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Microbial fuel cells: its potential and applications

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Introduction

Excessive uses of fossil fuels which are the exhaustible energy sources have triggered the global energy crisis and global warming along with heavy metal release from the anthropogenic sources has caused environmental pollution. These havocs have shifted the focus and interest of researchers on green energy production and environment friendly technology. Microbial fuel cells are considered as an alternative renewable energy sources which are known to convert chemical energy to electrical energy by catalytic reaction of microorganisms for production of electricity and also removal of pollutants from water and soil simultaneously. Advent of MFCs research began with the Potter's work in 1911 when a voltage of 0.3–0.5 V was generated with glucose as a substrate and Pt (platinum) as electrode by the *S. cerevisiae* followed by many researches till the present time for the development and use of MFCs. However, presently the researches are mainly focused on the use of MFCs for the oxidation of organic matter to produce electric energy as alternative renewable energy systems. MFCs are emerging as a promising and challenging technology which will help in a sustainable and environment friendly way by satisfactorily functioning for power generation and biological reduction of heavy metals from wastewater and soil.

What are microbial fuel cell and working of microbial fuel cell?

Microbial fuel cells are the bioreactors comprising of a bio-electrochemical process that produce electricity by converting chemical energy in the chemical bonds in organic compounds to electrical energy through biochemical reactions catalyzed by bacteria under anaerobic conditions. Microbial fuel cells basically work by bacterial respiration which is a big redox reaction where electrons are moved around and moving electrons show the potential of harnessing an electromotive force to perform useful work.

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Working

A microbial fuel cell consists of an anode and cathode compartments separated by an cation specific membrane through which protons can pass. An anode compartment comprises of an environment void of oxygen where bacteria oxidizes the organic fuel yielding CO_2, along with protons which pass through the membrane to the cathode and electrons which pass through the anode to an external circuit to generate current whereas the cathode compartment consists of an electrode subjected to a catholyte flow consisting of an oxidizing agent in the solution where the catalyst combines the electrons, protons and oxygen to generate water.

Types of microbial fuel cell

There are two types of MFCs mediator and mediator less microbial fuel cell

1) **Mediator microbe fuel cell**:

Microbial fuel cell which require a mediator chemical to transfer electrons from the bacterial cells to the electrode comprise of mediator microbe fuel cell. Non-conductive lipid membrane, lipo-polysaccharides and peptidoglycans in microbes hinders the transfer of electrons to the anode. Thus they require mediators for transfer of electrons to the anode. Neutral red, humic acid, thionine, methyl blue and methyl viologen are the synthetic mediators and anthraquinone, thiosulphate, humic acid and sulphate are the natural mediators which are used in mediator microbe fuel cell.

2) **Mediator less microbe fuel cell**:

Exoelectrogens are electrochemically active bacteria which can transfer electrons extracellular by direct transfer of electrons from the bacterial respiratory enzyme cytochrome to the electrode comprise of mediator less microbe fuel cell. *Shewanella putrefaciens*, *Aeromonas hydrophila* are some of the electrochemically active bacteria. Some bacteria, which have pili on their external membrane, are also able to transfer their electron production via these pili. These microbial fuel cells come under recent area of research and thus are designed into three types:

a) **Microbial electrolysis cell**: In microbial electrolysis cell CO_2 is reduced by bacteria using an external electric current to form multi carbon organic compounds. It is basically the variation of mediator less microbe

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fuel cell where a voltage is applied to bacteria to increase the voltage generated by the microbial decomposition of organic fuel which in turn leads to production of methane and hydrogen which can be used as clean fuel for vehicles running on natural gas.

b) **Soil Based Microbial fuel cell**: In soil based microbial fuel cell soil acts as the nutrient-rich anodic media, the inoculum, and the proton-exchange membrane (PEM). It is based on basic principles of microbial fuel cell.

c) **Phototrophic Microbial fuel cell**: In phototrophic microbial fuel cell anode is used made up of phototrophic bio-film containing photosynthetic microorganisms like cyanophyta, chlorophyta which act as act as both producers of organic metabolites and also as electron donors.

Microbes used in microbial fuel cell

Micro-organisms used in the microbial fuel cell which possess the ability to transfer the electrons derived from the metabolism of organic matters to the anode are listed in the table 1 below-

Table 1

Microbe	**Substrate**	**Type of Microbial fuel cell**
Escherichia coli	Glucose, Sucrose	Methylene blue mediators needed
Desulfovibrio desulfuricans	Sucrose	Sulphate / sulphide as mediator
Shewanella oneidensis	Lactase	Anthraquinone-2,-6-disulfonate as mediator
Pseudomonas aeruginosa	Glucose	Pyocyanin and phenazine-1-carboxamide as mediator
Shewanella putrefacians	Lactase, Pyruvate, Acetate, Glucose	Mediator-less MFC
Rhodoferax ferririducens	Glucose, Xylose	Mediator-less MFC

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Geobacter metallireducens *Geobacter sulfurreducens*	Acetate	Mediator-less MFC
Aeromonas hydrophila	Acetate	Mediator –less MFC

Source: Du et al., 2007

Applications of microbial fuel cell

- Treatment of waste water and waste solids
- Bio electricity
- Bio hydrogen
- Powering underwater monitoring devices
- Power supply to remote sensors
- BOD sensing

Advantages of microbial fuel cell

- Eliminates pollution caused by fossil fuels
- More stabilized and decentralized of power grid due to installation of small microbial fuel cells.
- Fuel cells provide high quality DC power
- Cogeneration capability
- The absence of combustion and moving parts means that fuel cell technologies are expected to provide much improved reliability over traditional combustion engines.

Disadvantages of microbial fuel cell

- Some fuel cells use expensive materials
- Fuelling fuel cells is still a major problem since the production, transportation, distribution and storage of hydrogen is difficult.
- The technology is still yet to be explored tom compete with the conventional energy sources.

Conclusion

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MFCs are considered as rapidly evolving technologies that will increase the understanding regarding use of renewable energy sources and will help in replacing the conventional energy sources which are polluting the environment. Simple operation and easy construction are the unique advantages of MFCs in which combination of biological technology with electrochemical technology help in heavy metal recovery and power generation in an eco-friendly manner. However for future application research towards reducing the cost and long-term operation of MFCs still need exploration scientifically.

Reference

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Fig 1: Two chambered microbial fuel cell

Source: https://microbiologynotes.org/wp-content/uploads/2020/12/Microbial-Fuel-Cells2.jpg