Efficiency Comparison of Electricigens/Exoelectrogens for Microbial Fuel Cells.

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ABSTRACT: Microbial Fuel Cell (MFC) technology is an advanced approach for electricity generation using microorganisms and with the advantage of subsequent treatment of waste water. Bacteria mediated electricity generation has been reported since the twentieth century. In todays world, fuel conservation is the most critical issue demanding availability of alternate energy resources. The main objective of MFC is to generate power using biological resources, which are readily available from nature. MFCs are used in waste water treatment plants thereby reducing waste treatment and power consumption costs. We have discussed different technology designs that employ MFC based energy generation method. Critical components required for construction of MFCs are reviewed and investigated. MFC based energy synthesis is discussed with reference to alternate technologies for renewable energy. The economics pertaining to efficient energy generation is studied for MFC mediated in comparison with other invented methodologies. Finally, the advantages and more importantly disadvantages of alternate energy generating technologies is been discussed.

KEY WORDS*:* Microbial Fuel Cell, Electricigens, exoelectrogens, Proton Exchange Membranes, Cation Exchange Membranes, Anion Exchange Membranes, salt bridge, renewable energy, anode, cathode, electron, bioenergy.

1: INTRODUCTION

Microbial Fuel Cell is also called as a bio-electrochemical device which uses microorganisms as biocatalysts to produce energy from organic matter. This energy can also be referred as bioenergy (Ebrahimi *et al*, 2018)**)**. The term MFC was coined in 1911 by M.C.Potter due to its ability to generate electricity from the electron potential gradient difference generated across microbial cell membrane (Ref). The microorganisms act as the power house of MFC that oxidize the organic substrate to carbon dioxide, protons and electrons (Ravinder Kumar *et al*, 2016, ELSEVIER). The fuel cell is made up of four parts; anode, cathode, proton exchange membrane (PEM) and the external circuits (Andrew de Jaun, *et al*, 2013). Environmental safety and energy sustainability are considered to be major drivers of future generations. MFCs consume organic substrate and convert their chemical energy to electricity using microorganisms. Bioenergy produced by MFC is a potential sustainable alternative resource to the depleting levels of fossil fuel. Microbial Fuel Cell use organic matter and produce electricity without polluting the environment. Enzymatic catalyzation of complex organic substrate mediate complete breakdown of a wide range of waste matter to carbon dioxide and water, which is easily achieved in MFCs (Soumya Pandit *et al*, 2018).

In this article, we have discussed different technology designs that employ MFC based energy generation method. Critical components required for construction of MFCs are reviewed and investigated. MFC based energy synthesis is discussed with reference to alternate technologies for renewable energy. The economics pertaining to efficient energy generation is studied for MFC mediated in comparison with other invented methodologies. Finally, the advantages and more importantly disadvantages of alternate energy generating technologies is discussed.

2: TYPES OF MFC:

2.1 SINGLE CHAMBER MFC:

Single chamber MFC is the simplest design that contains single compartment which contains both anode and cathode chambers. The anode cell may be placed away or closer to the cathode cell and separated by proton exchange membrane (PEM). It was reported that if anode is placed closer to the cathode, it decreases internal resistance resulting in increase of the power density

(Payel Choudhury *et al*, 2017). The major disadvantage of single chamber microbial fuel cell is back diffusion of oxygen from cathode to anode. The air-cathode is used in single cell MFC to treat wastewater along with bioelectricity production.

2.2 DOUBLE CHAMBER MFC:

Double chamber MFCs contains two chambers where the anode and cathode compartments are separated by membrane. Due to this complex system of double chamber, the generation of power is lower as compared to single cell MFC (Payel Choudhry *et al*,2017) .The anode chamber is kept oxygen free for anaerobic breakdown process to occur, which is usually purged with nitrogen. It is most challenging to scale up due to the impractical configuration (Andrew de Jaun,2013).

2.3 H-SHAPED CONFIGURATION:

H-shaped microbial fuel cell is widely used traditional design of two chambered MFC, that contains two glass or plastic bottles connected by a tube separated by a membrane called Cation Exchange Membrane (CEM). Nafion and Ultrex are the best known CEM (Bruce E. Logan, 2006). There are different types of membranes used in microbial fuel cell like PEM and CEM for power outputs. The significant role of this design is choice of membrane that allows optimal passage of protons to pass between two chambers. H-shaped MFC is mainly used to examine power production by different organic substrates or the type of microbial communities employed during the breakdown of these compounds. The electricity produced by this design is also lower as compared to other designs.

2.4 SALT BRIDGE MFC:

In many MFC designs a salt bridge is used instead of a membrane system. Power output in salt bridge MFC ranges from 2.2 Mw/m2. The low power output is due to the higher internal resistance of the salt bridge system as compared to that of membrane system (Bruce. E Logan, 2005).

3: PARTS OF MFC:

3.1 ANODE:

Anodic materials must exhibit high chemical stability in reactor solution and also show biocompatibility. In most MFCs copper is not used as anode due to its toxicity to microbes, even in trace amounts (Bruce E. Logan, 2006). Carbon is the most versatile electrode material, available in form of compact graphite plates, rods or granules, fibrous material and glassy carbon (S.K.Chaudhuri, *et al*, 2003). Altered chemical and physical strategies have been tested to increase anode performance. Passing the water flow through the anode material has been reported to increase power generation (Bruce E. Logan, 2006).

3.2 CATHODE:

The carbon paper having platinum wire windings is a material which is commonly used as a cathode (Yang,Y.,*et al*, 2012). They can either be obtained from various manufacturing facilities or as catalyst loaded on plain carbon paper. This can also be done in laboratories with the help of a catalyst binder solution such as Nafion (Bruce E. Logan, 2008). These catalysts mainly function to accelerate an oxygen reduction reaction (ORR) on the cathode (Arpita Nandy *et al*,2018).

3.3 MEMBRANES AND SEPARATORS:

Membranes are used to separate anodic and cathodic chambers. Such separation of both chambers is needed to allow and maintain clean, bacteria-free solution at cathode site. In most of the microbial fuel cell designs basically three types of membranes are used (1) Proton Exchange Membranes (PEMs) permeable to protons while avoiding other ions to be transferred. (2) Cation Exchange Membranes (CEMs) allowing passage of cations and (3) Anion Exchange Membranes (AEMs) permitting passage of anions. These have been widely used in multiple-chamber MFCs. The most commonly used CEMs are Nafion, Hyflon, Zirfon, and Ultrex CMI 7000. The main problem of CEMs is pH splitting between anode and cathode chambers caused by proton accumulation in the anodic compartment (S. Marzorati *et al*, 2016).

4 APPLICATION:

With growing global population, sustainability of energy, water resources, land use, and waste treatment poses a critical issue for future generations. As a solution to resolve such issues, MFCs provide an environment friendly alternative and therefore is attaining importance in the world. MFCs are bio-electrochemical device and are demonstrated to be employed as ideal models in remote areas (Arpita Nandy, *et al*,2018). They have potential to act as environmental sensors due to their ability to indicate microbial metabolic capacity in form of electrical signals. Examples of such MFC sensors are Enzymatic glucose biosensors and those that detect toxic levels of phenolic and petroleum derivatives **(**J.M. Morris, *et al*, 2008). Because of their independent nature of working in isolated spaces, MFCs have great potential to be used in Space programs intended to explore and expand natural resources for human race in the universe. The general areas of MFC application are Bioelectricity and Bio hydrogen synthesis, besides waste water treatment (X.A. Walter,A.Stinchcombe,B.E. Logan,1999). This is currently done via the microbial communities that form the principal component of MFCs as biocatalysts (Vipin Chandra Kalia *et al*, Springer,2017).

5 MICROBES USED IN MFC:

According to the current reports, microorganisms that possess the ability to transfer the electrons derived from the metabolism of organic matters to the anode are as follows:

-*Actinobacillus succinogenes*

-*Clostridium beijerinckii*

-*Escherichia coli*

-*Geobacter sulfurreducens*

-*Streptococcus lactis*

These are widely distributed in the marine sediments, soil, wastewater, fresh water sediments and activated sludge ecosystems. Such environments supply rich resources for these microorganisms. *Geobacter* is a metal reducing microorganism that can produce biologically useful energy in the form of ATP reservoirs. This occurs by the dissimilatory reduction mechanism of metal oxide in anaerobic conditions in soils and sediments (Zhuwei Du *et al*, 2007).

6 ECONOMIC ASSESSMENT OF MFC:

Significant improvements in MFC design and technology development is witnessed during the last decades. This scientific progress has brought MFCs to the level of feasible commercialization. An unavoidable factor of technology assessment requires precise establishment of profitability to serve market sector. Recent reports indicate implementation of MFC as a promising alternative to the conventional waste treatment methodologies with potential economic advantages (Jaun R. Trapero,2016). The annual growth rate of electricity pricing points to the growing importance in electrode related research pertaining to MFC technology. MFC led profits are directly proportional to growth rate of electricity costs, thereby making MFC technology beneficial with rising capital investment in electricity sector.

7 COMPARISON OF MFC WITH OTHER RENEWABLE ENERGY SOURCES:

Renewable energy sources are those that can be harnessed continuously from natural resources and phenomena. They also referred as alternative or renewable energy.

(A)Solar Power: This is the most common form of renewable energy. The short-comings of this technology are installation cost, geographical variation of sunlight and high maintenance (Mcroley, 2016).

(B)Geothermal energy: The main advantage of geothermal energy is steady supply of power, whereas other renewable technologies produce variable power (Macroley, 2016). However, these are confined to oceans and territories within the sea-shore range.

(C) Wind Turbine energy: Wind turbine dynamo based energy is widely produced, however in regions with high levels of wind or breeze. This poses a geographical inequality of air-flow current that is required for optimal electricity conversion.

(D)Microbial Fuel Cell: MFCs can operate on large variety of terrestrial substrates that are readily available and can be constructed in almost any naturally or artificially formed life sustaining areas. MFCs are environmentally friendly in terms of material composition and by-product generation (M.J.Angelaa Lincy *et al*, 2015).

8 FUTURE DIRECTIONS:

The principal goal of MFCs aims at improving efficiency and economics of power generation. Current statistics indicate a demand for significant improvement in power generation by MFCs. Wastewater treatment is a prime rationale for MFC application in real world. However the factors limiting utilization of MFC at full potential are as: composition of incoming waste, any pretreatment required, nature of organic and inorganic components, pH, temperature, Chemical and Biological Oxygen Demand (COD, BOD), microbial flora and plant design. All such factors need to be improved for achieving improved efficiency of the MFCs. Cost of MFC components like electrodes and membranes are of critical significance, especially, in relation to improved composition and shelf-life. Another yet unexplored area for MFCs is the utilization of photosynthetic flora that can aid in reversing the carbon foot prints caused by global pollution of environment. To be able to serve customer service sector, MFCs should impact the commercial potential with more satisfaction. At present, this area needs to be explored more.

9 CONCLUSION:

MFCs have indicated a great potential to become an alternate energy resource that can be renewed from natural microbial reservoirs. However, there are many factors and design parameters that need optimization for maximal output of currently available MFCs. We have discussed some of such significant comparisons in order to develop high yield MFC designs. The economics and MFC usage to reduce Carbon foot prints can aid in improving environmental resources available for renewable energy generation.

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