MICROBIAL FUEL CELL -REVIEW

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ABSTRACT

Energy is the most fundamental requirement of today's era. Energy is consumed very rapidly. The energy requirements are very increasing. Our population, abundant energy resources and industrial diversity make our self proficient enough in producing and consuming energy. This will definitely leads in contributing to the national economy. It is the fact that initially there is a cost issue with every new technology but gradually developing mind we can cope up with it. The need for optimization in cost and efficiency can create systems which are cost effective, non- hazardous in nature, commercially available, clean fuel, compete with regular ongoing systems, inherently safe in handling, having renewable power and sustainable to nature. We envision a future where industries can fulfil the growing demands in an environmentally sustainable way. Hydrogen fuel cells have the real potential to be the future technology in terms of applicability. This technology has the solution to the problem of increasing requirements in an environmentally viable option. This review article presents the working operation of Hydrogen Fuel Cell, Classification of fuel cell in a comparable way, applications, new developments, future technologies and economic growth. Fuel cell is very much similar to the electrochemical cell or an ordinary dry cell. There are basically three components in each and every fuel cell. They are cathode, anode and electrolyte. They are connected with the electrical circuit. This construction has no rotating parts in its design. Hence, they are pretty simple and efficient in design. The classification is based on the type of electrolyte used.

Keywords*: Fuel cell, Efficiency, electrolyte, cathode, anode and applications.*

1. INTRODUCTION

Fuel cell is an energy conversion based device. This will harness the power of hydrogen. Hydrogen is a handy fuel, which have the potential to power anything. It s versatility can produce clean and sustainable power in nature. A fuel

Load cell is simple in its operation. It is nothing but electrochemical cell that converts the chemical energy from fuel into electricity. It occurs through the electrochemical reaction of hydrogen and oxygen. There occurs the flow of electrons from one electrode to another through the electrolyte. There are classifications based on types of electrolyte. Its working is very easy to understand. It is clean and environmentally viable option. Here, the energy is liberated by the chemical reaction by the flow of electrons and electrical energy is produced. The very first demonstration of simple basic fuel cell was given by Lawyer and Scientist William Grove in 1839, in his experiment the water was electrolysed into hydrogen and oxygen by passing an electric current by the help of battery, then after it was replaced by multi meter, and a small current is obtained through it. Here, the products are neither pollutants nor harmful in nature. The electrolysis is being reversed by recombining and the products are water. Hence, the electric current is generated. The hydrogen fuel is being burnt or combustion takes place in simple reaction, which is represented as follows:

$2H2 + O2 \rightarrow 2H2O$ --------------------- (1)

There are three components in the structure of fuel cell. They are anode, cathode and electrolyte. The reaction takes place at anode and cathode. At the anode of electrolyte in the fuel cell, the hydrogen gas get ionizes which leads to release of electrons and creating H+ ions (or protons).

Anode: $2H2 \rightarrow 4H+ + 4 e-$ -------------- (2)

This reaction releases energy. At the cathode, the oxygen gets reacted with the electrons released from electrode and H+ ions from the electrolyte. This results in the formation of water.

Cathode: O_2 + $4e^-$ + $4H^+$ → $2H_2O$ --------- (3)

Generally, there are three segments of any type of fuel cell. They are as follows:

1) Anode

2) Cathode and

3) Electrolyte

The main segment of any fuel cell is electrolyte. The type of the electrolyte tells about the nature, characteristics and its operation. Hence, it is said that type of electrolyte used describes the type of fuel used. Whatever may be the fuel cell type used, their principle of working will always be the same. Considering these three segments in combination, the chemical reaction takes place in such a manner of generating electric power without giving harm to environment. There may be the catalyst at anode. Catalyst can be platinum powder. Or there may be the arrangements where platinum electrodes are used. The catalyst is used to oxidize the hydrogen fuel. The hydrogen gas turns into ions and electrons. The ions make their way through electrolyte to the cathode. After reaching the cathode, they get combines with the cathode and starts reacting with the oxidant, which results in producing water. The ions pass which leads to production of electricity. Nickel is also mainly as cathode catalyst. This process results in formation of electricity at the load and the by-products formed in the reactions is water. The fuel cell at the full load can produce the electricity up to 0.7 volt, the desired voltage electricity can be obtained by connecting the fuel cells in series and desirable amount of current can be procured by connecting the fuel cells in parallel arrangements.

2. PROCESS INVOLVED IN MFCS:

Microbial Fuel Cells (MFCs): Bio electrochemical systems (BESs) are the biological systems that could convert chemical energy of organic matter ranging from complex lignocelluloses biomass to low strength wastewater into electrical energy, hydrogen or other valuable products. Comparatively, BESs can efficiently work under mild conditions and are capable of utilizing a wide range of substrates without the use of precious metal catalysts unlike its peers such as conventional fuel cells. Based on the type of biocatalyst used, BESs are classified majorly into two classes,

i) Microbial fuel cells (MFCs) and

ii) Enzymatic Fuel Cells (EFCs).

Depending on the application, BESs can be further classified into,

i) Microbial fuel cells (MFCs),

ii) Microbial Electrochemical Cells (MECs),

iii) Microbial Desalination Cells (MDCs) and

iv) Microbial Solar Cells (MSCs) .

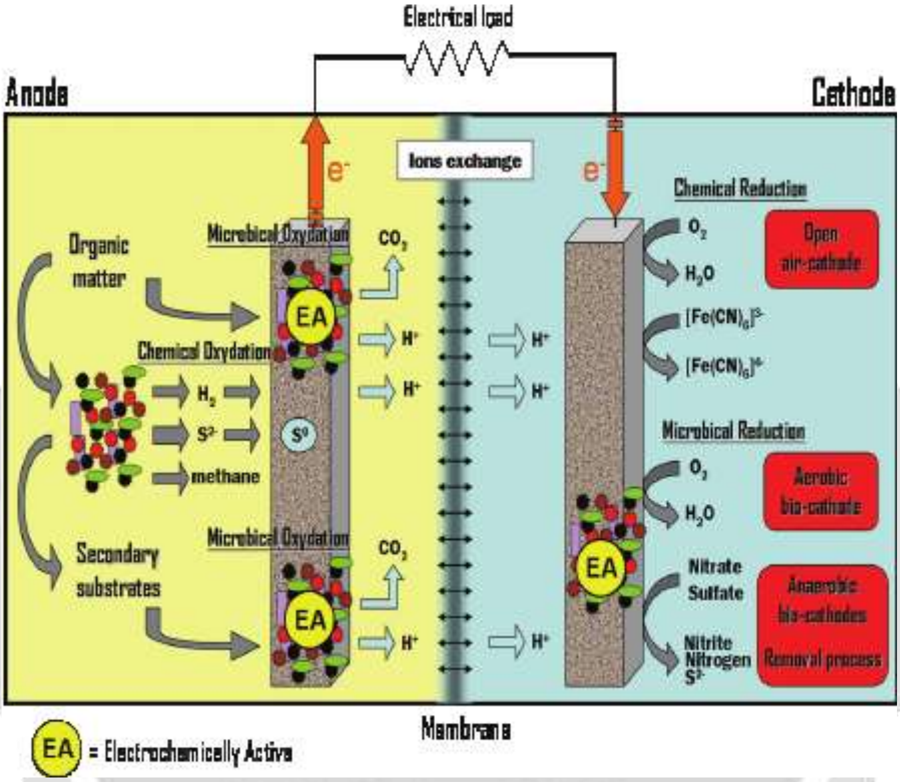
M.C.Potter in 1991 discovered through his experiments that a certain bacteria can release electrons extracellular (exoelectrogens) on degrading organic matter. Later, it has been inferred that breaking down of organic matter by the microorganisms accompanies generation of electrical energy. Development of such electron releasing microorganisms' biofilm facilitates renewable bioelectricity generation as well as removal of organic carbon simultaneously from waste water through a defined BES, called Microbial Fuel Cell technology. MFC is a compact reactor which can generate electricity spontaneously from the biomass through metabolic activity (anaerobic oxidation) of microorganisms. MFCs are found to be the potential devices to harvest bioenergy from the wastewater and concomitantly clean the wastewater, thereby, reducing the operational costs expending on the treatment of wastewater by conventional methods . A simple MFC set up consists of an anode in anodic chamber, a cathode in cathodic chamber, separated by a proton exchange membrane (PEM). MFC operates on a principle that biocatalysts oxidize organic substrates in the anodic chamber and releases protons and electrons in the process along with the generation of CO_2. Anode garners the electrons and passes them to the cathode through external circuit with simultaneous movement of protons from anode chamber to cathode chamber via

PEM. At the cathode, the electrons combine with protons and oxygen to form water . The complete process can be represented as

$C_2H_4O_2 + 2H_2O \rightarrow 2CO_2 + 8e^- + 8H^+$

$2O_2 + 8H^+ + 8e^- \rightarrow 4H_2O$

Electricity generated from wastewater through MFCs is pristine and can be used directly. It doesn't require further purification, separation or other conversion processes unlike hydrogen and methane produced from anaerobic digestion process which cannot be used directly. MFC technology is environmentally benign as they can operate at ambient conditions and produces pollution free energy .



Even though CO2 is produced as one of the end products of microbial oxidation, it is considered as carbon neutral process as the substrates consumes CO2 during their life cycle by photosynthesis . MFC can produce 1.43kWh/m3 to 1.8kWh/m3 of energy depending on the strength of the effluent. However, consumes only 0.024kW, which is roughly one order of magnitude less than what is consumed through anaerobic digestion process (~0.3kW). It can be inferred from the numerals that MFC requires approximately 10% of the energy for their operation compared to activated sludge process, exhibiting greater potentiality towards economical wastewater treatment and renewable energy generation . Despite the fact that MFC technology can efficiently treat wastewater with concomitant energy generation, it is still facing the challenges to move out of the boundaries of lab for field applications or commercialization. A number of factors such cost of the electrode materials, requirement of precious metal catalysts, low performance, low power densities and costly PEMs are limiting MFC technology in direct field applications. Even though these issues can be addressed at lab scale, ultimately pilot scale studies are necessary for analyzing the performance and longevity of materials at large scale especially when dealing with wastewater which doesn't possess constant conditions (composition, temperature etc) with time . A sundry of studies have been reported in recent decades focusing majorly on the reduction of cost of the electrode materials and the configuration of MFCs to maximize current densities. The present review is an attempt to address the recent advancements MFCs design and electrode materials.

3. APPLICATIONS OF MICROBIAL FUEL CELL [6]:

Attribute	Description Of the Attribute
Stationary Power	The fuel cells have found the major applications in power generation because of its higher efficiency. The low and high temperature fuel cell both are potential enough to be utilized in this area of application. The fuel cells like PEM, SOFC AND PAFC are generally employed for small power systems. The low temperature and high temperature fuel cell both have their own applicability. Generally the low temperature fuel cells have the advantage of giving faster start up time. The operating time needed is 40000 hours for the stationary applications. This start up operating time is a major obstacle in the fuel cell operation. There are fuel cells like SOFC and MCFC which are high temperature fuel cell. These type of fuel cell can directly be applied in place of heat cycle or can be used in an indirect way into combined systems of cycles.
Portable Devices	This will be the widely used major applications of fuel cell in the equipments such as portable computers, mobile phones, telephones and one of the important applications is military application. This area will include sustainability in terms of expansion.
Transportation	In today’s era the means of transport plays a vital role. The ongoing technologies are not environmentally sustaining in nature. So there is need to change the technology. The scientists have realized that they can demonstrate the vehicles with PEMFC technology. This technology can replace the older complicated technology. PEMFCs have its own advantage of low operating temperature range. The PEM techniques are suitable for the transporting devices. The main favouring point to consider is these technologies don’t require pure hydrogen used as fuel, can be operated without any rotating parts. Also, it doesn’t exhibit any significant poisoning systems. There are benefits recognized recently in several companies like BMW, Delphi automotive systems, etc. They have developed SOFCs as auxiliary power unit and companies implementing PEM fuel cells replacing hydrogen combustion engine. It is implemented in BMW7series and was found successful.
Space Applications	Space applications have proved that this technology is the most viable option for conventional energy resource. It can produce 1.5 kilowatts of continuous electrical supply. It was exemplary seen in the Apollo missions. The powerful alkaline fuel cells were highly reliable. The fuel cell is capable for supplying almost 12 KW continual periods and 16 KW for short period. The shuttle program in itself is the major and outstanding reliability. This in space not only provided electrical power but also was used by astronauts for the drinking purposes.

3.1. Applications Of MFC In Treatment Of Industrial Wastewater :

The process of wastewater treatment involves safe disposal or recycling of water that is highly polluted or contains toxic substances. Wastewater discharged from different industries can be particularly hazardous. MFC technology has the potential to provide an effective platform for the treatment of highly polluted industrial wastewater or urban wastewater and can curb the financial expenditure, which can be further used for other development programmes of a country.

In the late 19th century, Habermann and Pommer used MFCs for continuous treatment of wastewaters for nearly 5 years . They used sodium sulfate solutions with different concentrations (%, 0.5–5) as the electrolyte in the anode, sulfate-reducing microorganisms (such as Proteus vulgaris, Escherichia coli, Pseudomonas aeruginosa and Pseudomonas fluorescens) and two types of wastewaters (sewage work effluent and landfill effluent. The results showed that the MFC achieved a COD reduction of 35% with the sewage work effluent and 75% with the landfill leachate . In addition, a maximum anodic current density of 150 mA/cm2 at a potential of 50 mV was also obtained in the demonstration .In later years, different types of wastewaters were used in MFCs for their treatment and bioenergy production . On one side of the picture, MFC technology can be used to treat the wastewater, while on the other side, the wastewater can be used to provide the substrate as the carbon source for bacterial growth and hence for the end products of the oxidation process, that is, electrons and protons for sustainable bioelectricity generation . Primary wastewaters from an industry such as chocolate industry wastewater or palm oil mill effluent (POME) can be used to provide the inoculum or the biocatalysts for substrate oxidation. Moreover, defined bacterial culture (pure or mixed) can be isolated from the wastewater that can be further used as inoculum for the MFCs . The wastewater can be used as catholyte as well although it may contain some minerals that can act as electron acceptors.

Moreover, wastewaters are also the source of inoculum. The basic wastewater treatment assays (COD, BOD, total solids, nitrogen removal) can be employed to measure the treatment efficiency of the MFCs before and after the MFC operation The COD removal in MFCs can be further improved by operating the MFCs at optimized conditions such as mesophilic temperatures which have shown to increase the COD removal. Moreover, the MFC operation in fed-batch mode is advantageous to obtain high COD removal rate. Usually, the MFC studies operated for wastewater treatment are coupled with power generation, however the columbic efficiency obtained in such cases is quite low varying from 10 % to 30 % only[6] .

Performance of microbial fuel cells for wastewater treatment [10]

Wastewater	Type of MFC	Electrode material	% COD reduction
Swine wastewater	Single-chamber MFC	Toray carbon paper as anode Carbon cloth as cathode	92
Starch processing wastewater	Single-chamber MFC	Carbon paper	98
Real urban wastewater	Double-chamber MFC	Graphite electrodes	70
Olive mill wastewaters	Single-chamber MFC	Carbon cloth as electrodes	65
Protein-rich wastewater	Double-chamber MFC	Graphite rods as electrodes	80
Paper recycling wastewater	Single-chamber MFC	Graphite fibre brush	76
Cassava mill wastewater	Double-chamber MFC	Graphite plate electrode	86
Food processing wastewater	Double-chamber MFC	Carbon paper electrodes	95
Domestic wastewater	Double-chamber MFC	Plain graphite electrodes	88
Chocolate industry wastewater	Double-chamber MFC	Graphite rods as electrodes	75
Biodiesel wastes	Single-chamber MFC	Carbon brush electrodes	90
Beer brewery wastewater	Single-chamber MFC	Carbon fibres	43
Brewery wastewater	Single-chamber MFC	Carbon cloth as electrodes	98
Potato Processing	Tubular MFC	Graphite particles as anode Graphite felt as cathode	91
Palm oil mill effluent	UML-MFCs	Graphite granules, carbon fibre felt	90
Animal carcass wastewater	Upflow tubular MFC	Graphite felt as anode Carbon cloth as cathode	51
Food waste leachate	Double-chamber MFC	Carbon felt	85
Chemical wastewater	Double-chamber MFC	Graphite plates	63

CONCLUSION :

Fuel cells are simple, environmentally clean, efficient, and low emission device. These factors in itself makes fuel cell to hold wide range of applications. There is thrust to find the way mankind can generate as much as electricity in an sustainable way. Fuel cells have real potential to qualify as technology from which electricity can be generated with harmless by products. As our demand for electrical power grows, it becomes increasingly urgent to find new ways of meeting it both responsibly and safely. In the past, the limiting factors of renewable energy have been the storage and transport of that energy. With the use of fuel cells and hydrogen technology, electrical power from renewable energy sources can be delivered where and when required, cleanly, efficiently and sustainably.

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