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A Review on Different Configurations of Microbial Fuel Cell (MFC)

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Abstract:
Microbial Fuel Cell (MFC) technology is becoming popular day by day. It is considered as a future scope of renewable source of energy. The main focus is to generate energy on large scale to fulfil the energy requirement along with treatment of waste water. Lot of modifications in components parts used in MFC are happening to make this technology economical and simple in operation. Configuration of MFC is also one of the parameter in development of MFC. This review paper highlights on different configurations used for MFC set up.
***Key Word**: Microbial Fuel Cell; Renewable; Energy; Configuration; Economical.*

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I. Introduction

The non-renewable sources create lot of pollution while generating energy for utilization and are limited and eventually may run out over the time frame. Solar energy is ultimately long-term solution but it depends upon how we harvest this source of energy. Solar panels help in day time electricity needs but it will not serve as a primary source of energy throughout the day and night without efficient methods of energy storage. Considering this fact more focus is on renewable sources of energy. Many countries have started investing in renewable sources of energy which will help in sustainable development in energy sector. Environmental pollution is increasing day by day due to growing demand for energy, increasing population, rapid urbanization and industrialization. The MFC approach has received much interest in the modern era because of its unique methods to achieve energy and waste water treatment. Invention of microbial metabolism could provide energy in the form of electrical current has lead to an increasing interest in the field of MFC research.

In conventional treatment waste water is treated by activated sludge process or by anaerobic treatment methods. These conventional wastewater treatment systems require high demand of energy, hence there is need for alternative treatment technology which should generate energy in form that would make overall operation of waste water treatment self-sustainable, cost effective and requiring less energy for its efficient working. Waste water contains organic matter which can be harvested as renewable source of energy. MFC can be a source to utilize energy available in organic waste waters in the form of electricity. Bacteria help to catalyse the conversion of organic matter into direct electricity while accomplishing the biodegradation of organic matter to carbon dioxide as an end product.

II. Working principle of MFC

MFC basically consists of two compartments, anode and cathode chamber. Substrates can be oxidized by microorganisms or enzymes resulting in the releasing of protons and electrons. Protons and electrons passes through the proton exchange membrane (PEM) and external circuit respectively. Consequently, by the reaction of oxygen, electrons and hydrogen ions, water molecules will be generated in cathode chamber. The schematic representation of dual chamber MFC is represented in Fig.1. A typical MFC consists of an anodic chamber and a cathodic chamber separated by proton exchange membrane. The assembly of microbial fuel cell consists of following component parts as electrode (Anode and Cathode), Proton Exchange membrane (PEM), Substrate, Electrical circuit.

Electrodes facilitate the transport of electrons through an external circuit, resulting in electricity. Proton Exchange membrane is the key component of MFC. The majority of MFC designs require the separation of the anode and the cathode compartments by PEM. PEM should have high proton conductivity, low electronic conductivity, chemical /thermal stability, good mechanical stability and low cost. A substrate is the substance contained in the anode chamber that is to be oxidized, substrate used can be any form of organic matter. Hydrogen in Anode electrode change into a hydrogen ion and electrons are released. These electrons move through foreign circuit towards the cathode and produce the electrical current. After leaving anode, electrons travel through the circuit, these electrons power the load.

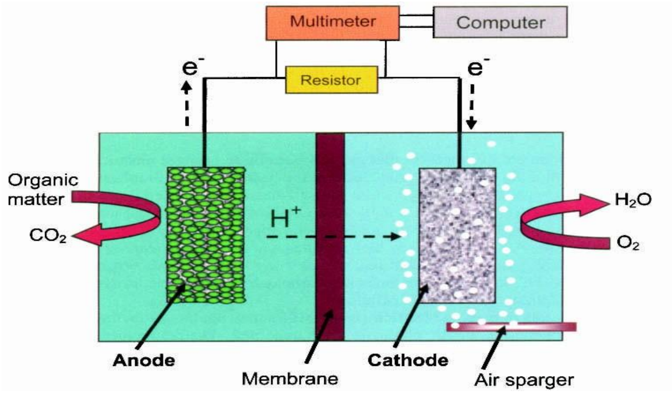

Figure 1: Schematic of the Basic Components of a Microbial Fuel Cell

III. MFC configurations

For laboratory studies, we can imagine a wide range of useful architectures depending on the goals of the research. Practical applications of MFCs will require a design that will not only produce high power and coulombic efficiencies, but one that is also economical to mass produce based on the materials being affordable and the manufacturing process being practical to implement on large scale. The structural configuration of MFCs varies from single and two chamber configurations and with or without the utilization of PEM. Research is still going on to develop and optimize the design of MFC to make it an acceptable technology. The essential requirement for MFCs is their appropriate design. MFCs are built according to a range of architectural requirements and various kinds of MFCs are usually appraised by power output, coulombic efficiency, stability and longevity [99]. MFC design has huge impact on power output and coulombic efficiency. Initially dual chamber MFC configuration was used This type was replaced by single chamber MFC in order to enhance the overall performance of MFC. The stacked MFCs were introduces to enhance the power output by connecting MFCs in series or in parallel.

Two chamber MFC

MFC configuration which consists of two chambers, an anodic chamber and cathodic chamber and are connected by a half cell separator, with most commonly utilized separator being PEMs, salt bridges and ceramics. PEMs, slat bridges or ceramics allow protons to move across to the cathode while blocking the diffusion of oxygen into the anode. Two chamber MFCs are being used to study the electrode materials. microbial activity and optimization of parameters. This basic design of two chamber MFC cannot reduce the energy costs of wastewater treatment due to continuous sparging of air to the cathode chamber, which is an energy consuming process. Two compartment MFCs are typically utilized with a defined medium as glucose or acetate and ran in batch mode or fed batch mode. MFCs can also be operated in a continuous mode and are currently used in laboratories to optimize MFC power outputs. The compartments can be in various practical shapes such as cylindrical, rectangular and miniature. Two chamber MFC separated by PEM is shown in Fig. 1 and MFC with salt bridge depicted in Fig. 2.

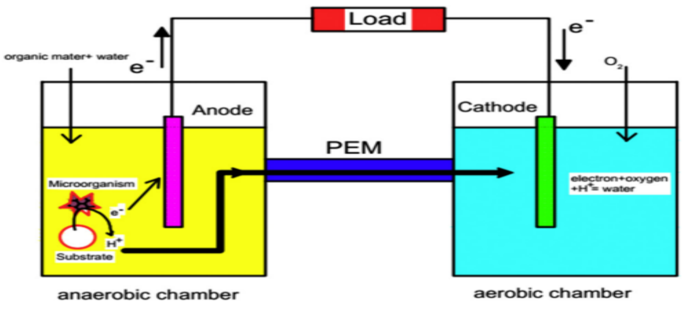

Figure : 2 Two chamber MFC with PEM bridge

Single chamber MFC

Due to complex design of two compartment MFCs, they are difficult to scale-up even though they can be operated in either batch or continuous mode. One compartment MFCs are simple to design and cost savings. They typically consist of only an anodic chamber without the requirement of aeration in a cathodic chamber. A single chamber MFC was configured based on the studies of hydrogen fuel cells by Lui, suggesting that direct bonding of cathode to PEM will allow direct interaction of oxygen from air with the cathode. A single chamber MFC consists of an anode chamber, a gas diffusion layer, which separates cathode from anode chamber and also allows passive transportation of oxygen to the cathode. This design eliminates aeration step consuming energy unlike two chambered MFC. The anode is placed far or near to the cathode separated by PEM.

It has been seen that by decreasing interelectrode spacing, internal ohmic resistance can also be diminished. This can be achieved by avoiding the use of catholyte as a result of joining two chambers and thus raises the power density. Thus single chamber MFC is simple and economical and produces much power in rival to double chamber MFC. However, in single chamber MFC, the major problem as microbial adulteration and reverse passage of oxygen from cathode to anode occur normally.

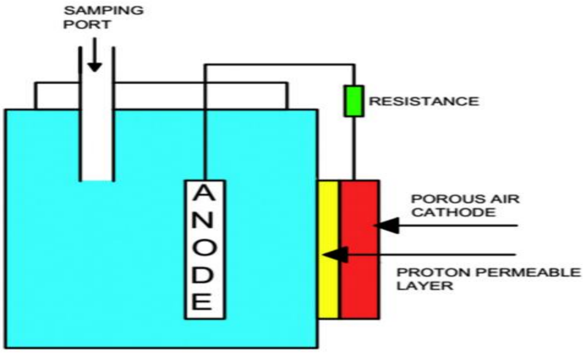

Figure 3: Single chamber MFC

Stacked MFC

MFC cannot generate sufficient power output to even run small scale equipment. This is the major reason due to which it has not been implemented yet in use. To root out this problem, MFC is stacked together in series or parallel connection for more power output based on the requirement which was studied by Aelterman. They concluded that parallel connection gave better output compared to series connection. There was no obvious adverse effect on the maximum power output per MFC unit observed. A stacked MFC is generally a combination of some MFCs that are either connected in series or in parallel to enhance the power output.

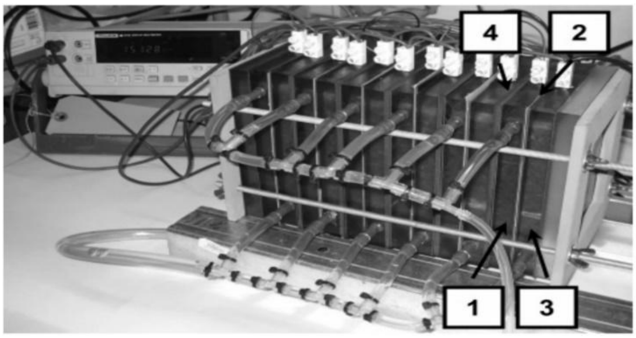

Figure 4:Parallel connected stack microbial fuel cell consisting of six individual microbial fuel cells consisting of six individual microbial fuel cells with (1) a granular graphite anode, (2) an Ultrex cation exchange membrane, and (3) a 50 mM hexacyanoferrate cathode separated by (4) a rubber sheet.

Upflow MFC

The new design came into existence with increase in the interest in MFC research. The upflow MFC is cylinder -shaped MFC [111] The MFC is made up of cathode chamber at the top and the anode at the bottom. Both the members are apportioned by glass wool and glass bead layers. The substrate is provided from the bottom of the anode that moves upwards to the cathode and leaves at the top as shown in Fig. 5. A gradient is formed between the electrodes which also helps in the favorable action of the fuel cell [112].

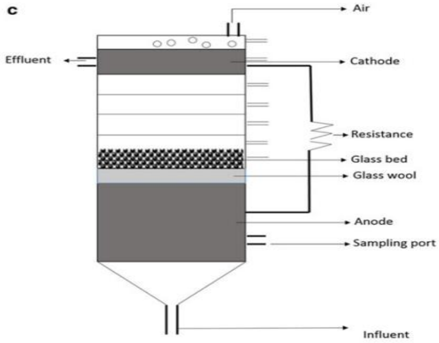

Figure5: Upflow MFC [127]

IV. Discussion

To tackle the energy problem in future, there is need of sustainable and clean development of energy. Microbial Fuel Cell technology can serve this purpose if developed economically for harvesting more energy. MFC not only generates electricity but the source for energy generation is waste, which makes it more special compared to the traditional energy sources. More focus is on the generation of energy. Different types of MFC configurations are discussed in this paper. To harvest large amount of energy, selection of configurations should be done properly considering drawbacks of it.

V. Conclusion

The commercialization of MFC is future need. For commercialization economy and output are important parameters. In this paper different configurations are discussed which are useful in harvesting energy. The commerlization of MFC can be achieved by employing correct design, efficient scaling up, cost reduction, ensuring high performance. MFCs are still at laboratory level stage of analysis and evaluation but some ideal designs have been developed to utilize MFC into wastewater treatment processes.

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