A Review on Microbial Fuel Cell for Electricity Generation

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Abstract Environmental protection and energy crisis are two recent challenges to us. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and eco-friendly. In this review a brief description is given for the bio-fuel cells. The review is mainly intended to concentrate on microbial fuel cells (MFCs) where micro-organisms are used to convert the fuel to electrical energy.

Keywords- Environment, Energy crisis, Bacteria, MFC, Electricity Generation

I. INTRODUCTION

Alternative sources of energy are in high demand because developed as well as developing countries are facing serious energy crisis[1,2]. High energy requirement of conventional sewage treatment systems are demanding for the alternative treatment technology, which will be cost effective and require less energy for its efficient operation. In addition, due to global environmental concerns and energy insecurity, there is emergent interest to find out sustainable and clean energy source with minimal or zero use of hydrocarbons[3,4].

Microbial Fuel Cell Microbial fuel cells (MFCs) are devices that use bacteria as the catalysts to oxidize organic and inorganic matter and generate current [5]. Electrons produced by the bacteria from these substrates are transferred to the anode (negative terminal) and flow to the cathode (positive terminal) linked by conductive material containing a resistor or operated under a load. Electrons can be transferred to the anode by electron mediators. Microbially catalyzed electron liberation at the anode and subsequent electron consumption at the cathode, when both processes are sustainable, are the defining characteristics of a MFC.

II. Literature review

Microbially catalyzed electron liberation at the anode and subsequent electron consumption at the cathode, when both processes are sustainable, are the defining characteristics of an MFC. Using a sacrificial anode consisting of a slab of Mg alloy does not qualify the system as an MFC because no bacteria are needed for catalyzing the oxidation of the fuel[5]. Systems that use enzymes or catalysts not directly produced in situ by the bacteria in a sustainable manner are considered here as enzymatic biofuel cells and are well reviewed elsewhere. MFCs operated using mixed cultures currently achieve substantially greater power densities than those with pure cultures [6]. In one recent test, however, an MFC showed high power generation using a pure culture but the same device was not tested using acclimated mixed cultures and the cells were grown externally to the device [8]. Community analysis of the microorganisms that exist in MFCs has so far revealed a great diversity in composition [8]. We believe that many new types of bacteria will be discovered which are capable of anode electron transfer (electron transfer to an anode) or even interspecies electron transfer (electrotransferred between bacteria in any form). We can produce clean energy by using MFC for wastewater treatment. The benefits of using MFC for wastewater treatment include: clean, safe, quiet performance, low emissions, high efficiency and direct electricity recovery. MFCs are being constructed using a variety of materials and in an ever increasing diversity of configurations. These systems are operated under a range of conditions that include differences in temperature, pH, electron acceptor, electrode surface areas, reactor size and operation time. Potentials are reported with different reference states and sometimes only under a single load (resistor). The ranges of conditions and in some cases a lack of important data like the internal types of MFCs, provide information on construction materials.

Microbial Fuel Cell Development

MFCs technologies represent the newest approach for generating electricity– bio electricity generation by using bacteria. While the first observation of electrical current generated by bacterial is generally credited to Potter in 1911, very few practical advances were achieved in this field even 55 years later [7]. However, in the past three to four years there has been resurgence in microbial fuel cell research. Advances have included the development of what could be the first microbial fuel cell that can generate more energy by using MFC for wastewater treatment include: clean, safe, quiet performance, low emissions, high efficiency and direct electricity recovery. MFCs are being constructed using a variety of materials and in an ever increasing diversity of configurations. These systems are operated under a range of conditions that include differences in temperature, pH, electron acceptor, electrode surface areas, reactor size and operation time. Potentials are reported with different reference states and sometimes only under a single load (resistor). The ranges of conditions and in some cases a lack of important data like the internal types of MFCs, provide information on construction materials.
The greatest advantage of chemical waste can be affected by changing the cathode working potential. When a CEM is used in an MFC, it is important to recognize that it may be permeable to chemicals such as oxygen, ferricyanide, other ions, or organic matter used as the substrate. The market for ion exchange membranes is constantly growing, and more systematic studies are necessary to evaluate the effect of the membrane on performance and long-term stability [7].

**Generation of voltage**

**Thermodynamics and the Electromotive Force:** Electricity is generated in an MFC only if the overall reaction is thermodynamically favorable. The reaction can be evaluated in terms of Gibbs free energy expressed in units of Joules (J), which is a measure of the maximal work that can be derived from the reaction calculated as 

$$\Delta G_r = \Delta G_{r0} + R T \ln(f)$$

where $\Delta G_r$ (J) is the Gibbs free energy for the specific conditions, $\Delta G_{r0}$ (J) is the Gibbs free energy under standard conditions usually defined as 298.15 K, 1 bar pressure and 1 M concentration for all species, $R$ (8.31447 J mol⁻¹ K⁻¹) is the universal gas constant, $T$ (K) is the absolute temperature and $f$ (dimensionless) is the reaction quotient calculated as the activities of the products divided by those of the reactants. The standard reaction Gibbs free energy is calculated from tabulated energies of formation for organic compounds in water available from many sources [1].

For MFC calculations, it is more convenient to evaluate the reaction in terms of the overall cell electromotive force (emf), $E_{cell}$ (V), defined as the potential difference between the cathode and the anode. This is related to the work $W$ (J), produced by the cell or $W=Emf \cdot Q=\Delta G_r$ Standard Electrode Potentials: The reactions occurring in the MFC can be analyzed in terms of the half cell reactions, or the separate reactions occurring at the anode and the cathode. According to the IUPAC convention, standard potentials (at 298 K, 1 bar, 1 M) are reported as a reduction potential, i.e., the reaction is written as consuming electrons.

**Microbial fuel cells in the future:** There are many challenges remaining to fully exploit the maximum power production possible by MFCs, to find ways to make the systems economical, and to create wastewater treatment systems based on MFC bioreactor. Discovery of new organisms that can directly transfer electrons to electrode might be exploited to remediate polluted waters or soils while concurrently generating electrical power. More fundamental studies might lead to an understanding of which proteins and cellular structures are responsible for electron transport across the cell membrane. Perhaps the most intriguing question of all is how these microorganisms ‘sense’ the electron sink, be it metal oxide or electrode, when deprived of oxygen. Answers to questions such as these will have implications across many disciplines in science and technology.

**III. Material of construction of MFC**

Anode: Anodic materials must be conductive, biocompatible and chemically stable in the reactor solution. Metal anodes consisting of non-corrosive stainless steel mesh can be utilized but copper is not useful due to the toxicity of even trace copper ions to bacteria. The most versatile electrodedmaterial is carbon, available as compact graphite plates, rods or granules, as fibrous material (felt, cloth, paper, fibers, foam) and as glassy carbon.

Cathode: Due to its good performance, ferricyanide is very popular as an experimental electron acceptor in microbial fuel cells [9]. The greatest advantage of ferricyanide is the low over-potential using a plain carbon cathode, resulting in cathode working potential close to its open circuit potential. The greatest disadvantage, however, is the insufficient reoxidation by oxygen, which requires the catholyte to be regularly replaced [8]. In addition, the long term performance of the system can be affected by diffusion of ferricyanide across the CEM and into the anode chamber. Oxygen is the most suitable electron acceptor for an MFC due to its high oxidation potential, availability, low cost (it is free), sustainability and the lack of a chemical waste product (water is formed as the only end product). The choice of the cathode material greatly affects performance and is varied based on application.

Membrane: The majority of MFC designs require the separation of the anode and the cathode compartments by a CEM. Exceptions are naturally separated systems such as sediment MFCs or specially designed single-compartment MFCs. The most commonly used CEM is Nafion. Alternatives to Nafion, such as Ultrex CMI-7000 also are well suited for MFC applications and are considerably more cost-effective than Nafion. When a CEM is used in an MFC, it is important to recognize that it may be permeable to chemicals such as oxygen, ferricyanide, other ions, or organic matter used as the substrate. The market for ion exchange membranes is constantly growing, and more systematic studies are necessary to evaluate the effect of the membrane on performance and long-term stability [7].

**Fig. 1MFC for electricity generation**
engineering and hold promise for a wide range of exciting new discoveries and technologies.

MFC designs need improvements before a marketable product will be possible. Both the issues identified above and the scale-up of the process remain critical issues. Most of the designs reviewed here cannot be scaled to the level needed for a large wastewater treatment plant which requires hundreds of cubic meters of reactor volume. Either the intrinsic conversion rate of MFCs will need to be increased, or the design will need to be simplified so that a cost-effective, large scale system can be developed. Designs that can most easily be manufactured in stacks, to produce increased voltages, will be useful as the voltage for a single cell is low.

In the long term more dilute substrates, such as domestic sewage, could be treated with MFCs, decreasing society’s need to invest substantial amounts of energy in their treatment. A varied array of alternative applications could also emerge, ranging from biosensor development

IV. Conclusion
The ultimate achievement in MFCs will be when they can be used solely as a method of price of fossil fuels makes it unlikely that electricity production can be competitive with existing energy production methods. However, MFCs are carbon neutral and power can be generated with cellulosic materials. Thus, advancements in power densities, reductions in materials costs, and a global need to produce power without net CO2 emissions may one day make MFCs practical just for electricity production. It will be a great success in the field of renewable energy production if we will integrate this small production of electricity in to powerful electricity.

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