World Applied Sciences Journal 14 (Special Issue of Food and Environment): 91-95, 2011
ISSN 1818-4952

Microbial Fuel Cell Production with Alga

[1]Maryam Otadi, [2]Sina Poormohamadian, [3]Fatemeh Zabihi and [4]Mahdi Goharrokhi

[1]Department of Chemical Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran
[2]Department of Petroleum, Science and Research Branch, Islamic Azad University, Tehran, Iran
[3]Department of Chemical Engineering, Ayatollah Amoli Branch, Islamic Azad University, Amol, Iran
[4]Department of Chemical Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran

Abstract: Microbial Fuel Cell (MFC) is a bioelectrical and chemical system in which bacteria is utilized for electricity generation by the organic material. The basis of MFCs applications are the same as conventional fuel cells applications. However the catalysis are substituted by the microorganisms and enzymes in MFCs. different microorganisms have been applied in the fuel cells based on biological reaction rates. Electrical flow and fuel cell efficiency have been affected by biological reaction rates. At the current study, a sort of alga existing in fresh waters of Iran is used as the model microorganism. 310 mg of this type of algae generates a continual electricity flow equal to 0.4V in about 160 min at the optimal conditions (the optimum conditions are: membrane length of 10 cm and copper electrodes with sectional area of the Electrode of 3 mm^2).

Key words: MFC · Alga · Membrane length · Electrode sectional area

INTRODUCTION

Microbial Fuel Cells applications have been recently developed in industrial different fields. Type of utilizing microorganism depends on the type of MFCs. For instance MFCs can be applied for supplementary energy production during waste water treatment (superfluous elements consumption by water bacteria specious) [1,2]. MFC technology is a clean and reproducible way for energy production. Actually MFC contamination is less than the standard acceptable amount [1,3]. A MFC also use energy much more effectively than the standard combustion cells. MFCs efficiency is theoretically more than 50% [1].

Any organic material can be a nourishing source for MFCs. Micro-organisms generate electrical flow by oxidizing the organic material and no pressure need in MFCs like other Fuel cells, this is the most important advantage of MFCs [4].

These cells include cathodic and anodic bodies. The fuel is oxidized by the micro-organisms and produces electron and proton [5,6]. Electrons are transferred to the cathodic body through an external circuit and proton passes through the membrane. Electrons and protons are combined with oxygen on the cathodic body to form water [4].

Several bacteria specious including pili on their external membrane can transfer their released electrons without intermediates [5]. Taking into considering the novelty of MFCs technology, efficiency dependence on the operational factors such as the sort of bacteria and ionic membrane and the operational temperature, are not fully understood [7,8]. In direct MFCs, bacteria often have active electrochemical enzymes as sythochromes on their external membrane that transfer the electrons to external materials [7].

The basic reaction takes place at the anode compartments, where the carbohydrates the fuels significant role accompanied by microorganisms. On the anode part, a series of anaerobe processes are carried out that result in electron production [1,9]. These reactions are divided into two categories: glucose reactions with water and respiration reactions by alga as a green plant [8, 10].

According to the following equation, reaction of a hydrocarbon and water in the anode part, releases electron and proton, at the anaerobe conditions:

$$C1_2H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H+ + 48e-$$

Then, the released protons diffuse into the cathode part across the membrane, while the electrons are

Coresponding Author: Maryam Otadi, Department of Chemical Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

Fig. 1: Alge Majotia

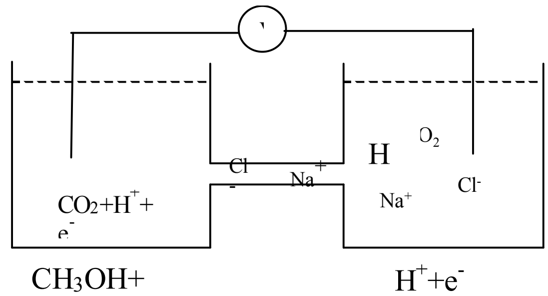

Fig. 2: Electron Transfer scheme in MFC

transferred to the cathode part throughout the electrodes. In the cathode, a salt solution plays the electrolyte role. At the presence of air, water steam is produced according to the following reaction [11,13].

$$3/2\ O_2 + 6H^+ + 6e- \rightarrow 3H_2O$$

A brief equation provided for respiration is as follows:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

The process of respiration is considerably depends on the reduction of NAD^+ to NADH and the counteraction that is the NADH oxidation. The photosynthesis is the counteraction of the oxidation-reduction reactions in the respiration process:

$$6CO_2 + 6H_2O + \text{sun light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

The biological energy is usually stored and released by the oxidation-reduction reactions [11,13].

Among the several resources utilizing as the micro-organisms, micro-alga specious are the only resources sounds to be applicable to produce fuels or even biodiesel in a few decades, because of the fast proliferation and photosynthesis capabilities, low costs of incubation environment and feasibility at the industrial scales [12]. Our country has also developed the unknown sources that can take the country up to the level of green fuel pioneer countries. In this project, Tehran province local micro-alga (calling Majoutia) has been used as the basic material in MFCs (Fig. 1).

MATERIALS AND METHODS

Materials: Alga (Majoutia, existing in fresh water of northern Tehran mountainside rivers) was the main part of basic material. is light green and is collected from that has to transfer to minus zero temperature 7 hours after sampling and after this time doesn't have the optimal result anymore and is so called dead. In order to get the precious results, alga was directly extracted from the river flow. However the stagnant and semi-stagnant water alga as well shows the trustable results, it has been proved that the water stream alga works out more efficient due to its high activity. Anzali Marsh and its surrounding alga can be used as the source of microorganisms.

Carbon textile (Saze industries, Tehran) and all other compounds and chemical materials including NaCl, glucose, agar, are purchased from Merck Company.

Methods

MFC Production Technique: In a fuel cell the membrane plays a key role. In fact the membrane permits the protons to transfer from anode to cathode. Positive and negative charges are generated at the both cathode and anode parts, due to the previously explained reactions, that are neutralized by the membrane electric charges (Na^+, Cl-). Only the charges passing through the wire generate the electrical flow and anode and cathode in general has a neutral charge (Fig. 2).

To make the agar membrane, first we added agar powder to boiling water to make a 50% w/v uniform solution. The solute must be completely dissolved into the solvent. Then 4% w/v of salt was added into the solution and dissolved completely.. After that the prepared solution was poured in a PVC test tube and put over to get cold gradually.

Electrodes are made from conductive metals and contain anode and cathode. In the present work, copper wires were utilized as the metal conductor. Impendence is the total amount of Ohmic, Self and Reservoir resistances ($Z=R_R + R_L + R$). Low Z values leds to the low electron wastes. Therefore, low impendence wires are recommended to be used in the fuel cells. We attached a piece of carbon textile (4*2 cm^2) at the cathode tip, in order to collect the electron easily from the solution surface. Another piece of wire is also used as anode. A cathodic solution (NaCl, 20% w/v) and the alga were used as fuel in the anodic part (310 mg). Anodic and cathodic bodies were attached in the wall layer by the generated membrane and the attached points were insulated. In order to make an anaerobe environment, the air in anodic part was pumped out after adding the all compounds and the electrical flow starts when the electrods were connected to the voltmeter.

The electrode type, dimensions and sectional area and the membrane characteristics were considered as the experimental variables. MFC efficiency has been measured by Electrical flow in the all runs as a function of these variables.

Electrode Type: The effect of electrode type was analyzed firstly. Similar electrons from Copper and Aluminum were chosen. The electrode type obviously affects on the generated flow magnitude. On the other hand, a strong electrical conductive electrode transfers high amounts of electrons.

Electrode Sectional Area: MFC efficiency dependence on the wire sectional area was investigated by employing three copper wires with the cutting edges of 2, 3 and 4 mm^2. Increasing the wire sectional area enhances the electricity generation. However, the high sectional area makes an undesirable impendence that causes adverse effects on the wire conductivity.

The resistance of intended wire has to be less than 70Ω to act as a transfer base. Higher resistance of wire reduces the electrical flow.

Membrane Tube Length: On this study, three different lengths of membranes (5, 10 and 15 cm.) were experimented in order to investigate the role of membrane length in a MFC system. The electrons flow accumulation at the short membrane tube prevents the electrons to pass resulting in generating an inconsistence electrical flow. On the other hand, utilizing the excessively long membranes results in the electrons dispersion.

Finally, the provided cell was tested in optimal condition in order to check the electricity flow power and persistency.

RESULTS AND DISCUSSION

At the current work, the Algae were employed in a microbial Fuel Cell. 0.3V electricity was initially generated by this fuel cell before the optimization procedure, which is a considerable value in proportion to what is expected of a MFC system. The flow power had remained continually steady for more than one hour. The effective factors optimization definitely improves the MFC efficiency.

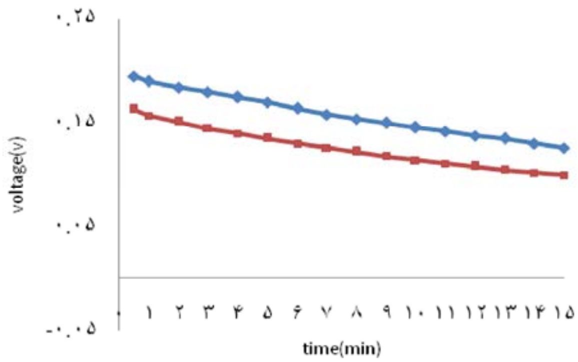

Fig. 3: Electrode Type (Cathodic Solution: NaCl 20%, Anode: 310 mg Alga with 10 gr Glucose, Electrode Sectional area: 0.5 mm^2, Membrane Length: 5cm, ♦ Copper, ■ Aluminium)

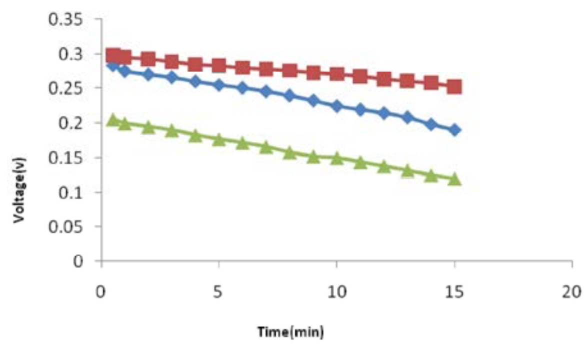

Fig. 4: Sectional area of the Electrode (Cathodic Solution: NaCl 20%, Anode: 310 mg Alga with 10 gr Glucose, Membrane Length: 5cm, Electrode Sectional area: ▲ 2 mm^2, ■ 3 mm^2, ♦ 4 mm^2)

Electrode Type: Figure 3 presents the effect of electrode material on the MFC efficiency. The copper electrode clearly causes high efficiency in comparison with the aluminum one. The observed difference arise from the copper wires have strong conductivity and week electrical resistance in relation to the aluminum.

Electrode Sectional Area: The bigger the wire sectional area, the more the number of the transferred electrons during a given interval of time or the more intensive flow rate. Actually, to make an acceptable amount of electrical flow, the wire resistance must be 70Ω at most. Wire electrical conductivity considerably reduces with the resistance of more than this threshold. The test was initially performed by a copper wire with the sectional area

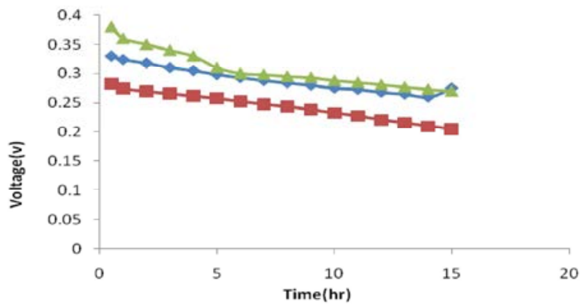

Fig. 5: Membrane Length (Cathodic Solution: NaCl 20%, Anode: 310 mg Alga with 10 gr Glucose, Electrode Sectional area: 3 mm^2, Membrane Length: ♦ 5cm, ▲ 10cm, ■ 20cm)

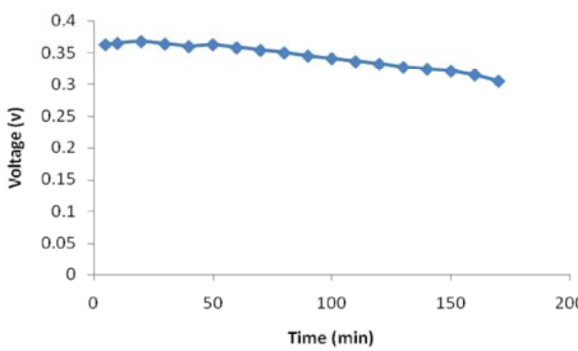

Fig. 6: Electrical flow in MFC with optimum conditions

of 0.5 mm^2 (10Ω resistance) which culminated in producing a poor electrical flow rate due to the small sectional area. Figure 4 compares the transferred electrical flow rates by three copper wires with various sectional area (2, 3 and 4 mm^2) The curves show that the electricity flow increases by increasing the copper wire cutting edge up to 3 mm^2 (Of a nominal resistance of 60Ω).

On the other part increasing the sectional area, more than 4 mm^2, causes decreasing the electrical flow power, based on the resistance role. Among the experimented copper wires the wire with 3 mm^2 sectional area made the most powerful flow rate.

Tube Membrane Length: Various membranes (5, 10 and 20 cm) were employed in the MFC. According to the results, the tube length adversely affects on the electrical voltage. This behavior is directly dominated by the electrons mass and motion. The longer the membrane lenght, the harder the electrons motion. On the other hand, for the excessively short membranes, accumulation of electrons hinders the electrons free motion. The most powerful electrical voltage was generated by using a 5 cm length membrane.

Finally, the generated electrical flow was measured at the MFC optimal condition (Figure 6). At the optimal condition (membrane length of 10 cm and copper electrodes as wires with cutting edge of 3 mm^2 and 10g Glocose) resulted in the highest value of voltage (0.38V) which almost remained steady in more than 2 hours. This is a valuable result that can be expected of a Microbe Fuel Cell system.

CONCLUSION

According to the energy consumption rising and the lack of current energy resources, we need to find the clean, renewable, high efficient and reasonable new energy resources. Microbial Fuel Cell is one of the energy generating novel aspects that reliably covers the mentioned necessities. The conventional energy resources are limited and need a long time for regenerating. They are also low efficient, expensive and environmentally destructive. None of these shortcomings are observed within the MFCs. Nevertheless the FCs are also employed in some industrial and pilot processes as the adequated energy sources, the generated electricity flow is too low. Therefore they are mostly used in the sensors.

A kind of microbial fuel cell with algae feeding has been developed at the current work, with the capability of producing 0.4V electrical flow and has acceptable stability. These MFAs could be used in sensors.

AKNOWLEDGEMENT

This publication was made possible by grant provided from the Islamic Azad University, Tehran Central Branch.

REFERENCES

1. Gregor Hoogers, 2002. Fuel Cell Technology Handbook, Second Edition (Handbook Series for Mechanical Engineering), CRC Press.
2. Logan, B.E., B. Hamelers, *et al.,* 2006. Microbia Feul Cells: Methodology and Technology, Environmental Science and Technology, published on web.
3. Sarah Strycharz, M., *et al.,* 2008. Applied and Environmental Microrobiology, Oct. 2008.
4. Amos, B., E.J. Suchomel, K.D. Pennell and F.E. Lo¨ffler, 2008. Water Res., 42: 5718-5726.

5. Aulenta, F., *et al.,* 2007. Environ. Sci. Technol., 41: 2554-2559.
6. Bond, D., D.E. Holmes, L.M. Tender and D.R. Lovley, 2002. Science, 295: 483-485.
7. Yi, H., K.P. Nevin, *et al.,* 2009. Biosensores and Bioelectronics, 24: 3498-3503.
8. Bond, D. and D.R. Lovley, 2005. Appl. Environ. Microbiol., 71: 2186-2189.
9. Fricke, K., F. Harnisch and U. Schreoder, 2008. Energy Environ. Sci., 1: 144-147.
10. Yia, H., K.P. Nevina, *et al.*, 2009. Biosensors and Bioelectronics, 24: 3498-3503.
11. Richter, H., *et al.,* 2007. Applied and Environmental Icerobiology, Aug. 2007.
12. Liu, Y., F. Harnisch, *et al.,* 2008. Biosens. Bioelectron, in press.
13. Bond, D. and D.R. Lovley, 2003. Appl. Environ. Microbiol., 69: 1548-1555.