilm of microorganism attached to the electrode breaks down some organic matters to carbon dioxides, water, protons and electrons. Electrons are collected to the anode and move to the cathode [10-12]. Protons in the anodic chamber move to the cathodic chamber through a Proton Exchange Membrane (PEM). In the cathodic chamber, protons and electrons react with, oxygen on the cathode to generate water. One chamber MFC has the same principal. The different point is that it has not the cathodic chamber, and the cathode is attached to the PEM. Compared with one chamber MFC, two chamber MFC can generate higher power. In contrast, one chamber MFC is more compact, simpler and lower cost than two chamber MFC. In MFC research, Shewanella and Geobacter are often used as microorganisms. Shewanella and Geobacter are anaerobic bacteria, which have flagella to transfer electrons to the electrode.

In this study, paper-based MFC which had an anodic and a cathodic chamber. We created the electrode (HE), which was composed of pulp from toilet paper

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and Multi Wall Carbon Nano Tube (MWCNT). A biofilm was made by Bacillus subtilis attached on the anodic electrode.

EXPERIMENTAL METHOD

2.1. Method

MFC was connected to external resister and Data acquisition (DAQ). (Figure1) After 10 mins we started recording, a 20 µl of water was dropped into the center of the anodic electrode. Voltage across the external resistance generated by MFC was recorded on PC. Interval time of recording was 30 seconds.

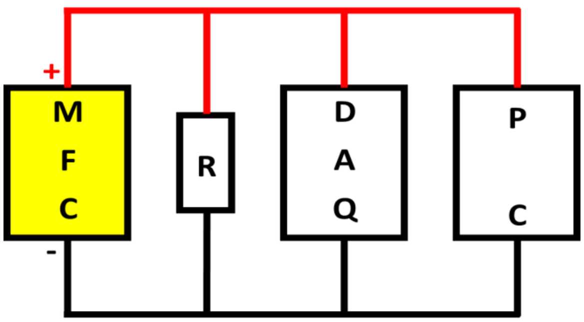

Figure 1 A circuit diagram

2.2 Analysis

An evaluation MFC performance needs data and calculation. Better MFC has a low internal resistance and high current connected to low external resistance. We calculated a current density J[$\mu A/cm^2$](1) and power density W[$\mu W/cm^2$](2) based on voltage across external resistance. MFC performance was evaluated by recorded data.

$$J = \frac{V}{R} \times \frac{1}{S} \qquad (1)$$

$$W = \frac{V^2}{R} \times \frac{1}{S} = VJ \qquad (2)$$

MATERIALs

MFC, HE, Broth for Bacillus subtilis and Membrane was composed as described in Table 1.

Table 1. Materials

MFC	Handmade Electrode	Broth	Membrane
Acrylic parts	Toilet paper 0.5g	Water 200ml	Toilet paper 0.5g
Membrame	MWCNT 5ml	Meat extract 0.5g	Water 50ml
Handmade Electrode	Water 50ml	Pepton 0.5g	
Hydrophobic substance		Yeast extract 0.5g	
		Glucose 0.5g	

3.1.1 MFC design

MFC was constructed using some materials showed in Table 1 (Figure 2).

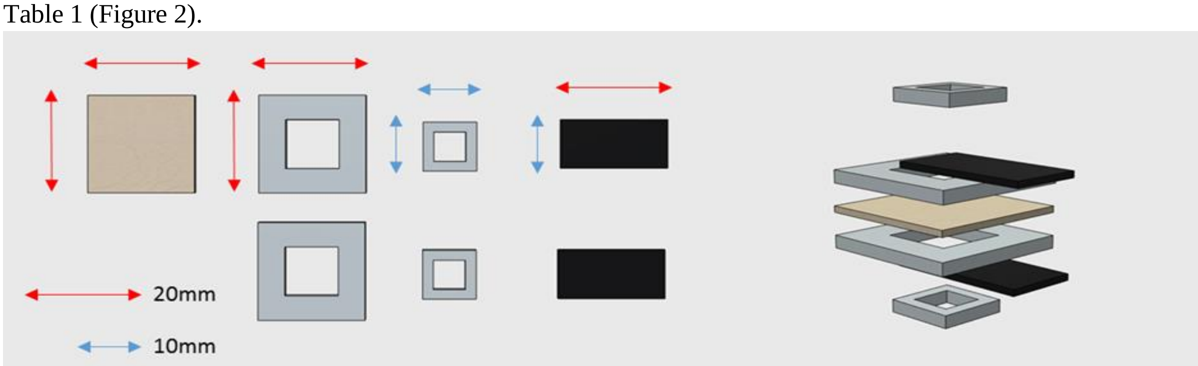

Figure 2 Materials and Constriction of MFC

Four Acrylic parts was cut each shape by laser cutter. Membrane was coated hydrophobic substance to prevent water from going through the anode side to the cathode side. So, they were assembled as figure 2 and fixed by four clips to keep the shape.

3.1.2 Electrode fabrication

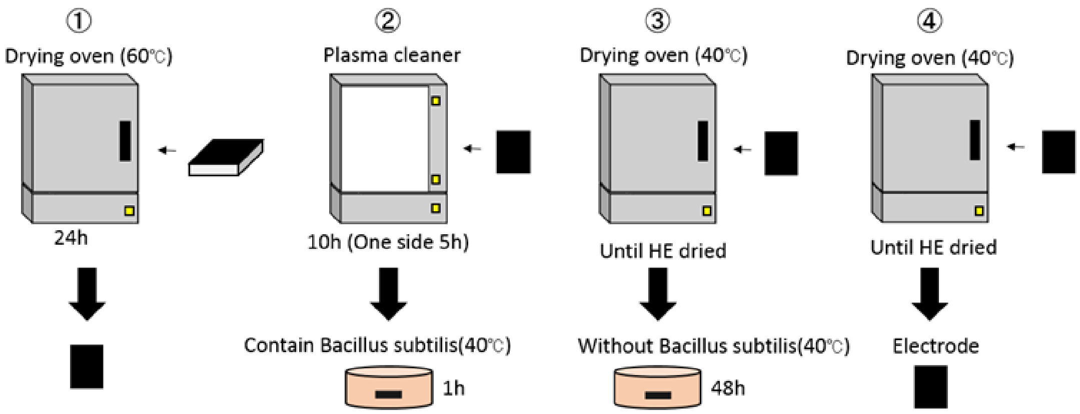

Figure 3 A process of making Electrode

HE used CNT to decrease internal resistance of the electrode. All materials were mixed by magnet stirrer for 24h. After that, HE solution was dried under 60 degrees. To modify from hydrophobic to hydrophilic, HE was cleaned up by a plasma cleaner. HE was soaked in Bacteria solution for an hour and dried under 40 degrees. Once dried HE attached Bacillus subtilis, it was cultivated in broth to grow and make biofilm in the HE under 40 degrees. MFC used dried electrode of HE. (Figure 3)

3.1.3. Bacterial Solution

Broth was prepared using some materials showed in table 1. All materials were mixed and boiled for 3mins to sanitize other bacterium. When broth temperature turned to 80 degrees, 0.1mg of Bacillus subtilis powder was mixed in. After broth temperature turned to room temperature, broth was left in shaking incubator under 40 degrees for 2 days for Bacillus subtilis growing.

3.1.4. Membrane

Membrane was made from toilet paper and hydrophobic substance. A process was same as HE without MWCNT. After dried all membrane was coated by hydrophobic substance. Thickness of the membrane was 0.1mm.

RESULTS AND DISCUSSION

4.1. Comparing Carbon Sheet (CS) and HE

CS is often used as the electrode for MFCs. Better conductive and stability generates good performance and therefore needed for MFC. To compare CS with HE, we measured Voltage across the external resistor (10kΩ) output of MFC with CS and HE electrodes. The MFC using CS generated the maximum of 6mV, while the one using HE generated the maximum of 80mV (Figure 4)

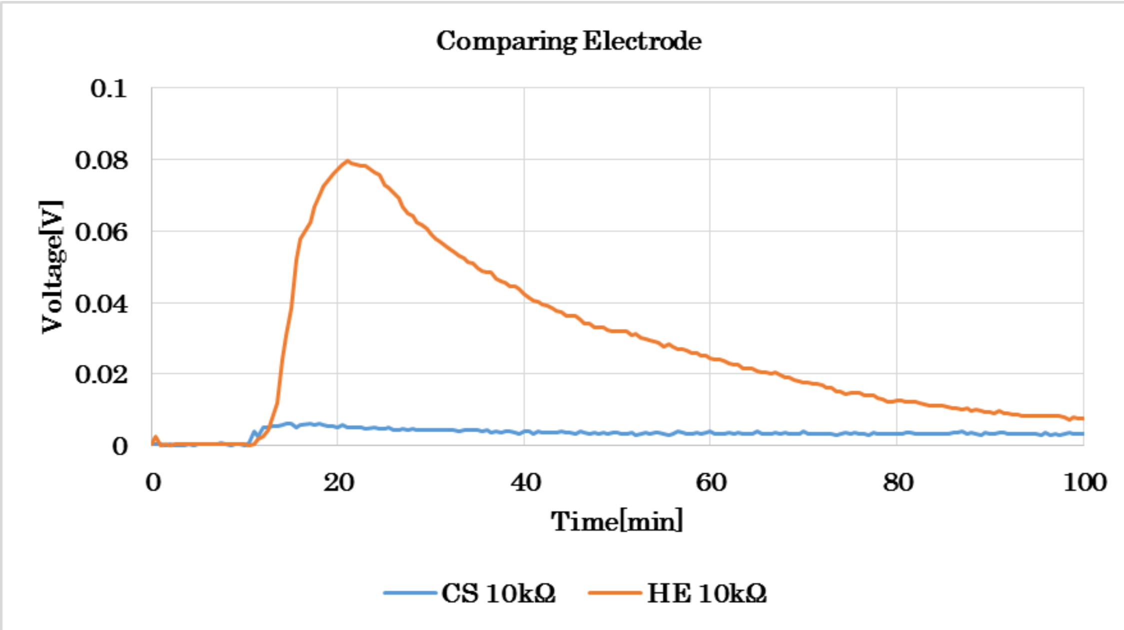

Figure 4 Comparing Electrode

From this result, HE had much better performance than CS. Because, HE had low internal resistance and good conductive compared with CS.

4.2. Power density measurement

To measure evaluate the performance, we measured voltage discharged by 1kΩ (MFC1), 5kΩ (MFC2), 10kΩ (MFC3), 50kΩ (MFC4) and 100kΩ (MFC5). Output voltage was shown in table 2.

Table 2. Maximum voltage

Device	**Voltage**	**Resistance**
MFC1	12mV	1kΩ
MFC2	34mV	5kΩ
MFC3	80mV	10kΩ
MFC4	170mV	50kΩ
MFC5	194mV	100kΩ

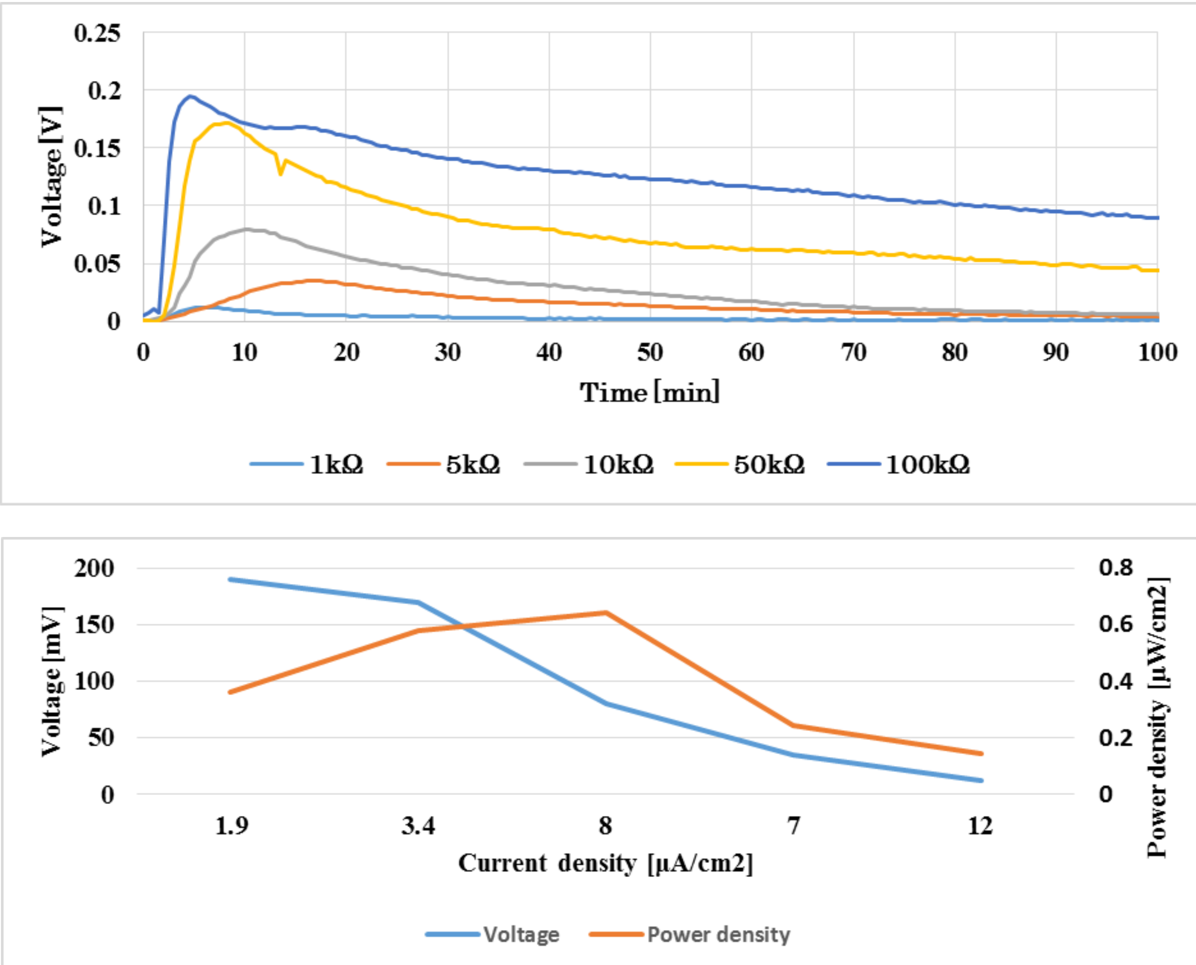

Figure 5. Output voltage as discharged by different external resistors (top) and polarization curve (bottom)

In figure 5, the MFC generated the maximum voltage of 12mV (MFC1), 34mV (MFC2), 80mV (MFC3), 170mV (MFC4), and 194mV (MFC5). Based on this data, we calculated current density and power density of each MFC as follows, 12µA/cm2 and 0.144µW/cm2 (MFC1), 7µA/cm2 and 0.245µW/cm2 (MFC2), 8µA/cm2 and 0.64µW/cm2 (MFC3), 3.4µA/cm2 and 0.578µW/cm2 (MFC4) and 1.9µA/cm2 and 0.361µW/cm2 (MFC5). From the polarization curve, it can be confirmed that the highest power density was obtained at 10kΩ. Therefore, the internal resistance of MFC was presumed around 10kΩ. In addition, the response time of the MFC was fast. As water was dropped, voltage increased quickly to the peak voltage in less than 1 min. After voltage reached to the peak, it decreased gradually because of the connected load.

CONCLUSION

We made a disposable MFC using paper based materials and bacillus subtilis. Electrodes were made from toilet paper. Voltage across external resistance was generated by Bacillus subtilis biofilm degrading organic matters in the electrode. 5 types of resistors (1kΩ, 5kΩ, 10kΩ, 50kΩ and 100kΩ) were connected to measure the maximum power density. MFC generated maximum power density of 0.64µW/cm2 and current density of 8µA/cm2 at external resistance of 10kΩ. The proposed MFC offered a realistic microbial power source that can potentially empower micropower devices.

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