© 2017 IJSRST | Volume 3 | Issue 7 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X
Themed Section: Science and Technology

A Review of Microbial Fuel Cells for Bioelectricity Generation

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ABSTRACT

In this review a brief description of microbial fuel cells technology for generation of bioelectricity has been done. The review is mainly intended to focus on standard configurations, electrode materials, membranes, substrates, microorganisms and generation of bioelectricity. Being low in power generation, MFC is a slow pacing technology but has the enormous ability to act as long term sustainable power generation source. The most spectacular feature of MFC is the utilization of organic matter which is generally supposed to be as waste. This innovative expertise has opened the way for alternative renewable energy generation.

Keywords: Double Chamber, Electrode, Microbes, Substrate, Single Chamber

I. INTRODUCTION

The recent rapid change in energy sector is mainly due to depletion of conventional energy resources, increasing demand and global warming. The long term solution to such multiple problems is the development of inexhaustible, environmental friendly renewable energy technologies. To satisfy the world's ever increasing energy demand, renewable energies are feasible and mostly economic. International Energy Agency report reveals that energy produced from biomass based fuels and bio waste has 10-14% contribution in meeting primary energy needs. These findings project that biomass based fuel will pay vital role in future sustainable energy source [1]. There are many technologies to produce bio-energy and the most recent technique is the Microbial Fuel Cell (MFC). Many researches express that the development of this biotechnology, could supply 30% of global fuel demand with environmentally friendly manner. Potter substantiates that with decomposition of organic matter like biomass, electricity can be generated by microorganism [2-3]. Microbial fuel cells are devices that use microorganism to generate an electric current from wide range of organic substrates [4-5-6]. Micro-organisms oxidise substrates in the anode chamber to produce electrons and protons, while producing carbon-dioxide as an oxidation product. Electrons attached on the anode flow to the cathode through an external circuit. Protons migrate across the proton exchange membrane to combine with electrons to form water [7]. The completion of this process leads to generation of bioelectricity and demonstrated well with fig 1.

II. MICROBIAL FUEL CELLS

A. Configurations

Many different configurations are possible for successful operation of MFC. MFC configurations are evaluated on the basis of output power or power density, coloumbic efficiency, cost and feasibility of scaling for higher power outputs [3-4-5-8]. In MFC configurations, a widely used and inexpensive design are two chamber H-shaped, consisting of two separate chambers connected by PEM and act as anode chamber and cathode chamber. Two chamber MFCs have wide acceptability for analyzing power generation with different electrodes, substrates and microbial communities, but typically with low power outputs [4-6-8]. This configuration suffers from low power density due to high internal resistance and mass transfer losses [3]. The distance between electrodes and the specific surface of the anode, cathode or separator are key factors on which the internal resistance of the system and power density directly depend. The practical problem posed with double chamber is during scaling up. To overcome all these operational complexities of double chamber configuration a single chamber MFC represents a genuine alternative with several advantages [5]. When using the oxygen at the cathode like in double chamber, it is not essential to place the cathode in water or in a separate chamber. Cathode can be placed in direct contact with air either in presence or absence of membrane [3-5]. A single chamber MFC involves only the anodic chamber coupled with an air cathode through PEM to which protons and electrons are transferred. Various designs have been proposed by researchers even in single chamber configurations. Fig 2 & 3 represents the basic structures of double chamber and single chamber MFCs.

B. **Electrodes**

The ideal electrode materials should have good electrical conductivity, low resistance, large surface area, chemical stability, mechanical strength and good biocompatibility [3-4]. A wide range of materials such as carbon family, metal or metal oxides, and composite materials are available. A family of carbon materials is widely accepted for MFC configurations, being good bio-compatibility, chemical stability and conductivity. On the other side metals are much more conductive than carbon family materials but still these are not gaining much popularity in MFCs [3-5-9]. Researchers support that usage of some metals in MFC leads to corrosion and other hinders the adhesion of the bacteria. [5]. Aqueous and air cathodes are the most common in MFC configurations. Air cathode is widely used due to simple design, in which one side of cathode is directly exposed to air. The most common material for cathode is carbon cloth. To ensure the good contact between cathode and membrane, these are separately manufactured and then assembled [3-5-7-8].

C. **Membranes**

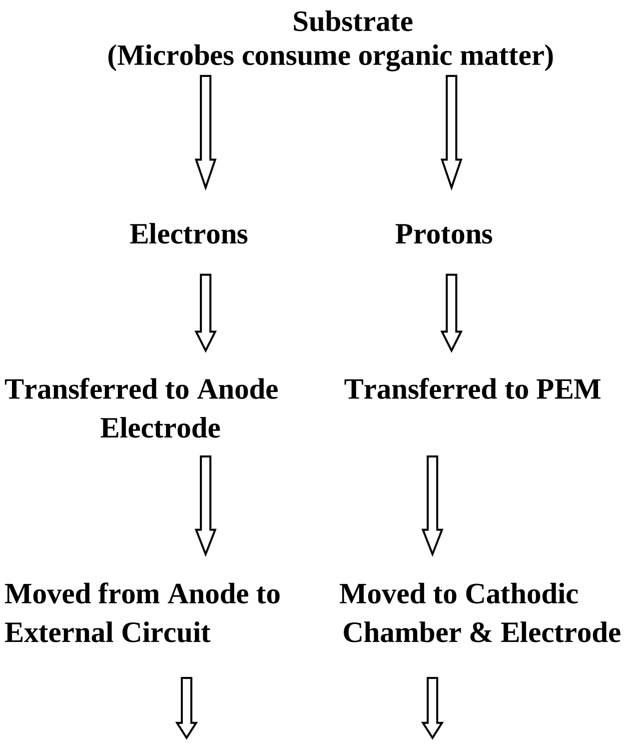
A bio-potential developed between the bacterial metabolic activity and electron acceptor condition which are separated by proton exchange membrane (PEM) leads to generate bio-electricity. In the MFC configurations another important material is membrane or separator to keep anode and cathode to physically separate to avoid any short circuit. Membrane help in increasing columbic efficiency and fuel transfer rate by reducing oxygen diffusion form cathode to anode [4-5-10]. The materials of separators are divided into three categories as salt bridge, size selective separators and ion exchange membrane. For salt bridge 10% of potassium chloride or sodium chloride with 5% of agar solution is prepared and poured in pipe which acts as membrane. Other membranes used are bipolar membrane, dialyzed membrane, Nafion, glass wool, nano-porous filters and microfiltration membranes. High cost of membrane is a barrier in economics of MFC with high internal resistance [4].

D. **Substrates**

For bio-electricity production, a range of organic substrates having rich in microbes for anaerobic digestion can be used. The commonly used substrates are domestic waste water, swine waste water, oil wastewater, waste sludge, fruit and vegetable waste, brewery waste water and bio-waste. The simple substrates are glucose, propionate and butyrate [4-10].

E. **Microorganism Inoculated in MFC**

MFC use microorganisms that biologically oxidize organic matter and transfer electrons to the electrode. Microorganisms are very aspiring to anode electrodes, electrochemically active bacteria having the capability of exocellular electron transfer. A variety of micro-consortium such as Geobacter, Pseudomonas, Bacillius, Clostridium species are often inoculated into MFCs for electricity production [10-11-12]. These microorganisms have the capability to oxidize the contents such as acetate, ethanol, propionate and butyrate present in organic matters.



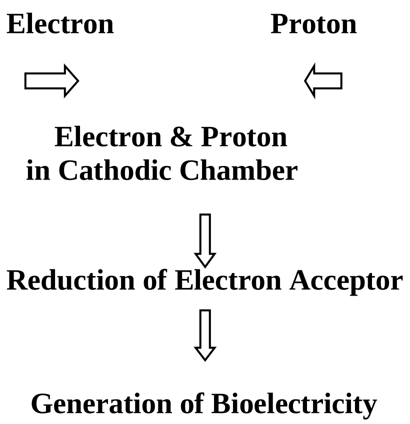


Figure 1. Process of Bioelectricity Generation in MFC

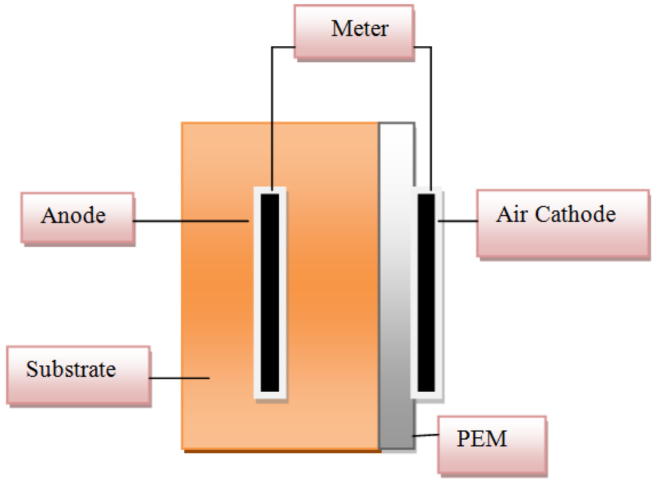


Figure 3. Standard Single Chamber MFC

F. Bioelectricity Production

MFCs convert the chemical energy present in biomass into electrical energy through the action of microorganisms. It involves the direct conversion of fuel molecules into electricity without the production of heat, which generally limits the conversion efficiency. The main feature of MFC is the utilization of organic substrates from bio-fuels for production of bioelectricity [4-5-10]. Although MFCs are not currently an economical method for power production, the last few years have proved to be progressive arch for power generation with MFC. It is particularly preferred for sustainable long term power applications.

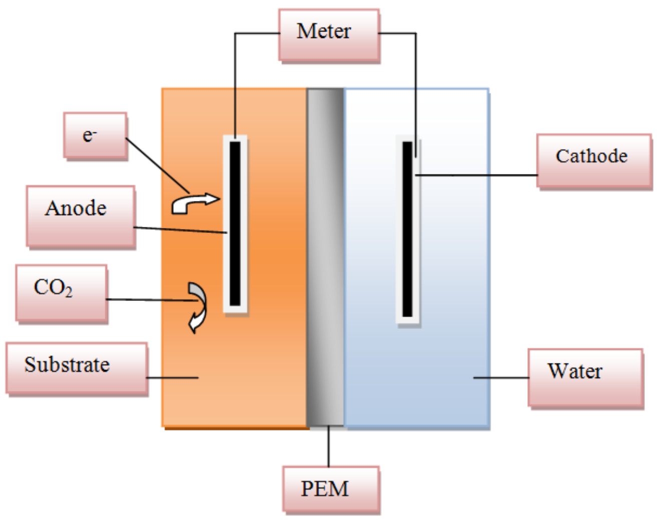


Figure 2. Standard Double Chamber MFC

MFC could convey 25mW of power which would be suitable for cardiac stimulation, however the amount of surface area needed is quite large. The main objective of MFC is to achieve a suitable current and power for the application in small electrical device [4]. Power output of 10-50 and 250-500 mW/m^2 have been generated using domestic waste water and glucose. Rabey generated a power density of 3.6 W/m^2 using glucose and mixed consortium of microbial community [10].

III. CONCLUSION

This review presents the overview of MFC technology for generation of bioelectricity. It is very simple to assemble the MFC configurations but very complex to simultaneously handle number of parameters for better MFC performances. Two standard configurations of double and single chamber are popularly used for assemblies with carbon family electrodes and several types of membranes. Microbial communities act as catalyst to activate the movement of electrons in substrate and enhance the power density and coloumbic efficiency of MFCs. Though MFCs till date produce low power densities but has immense potential to generate power for small and long term sustainable applications.

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