© MAR 2018 | IRE Journals | Volume 1 Issue 9 | ISSN: 2456-8880

Evolution of Microbial Fuel Cell as a Prompting Technology for Wastewater Treatment

AAKASH SANKHALA[1], ANAND KUMAR[2], GAUTAM KUMAR[3]
[1,2,3] *Department of Electrical Engineering, Poornima college of Engineering, Jaipur, Rajasthan, India*

Abstract -- This paper presents microbial power modules (MFCs) that change over biochemical metabolic vitality into electrical vitality. Microorganisms can be bolstered with squander items rich in natural issue (residential wastewater, lignocellulosic biomass, distillery wastewater, starch handling wastewater, landfill leachates and so forth.) to create power. MFCs can likewise be utilized for wastewater treatment, as biosensors and creation of auxiliary powers like hydrogen.

Index Terms- Biosensors, ETC, MFCs, Wastewater treatment

I. INTRODUCTION

Microbial power modules (MFCs) utilize microorganisms to create power from biochemical vitality delivered amid digestion of natural substrates. MFC comprises of anode and cathode associated by an outside circuit and isolated by proton trade layer (PEM). In anode chamber, disintegration of natural substrates by microorganisms produces electrons (e-) and protons (H+) that are exchanged to cathode through circuit and layer respectively1. Natural substrates are used by organisms as their vitality sources, result of this procedure is in arrival of high-vitality electrons that are exchanged to electron acceptors (sub-atomic oxygen) yet without such electron acceptor in a MFC, microorganisms carry electron onto anode surface that outcomes in age of electricity2. Microscopic organisms are most favored microorganisms that can be utilized as a part of MFCs to produce power while achieving biodegradation of natural issues or wastes. Biodegradable natural rich waters (city strong waste, modern and farming wastewaters) are perfect competitors of reasonable vitality hotspots for power creation. MFCs can likewise be utilized as biosensors and in auxiliary fuel creation.

This paper surveys late improvements in MFC innovation featuring working rule and uses of MFC innovation.

II. MFCS: SETUP AND WORKING PRINCIPLE FOR ELECTRICITY GENERATION

Basic Machinery

A perfect MFC mechanical assembly (Fig. 1) comprises of two chambers (anodic and cathodic) made up of glass, polycarbonate or Plexiglas, with separate terminal of graphite, graphite felt, carbon paper, carbon-material, Pt, Pt dark or reticulated vitreous carbon (RVC). These chambers are isolated by PEM (Nafion or Ultrex5). Anodic chamber is loaded with natural substrates that are processed by microorganisms for development and vitality creation while producing electron and proton. Cathode is loaded with a high potential electron acceptor to finish circuit. A perfect electron acceptor ought not meddle with organisms at all and must be a practical compound with no poisonous impact. Oxygen fills in as a perfect electron acceptor because of its non-harmful impact and favored as oxidizing reagent as it streamlines activity of a MFC, generally standard media with appropriate electron acceptor, for example, ferricyanid can likewise be utilized to build control density. In light of get together of anode and cathode chambers, a basic MFC model can either be a twofold chambered or single chambered. Other than these two basic outlines, a few adjustments have been made in model of MFC plan and structure.

Double Compartment MFC System

In general, this kind of MFCs has an anodic and a cathodic chamber associated by a PEM that intercedes

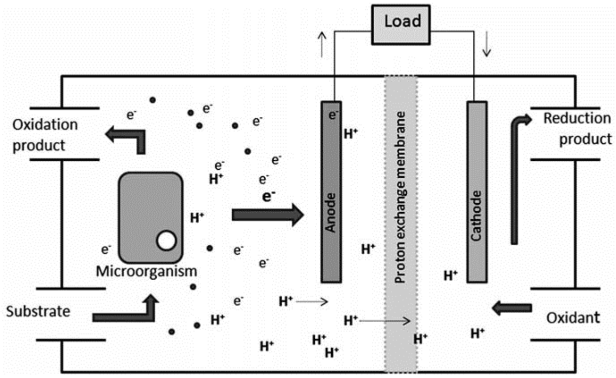

Fig. 1—A simple setup of microbial fuel cell (MFC)

proton exchange from anode to cathode while blocking dissemination of oxygen into anode. This sort of framework is for the most part utilized for squander treatment with concurrent power age. Scaling up of two compartment MFCs to mechanical size is very extreme. In addition occasional air circulation of cathodic chambers additionally constrains application range of two fold compartment MFCs.

Single Compartment MFC System

In a solitary compartment MFC, an anodic chamber is connected to a permeable air uncovered cathode isolated by a gas dispersion layer or a PEM. Electrons are exchanged to permeable cathode to finish circuit. Restricted prerequisite of occasional reviving with an oxidative media and air circulation makes single compartment microbial energy component framework more adaptable. Among various points of interest, single compartment MFC incorporates its lessened setup costs (because of nonattendance of costly layers and cathodic chambers) that make adaptable application in wastewater treatment and power generation.

III. WORKING PRINCIPLE

MFC investigates metabolic capability of microorganisms for transformation of natural substrate into power by exchanging electrons from cell to circuit. In anodic chamber, oxidation of substrate without oxygen by respiratory microscopic organisms deliver electron and proton that are passed onto terminal e-acceptor either by an unconstrained (coordinate) or by methods for some electron moving mediators. Guide electron exchange to anode by microscopic organisms requires some physical contact with cathode for current age. Dive line up amongst microbes and anode surface includes external film bound cytochromes or putative conductive pile called nanowires. These arbiter less MFCs frequently use anodophiles to shape a biofilm on anode surface to make simple utilization of anode as their end terminal electron acceptor in anaerobic breath.

In intervened electron exchange apparatus, microorganisms create/get indigenous dissolvable redox mixes (quinones and flavin) or manufactured exogenous arbiters (color or metalloorganics) to carry electron between terminal respiratory chemical and anode surface. These middle people can redirect electrons from respiratory chain by entering external cell film, getting to be decreased, and afterward leaving in a diminished state to carry electron to electrode. Quantities of electron and proton created relies on substrate used by organisms. Go between less MFCs have more business potential as middle people are costly and are in some cases poisonous to microorganisms. Electrode reactions in a MFC compartments are as follows:

i) If acetate is used as substrate microbes

Anodic reaction: $CH_3COO^- + H_2O \rightarrow 2CO_2 + 2H^+ + 8e^-$

Cathodic reaction: $O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$

[O2, nitrate or Fe (III)] through electron transport chain (ETC) (Fig. 2). However, in absence of e-acceptor in a

ii) If sucrose is used as substrate microbes

Anodic reaction: $C_{12}H_{22}O_{11}$ +13H_2O ->12CO +48H_2+ + 48e-

Cathodic reaction: O_2 +4e +4H -> 2H_2O

MFC, some microorganisms pass electron onto anode2.

Natural part rich sources (marine dregs, soil, wastewater, crisp water sediment and actuated slop) are rich wellspring of microorganisms that can be utilized as a part of MFCs reactant unit. Microscopic organisms utilized as a part of MFCs with go between or without arbiters have been widely considered and surveyed. Metal lessening and anodophilic microorganisms indicate better open doors for middle person less task of a MFC.

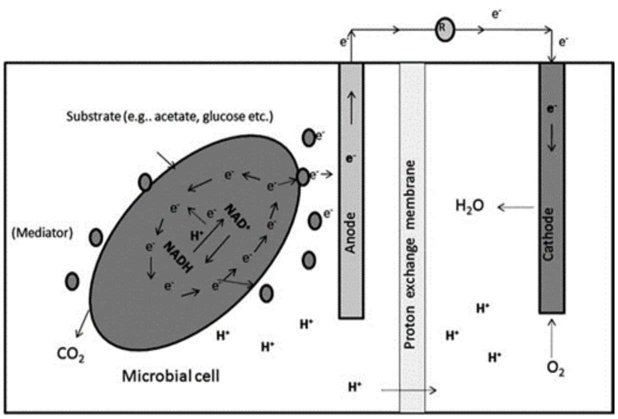

Fig. 2—Electron shuttling mechanism in a MFC

Substrate used for Electricity Generation

Substrate is a key factor for effective generation of power from a MFC. Substrate range utilized for power age ranges from easy to complex blend of natural issue show in wastewater. Despite the fact that substrate rich in complex natural substance helps in development of assorted dynamic organisms however straightforward substrates thought to be useful for prompt gainful yield. Acetic acid derivation and glucose are most favored substrate for fundamental MFC activities and power age. Lignocellulosic biomass from horticulture buildups as hydrolysis items (monosaccharides) are a decent hotspot for power creation in MFCs. Another promising and most favored uncommon substrate utilized as a part of MFCs tasks for control age is bottling works wastewater as it is supplemented with development advancing natural issue and without inhibitory substances. Starch preparing water can be utilized to create microbial consortium in MFCs. Cellulose and chitin (from modern and metropolitan wastewaters), engineered or concoction wastewater, color wastewater and landfill leachates are some eccentric substrates utilized for power creation by means of MFCs .

Commonly used Microbes in Microbial Fuel Cells (MFCs)

Generally blended culture of organisms is utilized for anaerobic absorption of substrate as intricate blended culture grants expansive substrate usage. However, there are some customary MFCs plans which investigate metabolic propensity of single microbial species to produce power.

IV. OTHER APPLICATIONS

Wastewater Treatment and Electricity Generation

Because of interesting metabolic resources of organisms, assortment of microorganisms are utilized as a part of MFCs either single species or consortia. A few substrates (clean squanders, nourishment handling wastewater, swine wastewater and corn stovers) are uncommonly stacked with natural issue that itself sustain extensive variety of microorganisms utilized as a part of MFCs. MFCs utilizing certain organisms have a unique capacity to expel sulfides as required in wastewater treatment. MFC substrates have enormous substance of development promoters that can upgrade development of bio-electrochemically dynamic microorganisms amid wastewater treatment. This synchronous activity lessens vitality request on treatment plant as well as decreases measure of unfeasible slime deliver by existing anaerobic generation. MFCs associated in arrangement have abnormal state of evacuation proficiency to treat leachate with supplementary advantage of creating power.

Biosensors

MFCs with replaceable anaerobic consortium could be utilized as a biosensor for on-line observing of natural issue. Despite the fact that assorted ordinary strategies are utilized to figure natural substance in term of organic oxygen request (BOD) in wastewater, a large portion of them are unacceptable for on-line checking and control of organic wastewater treatment forms.

A direct relationship between's Coulombic yield of MFC and quality of natural issue in wastewater makes MFC a conceivable BOD sensor. Coulombic yield of MFC gives a thought regarding BOD of fluid stream that ends up being an exact technique to quantify BOD esteem at very wide focus scope of natural issue in squander water.

Secondary Fuel Production

With minor change, MFCs can be utilized to create auxiliary powers like hydrogen (H2) as an option of power. Under standard exploratory conditions, proton and electron delivered in anodic cham-ber get exchanged to cathode, which at that point joins with oxygen to shape water. H2 age is thermodynami-cally not favored or it is an unforgiving procedure for a phone to change over proton and electron into H2. Increment in outside potential connected at cathode can be equipped to over-come thermodynamic obstruction in response and utilized for H2 age. Thus, proton and electron created in anodic response chamber join at cathode to shape H2. MFCs can presumably create additional H2 when contrasted with amount that draw off from traditional glucose aging technique. Wagner et al detailed H and methane generation by utilizing microbial electrolytic cells that are altered MFC with expanded outer potential at cathode. Along these lines, MFCs give a sustainable H2 to add to general H2 request in a H2 economy.

Advancement in MFC Technology

Improvement of MFCs was activated by USA space program in 1960s as a conceivable innovation for a waste transfer framework for space flights that would likewise create control. MFC innovation has been broadly investigated concentrating on late change, viable execution, anode execution, cathodic constraints, distinctive substrates utilized as a part of MFCs and so forth. MFCs have been investigated as another wellspring of power age amid operational waste treatment. What's more, a portion of the current adjustment in MFCs innovation incorporates its utilization as microbial electrolysis cell (MEC), in which anoxic cathode is utilized with expanded outer potential at cathode. Phototrophic MFCs and sunlight based controlled MFC likewise speak to an outstanding endeavor in the advance of MFCs innovation for power creation.

V. CONCLUSIONS

MFC is a perfect method for creating power since it as an inexhaustible source as well as it can be utilized to treat squander. It can likewise be utilized for generation of auxiliary fuel and in bioremediation of dangerous mixes. Notwithstanding, this innovation is just in inquire about stage and more research is required before local MFCs can be made accessible for commercialization.

REFERENCES

[1] Logan B E, Hamelers B, Rozendal R, Schroder U, Keller J, Freguia S, Aelterman P, Verstraete W & Rabaey K, Microbial fuel cells: methodology and technology, Environ Sci Technol, 40 (2006) 5181-5192.

[2] Wrighton K C & Coates J D, Microbial fuel cells: plug-in and power-on microbiology, Microbes, 4 (2009) 281-287.

[3] Park D H & Zeikus J G, Electricity generation in microbial fuel cells using neutral red as an electronophore, Appl Environ Microb, 66 (2000) 1292-1297.

[4] Oh S E & Logan B E, Hydrogen and electricity production from a food processing wastewater using fermentation and microbial fuel cell technologies, Water Res, 39 (2005) 4673-4682.

[5] Du Z, Li H & Gu T, A state of the art review on microbial fuel cells: A promising technology for wastewater treatment and bioenergy, Biotech Advances, 25 (2007) 464-482.

[6] Watanabe K, Recent developments in microbial fuel cell tech- nologies for sustainable bioenergy, J Biosci Bioeng, 106 (2008) 528-536.

[7] Pant D, Bogaert G V, Diels L & Vanbroekhoven K, A review of the substrates used in microbial fuel cells (MFCs) for sustain- able energy production, Biores Technol, 101 (2010) 1533-1543.

[8] Liu H & Logan B E, Electricity generation using an air-cathode single chamber microbial fuel cell in the presence and absence of a proton exchange membrane, Environ Sci Tech, 38 (2004) 4040-4046.

[9] Rabaey K & Verstraete W, Microbial fuel cells: novel biotech- nology for energy generation, Trends Biotechnol, 23 (2005) 291-298.

[10] Bennetto H P, Stirling J L, Tanaka K & Vega C A, Anodic reac- tion in microbial fuel cells, Biotechnol Bioeng, 25 (1983) 559-568.

[11] Catal T, Li K, Bermek H & Liu H, Electricity production from twelve monosaccharides using microbial fuel cells, J Power Sources, 175 (2008) 196-200.

[12] Feng Y, Wang X, Logan B E & Lee H, Brewery wastewater treatment using air-cathode microbial fuel cells, Appl Microbiol Biotechnol, 78 (2008) 873-880.

[13] Kim B H, Park H S, Kim H J, Kim G T, Chang I S, Lee J & Phung N T, Enrichment of microbial community generating elec-tricity using a fuel cell-type electrochemical cell, Appl Microbiol Biotechnol, 63 (2004) 672-681.

[14] Rezaei F, Richard T L & Logan B E, Analysis of chitin particle size on maximum power generation, power longevity, and Cou-lombic eficiency in solid-substrate microbial fuel cells, J Power Sources, 192 (2009) 304-309.

[16] Niessen J, Harnisch F, Rosenbaum M, Schroder U & Scholz F, Heat treated soil as convenient and versatile source of bacterial communities for microbial electricity generation, Electrochem Commun, 8 (2006) 869-873.

[17] Vega C A & Fernandez I, Mediating effect of ferric chelate com- pounds in microbial fuel cells with Lactobacillus plantarum, Streptococcus lactis and Erwinia dissolvens, J Bioelectrochem Bioenerg, 17 (1987) 217-222.

[18] Choi Y, Jung E, Kim S & Jung S, Membrane fluidity sensoring microbial fuel cell, Bioelectrochemistry, 59 (2003) 121-127.

[19] Rabaey K, Boon N, Siciliano S D, Verhaege M & Verstraete W, Biofuel cells select for microbial consortia that self-mediate elec-tron transfer, Appl Environ Microbiol, 70 (2004) 5373-5382.

[20] Ringeisen B R, Henderson E, Wu P K, Pietron J, Ray R, Little B, Biffinger J C & Jones-Meehan J M, High power density from a miniature microbial fuel cell using Shewanella oneidensis DSP10, Environ Sci Technol, 40 (2006) 2629-2634.

[21] Pham C A, Jung S J, Phung NT, Lee J, Chang I S, Kim B H, Hana Y & Chun J, A novel electrochemically active and Fe(III)-reducing bacterium phylogenetically related to Aeromonas hydrophila, isolated from a microbial fuel cell, FEMS Microbiol Lett, 223 (2003) 129-134.

[22] Min B, Cheng S & Logan B E, Electricity generation using membrane and salt bridge microbial fuel cells, Water Res, 39 (2005) 1675-1686.

[23] Bond D R & Lovley D R, Electricity production by Geobacter sulfurreducens attached to electrodes, Appl Environ Microbiol, 69 (2003) 1548-1555.

[24] Bond D R, Holmes D E, Tender L M & Lovley D R, Electrode- reducing microorganisms that harvest energy from marine sedi- ments, Science, 295 (2002) 483-485.

[25] Chaudhuri S K & Lovley D R, Electricity generation by direct oxidation of glucose in mediatorless microbial fuel cells, Nat Biotechnol, 21 (2003) 1229-1232.

[26] Liu Z D, Lian J, Du Z W & Li H R, Construction of sugar-based microbial fuel cells by dissimilatory metal reduction bacteria, Chin J Biotech, 21 (2006) 131-137.

[27] Kim B H, Kim H J, Hyun M S & Park D H, Direct electrode reaction of Fe (III)-reducing bacterium Shewanella putrifaciens, J Microbiol Biotechnol, 9 (1999) 127-131. Park D H & Zeikus J G, Impact of electrode composition on electricity generation in a single-compartment fuel cell suing Shewanella putrefaciens, Appl Microbiol Biotechnol, 59 (2002) 58-61.

[28] Rhoads A, Beyenal H & Lewandowshi Z, Microbial fuel cell using anaerobic respiration as an anodic reaction and biomineralized manganese as a cathodic reactant, Environ Sci Technol, 39 (2005) 4666-4671.

[29] Rabaey K, Van De Sompel K, Maignien L, Boon N, Aelterman P, Clauwaert P, De Schamphelaire L, Pham H T, Vermeulen J, Verhaege M, Lens P & Verstraete W, Microbial fuel cells for sulfide removal, Environ Sci Technol, 40 (2006) 5218-5224.

[30] Liu H, Ramnarayanan R & Logan B E, Production of electricity during wastewater treatment using a single chamber microbial fuel cell, Environ Sci Technol, 38 (2004) 2281-2285.

[31] Gálvez A, Greenman J & Ieropoulos I, Landfill leachate treat- ment with microbial fuel cells; scale-up through plurality, Biores Technol, 100 (2009) 5085-5091.

[32] Kumlaghan A, Liu J, Thavarungkul P, Kanatharana P & Mattiasson B, Microbial fuel cell-based biosensor for fast analy- sis of biodegradable organic matter, Biosens Bioelectron, 22 (2007) 2939-2944.

[33] Kim H J, Hyun M S, Chang I S & Kim B H, A microbial fuel cell type lactate biosensor using a metal-reducing bacterium,

Shewanella putrefaciens, J Microbiol Biotechnol, 9 (1999) 365-367.

[34] Chang I S, Jang J K, Gil G C, Kim M, Kim H J, Cho B W & Kim B H, Continuous determination of biochemical oxygen demand using microbial fuel cell type biosensor, Biosens Bioelectron, 19 (2004) 607-613.

[35] Chang I S, Moon H, Jang J K & Kim B H, Improvement of a microbial fuel cell performance as a BOD sensor using respiratory inhibitors, Biosens Bioelectron, 20 (2005) 1856-1859.

[36] Liu H, Grot S & Logan B E, Electrochemically assisted micro- bial production of hydrogen from acetate, Environ Sci Tchnol, 39 (2005) 4317-4320.

[37] Wagner R C, Regan J M, Sang-Eun O, Yi Z & Logan B E, Hydrogen and methane production from swine wastewater us- ing microbial electrolysis cells, Water Res, 43 (2009) 1480-1488.

[38] Bullen R A, Arnot T C, Lakemanc J B & Walsh F C, Biofuel cells and their development, Biosens Bioelectron, 21 (2006) 2015-2045.

[39] Rozendal R A, Hamelers H V M, Rabaey K, Keller J & Buisman C J N, Towards practical implementation of bioelectrochemical wastewater treatment, Trends Biotechnol, 26 (2008) 450-459.

[40] Pham T H, Aelterman P & Verstraete W, Bioanode performance in bioelectrochemical systems: recent improvements and prospects, Trends Biotechnol, 27 (2009) 168-178.

[41 Rismani-Yazdi H, Carver S M, Christy A D & Tuovinen A H, Cathodic limitations in microbial fuel cells: an overview, J Power Sources, 180 (2008) 683-694.

[42] He Z, Kan J, Mansfeld F, Angenent L T & Nealson K H, Self-sustained phototrophic microbial fuel cells based on the synergistic cooperation between photosynthetic microorganisms and heterotrophic bacteria, Environ Sci Technol, 43 (2009) 1648-1654.

[43] Cho Y K, Donohue T J, Tejedor I, Anderson M A, McMahon K D & Noguera D R, Development of a solar-powered microbial fuel cell, J Appl Microbiol, 104 (2008) 640-650.