STUDIES ON MICROBIAL FUEL CELL USING RICE WATER AS SUBSTRATE

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE

OF

BACHELOR OF TECHNOLOGY

IN

BIOTECHNOLOGY

By

Sameer Kr Gupta

Roll No-110BT0607

DEPARTMENT OF BIOTECHNOLOGY & MEDICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA-769008

MAY-2014

STUDIES ON MICROBIAL FUEL CELL USING RICE WATER AS SUBSTRATE

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENT FOR THE DEGREE

OF

BACHELOR OF TECHNOLOGY

IN

BIOTECHNOLOGY

By

SAMEER KR GUPTA

Roll No-110BT0607

UNDER THE GUIDANCE OF

Prof. Krishna Pramanik

DEPARTMENT OF BIOTECHNOLOGY & MEDICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA-769008

MAY-2014

DEPARTMENT OF BIOTECHNOLOGY & MEDICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA-769008

CERTIFICATE

This is to certify that the thesis entitled "**Studies on Microbial fuel cell using Rice water as substrate**" which is being submitted by Mr. **Sameer Kumar Gupta** (**110BT0607)**, for the award of the degree Bachelor of Technology from National Institute of Technology, Rourkela, is a record of bona fide research work, carried out by him under my supervision. The results personified in this thesis are new and have not been submitted to any other university or institution for the award of any degree or diploma.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to elsewhere for the award of any degree.

Place:

Date:

Prof: Krishna Pramanik
Department of Biotechnology & Medical Engineering
National Institute of Technology
Rourkela 769008

DEPARTMENT OF BIOTECHNOLOGY & MEDICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

ROURKELA-769008

DECLARATION

I hereby declare that the thesis entitled "Studies on Microbial fuel cell using rice water as substrate", submitted to the Department of Biotechnology & Medical engineering, National Institute of Technology, Rourkela for the partial fulfilment of the Bachelor of Technology in Biotechnology, is a faithful record of bona fide and original research work carried out by me under the guidance and supervision of Prof. Krishna Parmanik, Department of Biotechnology & Medical engineering, National Institute of Technology, Rourkela. To the best of my knowledge no part of this thesis has been submitted to any other institutes or organization for the award of any degree or diploma.

Place: SAMEER KR.GUPTA

Date: ROLL NO:-110BT0607

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In the present study, electricity was produced from rice water which is considered as waste product using a H-shaped double chamber microbial fuel cell. The effect of silver nanoparticle, anode surface area, cathode surface area, and chemical treatment of electrodes on voltage and current generated by microbial fuel cell was investigated. It was found that with the help of silver nanoparticle, the maximum value of current produced by microbial fuel cell was increased from 0 .011µA to 10µA. Furthermore, when the anode surface area was increased from 55.25cm^2 to 221cm^2, the maximum value of power generated by microbial fuel cell was increased from 2070.2nW to 2339.1644nW and an increment of more than 50% power generation was achieved by increasing cathode surface area from 55.25cm^2 to 221cm^2.

Similarly the chemical treatment of electrodes prior to the operation gave the maximum value of power generated by microbial fuel cell that equals to 32980nW while the corresponding current produced was 170µA. Since the conventional proton exchange membranes (nafion) used in microbial fuel cell are expensive. So in the present study, an alternative chitosan membrane which is comparatively cheaper and has lower value of impendence was found to be an effective separator for MFC.

Key Words – Microbial fuel cell, Rice water, Salt bridge, Chitosan membrane, Silver nanoparticle, Graphite sheet.

1. INTRODUCTION

SIGNIFICANCE: Due to continuous depletion of fossil fuels and constant increase in price of fuels, he world is moving towards the energy catastrophe. However consumption of fossils fuel cause an increase in pollution level which is a major cause of global warming.(Reddy et al 2007). So requisition of an alternative source of energy is increasing day by day which should be economical, reusable and clean. The microbial fuel cells provide a promising technology to handle the above two problems by decomposing organic waste to using it. For building a practical world we require to minimize the use of fossil powers and also the contaminants created. These two points could be achieved all together by treating the waste water or bio-waste.

BACKGROUND: In 1911, M.C Potter observed that bacteria can be used produce electrical energy (Potter 1911). However not sufficient research was done to advance this technology during 1911-1967. But in 1967, John Davis patented the first microbial fuel cell technology (Biffinger & Ringeisen 2005) & possible application and research on microbial fuel cell was began after 1990's. Most of the patents were issued in 2000's (Biffinger & Ringeisen 2005).

Microbial fuel cell technology: MFC might be best characterized as a bio-reactor where microorganisms act as catalyst in metabolizing the natural substance containing the organic carbon to produce electricity. The microbial fuel cell is a system in which enzyme catalytic energy is converted into electrical energy by electrochemical process (Allen and Benetto, 1993). Electrons are produce by the oxidation of organic material in which microbes act as catalyst. The electrons thus produced are transferred to a terminal electron acceptor such as oxygen nitrate and sulphate. Now these terminal electron acceptor are get reduced by these electrons. A new product is formed which can leave the cells when terminal electron acceptors are diffused into the cells. However there are some microorganisms specially bacteria that can transfer their electrons in the

outer space surrounding the cells which are accepted by the awaiting terminal electron acceptors. These bacteria are called exogenic and can be used to produce power within a microbial fuel cells (Logan 2008). The advantages of microbial fuel cells are as follows:-

- Easily available exogenic material which is used as substrate and microbes which act as catalyst.
- It ia a simple system and unlike the hydrogen fuel cells, a MFC does not require extremely synchronized division system.
- It is more effective than enzymatic fuel cell in harvesting electrons from the electron transport system of bacteria.

This Power device (MFC) generally comprises of two chambers, one of the chamber where oxidation take place is called anodic chamber (anode) and the other chamber where reduction take place is called cathode chamber (cathode). In presence of oxygen, microbes oxidize organic compound to produce CO_2 and water, but if the reaction take place in anaerobic environment then microorganisms decomposes organic material to produce CO_2 while proton and electrons are produced simultaneously. (Delaney et al., 1984; Park and Zeikus, 2000; Rabaey et al., 2004).

$C_6H_{12}O_6 + 6H_2O \longrightarrow 6CO_2 + 24H^+ + 24e^-$ (Reaction in anode chamber)

$24H^+ + 24e^- + 6O_2 \longrightarrow 12H_2O$ (Reaction in cathode chamber)

Electrons thus produced are transfer to the cathode chamber via an external circuit while protons are transferred through proton exchange membrane (PEM). MFCs have various configurations such as single chamber vs double chamber, mediator and mediator-less microbial fuel cells, air cathode microbial fuel cells….etc. However mediator-less microbial fuel cells have many limitations as mentioned below:-

(1) There is a decomposition of fuel at anode
(2) Transport of electrons from microbial fuel cells to anode.
(3) Resistance of the circuit,
(4) Transfer of proton from anodic chamber to cathode chamber through proton exchange membrane
(5) O_2 decreases at the cathode.

MFC engineering is still basic and there are a few ranges for advancement (Rabaey and verstsaete, 2005). Columbic efficacy of conventional microbial fuell cells is low due to insufficient electron exchange joining MFCs and negative electrode. This incapability results in partial oxidation of the fuel and unsought integration of a portion of the fuel carbon into biomass.

Microorganisms tacked together in biofilms for their electro activity. Electro genic microbial biotic groups are additionally found in marine residue, impelled mud, fertilizer groups, and soils (Logan, 2009).

MFCs can be used to process hydrogen gas by taking oxygen from the cathode and including a little voltage through the bio electrochemically supported microbial reactor (BEAMR) procedure or electrolysis process which is bio-catalysed.. MFC can additionally be utilized for desalinating seawater as Fresh water sources are running out.

The efficacy of the MFC relies upon methodology and working parameters. Some of these parameters are pH, substrate charging, stream speed and oxygen transportation into the anodic chamber. The transformation of chemical energy to electrical energy take place by pairing oxidation of organic or inorganic compounds to the chemical, which is biologically catalysed, to reduction of an oxidant at the edge between the anode and cathode (Willner et al.,1998).

. To tackle the issues of low columbic effectiveness a very few experiment have been performed with singular types of microorganisms that utilize the anode specifically as finial electron acceptor (Logan and Regan, 2006).The initiation of anodic chamber take place by the formation of NADH from liquor, lactic acid, amino acid that gives the bio-moves (Williner et al., 1998).

Hypothetically, any natural or inorganic compound or a blend might be outfitted as a fuel which is oxidized by the electro genic bacteria as:-

$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24e^- + 24\ H^+$.

The matching of metabolic oxidation of the introductory electron benefactor (NADH) to decrease of the terminal electron acceptor, (for example, oxygen or fumarate in bacterial breath frameworks) is fundamentally the same to the blending of the electrochemical half-response of the reductant (electron giver) to the half-response of the oxidant (electron acceptor) in a power device or battery framework (Chang,1981). It has been demonstrated that microorganisms could pick up vitality from the potential between NADH and cytochrome c (green bolt), though the MFC could get energy from the potential between cytochrome c and oxygen (blue shaft). True possibilities rely on concentration and potential of particular proteins and electron acceptors.

High anodic potential is needed for expanded vitality preparation, while easier possibilities can prompt electron misfortune by means of exchange to capricious acceptors. To keep the anodic chamber free of oxygen to hold redox potential, fermentative organic entities must be chosen. The cathode finishes the circuit of the cell by directing electrons to a high potential electron acceptor.

The pH and buffering properties of the anodic chamber could be varying to get the most out of microbial extension , vitality creation, and electric potential (Du Z et al., 2007).

MFCs microbial groups can be characterized into three classes: heterotrophic cells, photoheterotrophic cells, and cells from the watery dregs. Heterotrophic cells incorporate a sole indistinguishable state of microorganisms whichever balanced in media or in biofilms developing on terminals. Photoheterotrophic cells devour photoheterotrophic organisms ready to go about as the biocatalysis of microbial digestion system notwithstanding photosynthetic sources. Sedimentary cells use microbial groups stopping in marine environment to produce electric potential (Rabaey et al., 2003).

The primary issues that shortly hampering the advancement of microbial fuel cells are:-how to utilize microbial fuel cells on an industrialized scale while maintaining low expenses, how to minimize the hazards associated with microbial fuel cells and hot to maximize the power output.

2. LITERATURE REVIEW

Beginning of microbial fuel cell: In 1911, M.C Potter observed that bacteria can be used produce electrical energy (Potter 1911). However not sufficient research was done to advance this technology during 1911-1967. But in 1967, John Davis patented the first microbial fuel cell technology (Biffinger & Ringeisen 2005) & possible application and research on microbial fuel cell was began after 1990's. Most of the patents were issued in 2000's (Biffinger & Ringeisen 2005).

Mechanism of Microbial fuel cell: MFC might be best characterized as a bio-reactor where microorganisms act as catalyst in metabolizing the natural substance containing the organic carbon to produce electricity. The microbial fuel cell is a system in which enzyme catalytic energy is converted into electrical energy by electrochemical process (Allen and Benetto, 1993). Electrons are produce by the oxidation of organic material in which microbes act as catalyst. The electrons thus produced are transferred to a terminal electron acceptor such as oxygen nitrate and sulphate. Now these terminal electron acceptor are get reduced by these electrons. A new product is is formed which can leave the cells when terminal electron acceptors are diffused into the cells. However there are some microorganisms specially bacteria that can transfer their electrons in the outer spac surrounding the cells which are accepted by the awaiting terminal electron acceptors. These bacteria are called exogenic and can be used to produce power within a microbial fuel cells (Logan 2008).

Bacterial metabolism: Anaerobic bacteria which get die in the presence of oxygen is used as a catalyst & their extra cellular electrons are utilized by microbial fuel cell. To complete the electron transfer to the electrodes the fermented product must combine with other constituents such as aromatic compounds through effective and anaerobic oxidation (Lovely, 2006)

The transfer of electron to electrode take place by the following mechanism to produce current:-

1. With the addition of synthesized mediator
2. By the direct contact with anode
3. With the help of self-produced mediator

MASS TRANSFER AND KINETICS: A bio-film is formed when exogenic bacteria attached and grow on anode. Thus the bio-film contain many microorganisms. The thickness of bio-film is limited by other factors which is essential for the growth of microorganisms such as pH, temp, stress…etc. Initially activation losses get decreased by the growth of bio-film which is beneficial for the kinetics of bio-electrochemical system. But when the thickness of bio-film increases then the transfer of nutrients and other growth factors which are involved in formation of bio-film become the limiting factors in production of power (Logan 2008).

VOLTAGE AND POWER GENERATION

The activity of living organisms affect the voltage and power generation in microbial fuel cell.

From Kirchoff's law, we know that

E=I*R

Where E= Generated voltage

I= Current produced

R= External resistance

This is valid only when Gibb's free energy is negative (Logan et. al, 2006)

Furthermore,

$$\Delta G = \Delta G^0 + RT\ln[Q]$$

Where,

ΔG= Gibb's free energy at temperature T

ΔG = Gibb's free energy at temperature standard temperature

R = Universal gas constant

T = absolute temperature

Q = Reaction quotient

Again,

$$E = E^0 - \frac{RT\ln[Q]}{nF}$$ (Logan et. al ,2006)

Where,

E = Electromotive force of cell

E^0 = Electromotive force of standard cell

n = Number of electrons per mole

At equilibrium,

E =0 and ΔG=0

So,

$$E^0 = \frac{\Delta G^0}{nF}$$

Further the total cell potential can be found by the half-cell potential of anode and cathode

$$E_{emf} = E_{cat} - E_{an}$$ (Logan et. al 2006)

and

$$\mathbf{P = E^2/R_{ext}}$$

Where,

P = Power generated by microbial fuel cell

$\mathbf{R_{ext}}$ = External resistance

3. OBJECTIVES

1. To generate electrical energy from rice water using a Microbial Fuel Cell
2. To study the effect of anode surface area, cathode surface area and chemical treatment of electrodes on voltage and current generated by Microbial fuel cell
3. To study the effect of silver nanoparticles incorporated with salt bridge on current generated by Microbial fuel cell.
4. To find an alternative to conventional proton exchange membrane such as nafion used in Microbial fuel cell.

4. MATERIALS AND METHODS

4.1. COLLECTION OF BIOWASTE

Bio waste (rice water) was collected from mess of MSS hall of residence, NIT Rourkela

Salt Bridge

1M NaCl (150ml), 3% agarose.

4.2. MFC FABRICATION AND DESIGN

Electrode

We use carbon electrode (graphite sheet) of dimension 5cmx5cm as electrode i.e anode and cathode. However to check the effect of cathode surface area or anode surface area we use graphite sheet of dimension 10cmx5cm.

Cathode chamber or aerobic chamber

To make the cathode chamber we use a 2 litre plastic bottle and filled it with distilled water. Cathode was fixed to the lid of the bottle and wire is attached to the cathode using crocodile clamp.

Anode Chamber or anaerobic chamber

To make the anode chamber we use a 2 litre plastic bottle and filled it with substrate i.e rice water and shield it properly with plastic tape so that air cannot enter in to it. Anode is fixed to the lid of the bottle and is connected with wire using crocodile clamp.

Salt bridge

To prepare the salt bridge we dissolve 3gm of agarose in 100 ml of 1M NaCl solution by heating the mixture until we get a homogeneous solution (Figure-3). After that we caste the solution in to a PVC pipe of length 10cm and diameter 2cm. Now put it in refrigerator for proper settling.

Figure 1:-Image of salt bridge

4.3. Preparation of Silver Nanoparticles

We prepare 0.002M solution of sodium borohydride ($NaBH_4$). Now take 30ml of this solution in a conical flask and placed it on an ice bar and stir it for about 25minutes. Now take 2ml of 0.001M solution of silver nitrate ($AgNO_3$) and add it to the above solution at a rate of 1 drop per second. Now stop stirring and add the solution of salt bridge and caste the solution in a PVC pipe and keep it inside a refrigerator for proper settling.

4.4. Preparation of Chitosan membrane

To prepare the chitosan membrane we dissolve 3gm of chitosan powder in 100ml of 3% acetic acid. Now take a Petridis and apply some oil on its bottom and pour the chitosan solution to the Petridis and keep it inside an oven at 60C for 24hrs. Now remove the membrane from Petridis.

4.5. Measurement of potential difference and current

To measure the potential difference and current generated by MFC a multimeter of DIGITAL Company (model no-DT830D) was used.

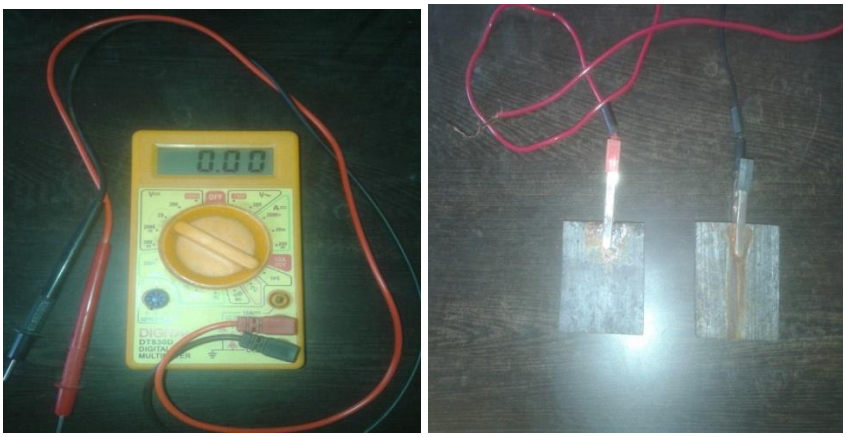


Figure 2:-. A Multimeter and Electrode

4.6. Formulations of salt bridge containing nanoparticles

Take 15 ml of the nanoparticle colloidal solutions in separate conical flask and add 20ml of IM NaCl to it. After that 3% agarose was added in all to it and mixture was boiled for 2 min and the casted in PVC pipes.

4.7. MFC operations

Salt bridge is used to internally connect the all component of MFC while it is externally connected to multimeter with the help of wire as shown in Figure-5. 70% alcohol and 1% $HgCl_2$ wasused to surface sterilized the bottles and was exposed to UV radiation for 20 minutes and salt bridge was sealed inside the holes with fevidite in aseptic conditions. Now 1000ml of rice water was added in one of the bottle which will serve as anodic chamber while 1000ml of distilled water was added in another bottle and this will serve as cathodic chamber. The microbial fuel cell was kept at room temperature while voltage and current was measured in a interval of 0.5hr for 32hrs. Now to measure the effect of cathode or anode surface area we use an electrode (graphite sheet) having dimension 10cmx5cm. To measure the effect of chemical treatment of electrode we took 100ml of distilled water and put the electrodes and boil it for 10minutes. After that we washed the electrode with 5% HCl.

5. RESULTS AND DISCUSSION

5.1. Construction of MFC: A H-shaped microbial fuel cell was constructed with two 2l bottles. To prepare the microbial fuel cell first we made one hole on each bottle whose diameter is equal to the diameter of PVC. Now these two bottles are attached together with the help of salt-bridge and araldite. Electrodes are mounted on the lid of the bottles. After putting the substrate the anodic chamber was completely shield by the plastic tape so that air cannot go to this chamber.

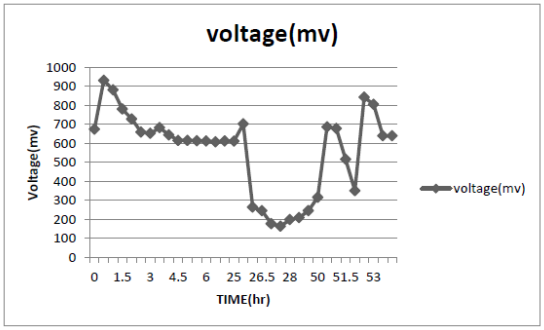
Figure 3: The complete setup of microbial fuel cell

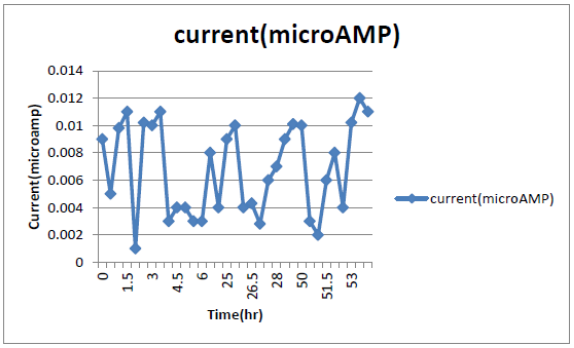
5.2. Voltage and current generation in a simple Microbial Fuel Cell

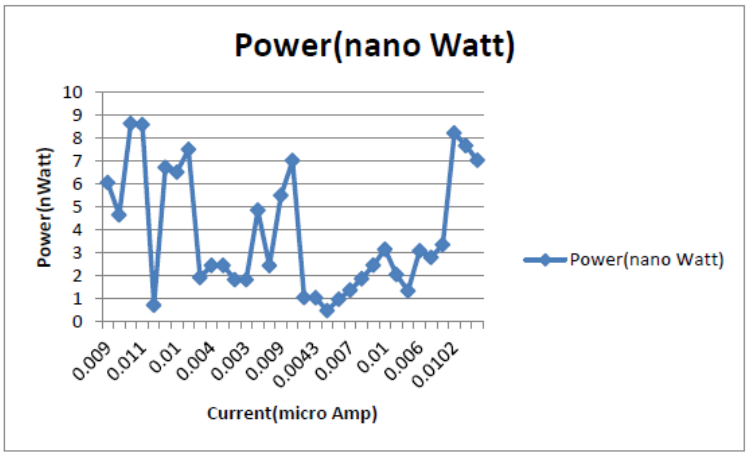
TABLE-1 :-Voltage generation in simple Microbial fuel cell

TIME(hrs.)	VOLTAGE(V)	CURRENT(μA)	POWER(mW/m^2)
0	0.674	0.009	0.006066
0.5	0.931	0.005	0.004655
1	0.881	0.0098	0.0086338
1.5	0.783	0.011	0.00858
2	0.728	0.008	0.005824
2.5	0.659	0.0102	0.0067218
3	0.652	0.01	0.00652
3.5	0.682	0.011	0.007502
4	0.644	0.003	0.001932
4.5	0.615	0.004	0.00246
5	0.615	0.004	0.00246
5.5	0.613	0.003	0.001839
6	0.612	0.003	0.001836
24	0.607	0.008	0.004856
24.5	0.612	0.004	0.002448
25	0.611	0.009	0.005499
25.5	0.702	0.01	0.00702
27	0.264	0.004	0.001056
27.5	0.245	0.0043	0.0010535
28	0.177	0.0028	0.0004956
28.5	0.164	0.006	0.000984
29	0.198	0.007	0.001386
29.5	0.209	0.009	0.001881
30	0.245	0.0101	0.0024745
49	0.326	0.01	0.00326
49.5	0.686	0.003	0.002058
50	0.678	0.002	0.001356
50.5	0.516	0.006	0.003096
51	0.351	0.008	0.002808
51.5	0.842	0.004	0.003368
52	0.805	0.0102	0.008211
52.5	0.639	0.012	0.007668
53	0.639	0.011	0.007029

Figure 4:-Voltage and Current generated in a simple operation







As it is observed from the graph that our MFC produced sufficient voltage but current is negligible due to which power generated by microbial fuel cell is less.

5.3. Effect of Silver Nanoparticles on current generation

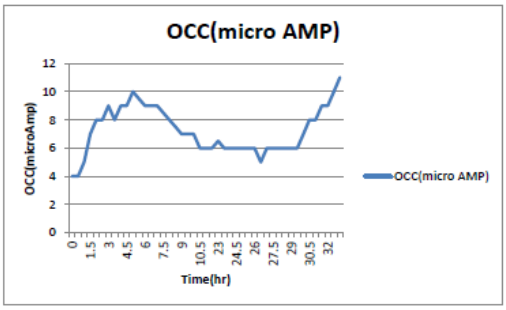
The effect of use of silver nanoparticle in salt bridge on the generation of electrical energy is shown in table 2 and the corresponding trend is depicted in figure 5

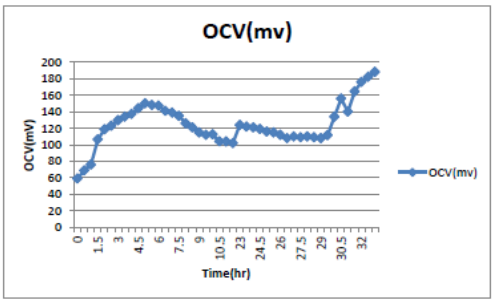
TABLE 2:- Voltage generation using nanoparticle in salt bridge

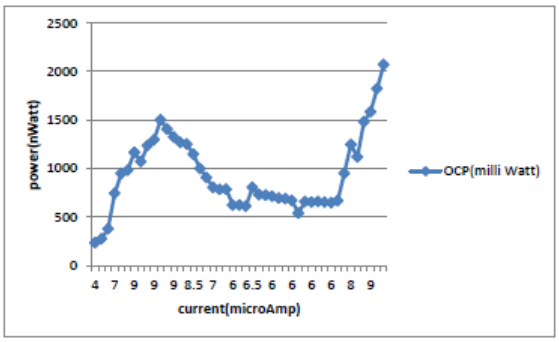
TIME(hrs.)	VOLTAGE(V)	CURRENT(μA)	POWER(mW/m^2)
0	59.1	4	236.4
0.5	69	4	276
1	76.1	5	380.5
1.5	106.4	7	744.8
2	118.7	8	949.6
2.5	123	8	984
3	129.6	9	1166.4
3.5	134	8	1072
4	137.4	9	1236.6
4.5	144.2	9	1297.8
5	150.6	10	1501
5.5	148.1	9.5	1406.95
6	147.4	9	1326.6
6.5	141	9	1269
7	139	9	1251
7.5	135	8.5	1147.5
8	126	8	1001
8.5	121	7.5	907.5
9	115	7	805
9.5	112	7	784
10	112.5	7	787.5
10.5	104.1	6	624.6
11	104	6	624
11.5	102	6	612
23	124	6.5	806
23.5	122	6	732
24	121	6	726
24.5	119	6	714
25	116	6	696
25.5	115	6	690
26	112	6	672
26.5	108	5	540
27	110	6	660
27.5	109	6	654
28	110	6	660
28.5	109	6	654
29	108	6	648
29.5	111.6	6	669.6
30	134	7	952

30.5	156	8	1248
31	140	8	1120
31.5	164.7	9	1482.3
32	176.1	9	1584.9
32.5	182.3	10	1823
33	188.2	11	2070.2

Figure 5- Voltage and Current generated by Microbial Fuel Cell using nanoparticle incorporated salt bridge.







As it is indicated, due to the use of silver nano particle the maximum value of current driven by microbial fuel cell was increased from 0.011µA to 10µA.

5.4. Effect of anode surface area

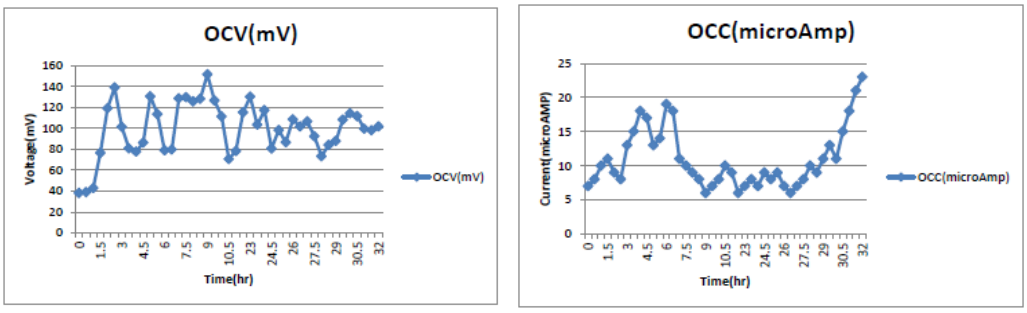
The effect of use of increased anode surface area on the generation of electrical energy is shown in table 3 and the corresponding trend is depicted in figure 6

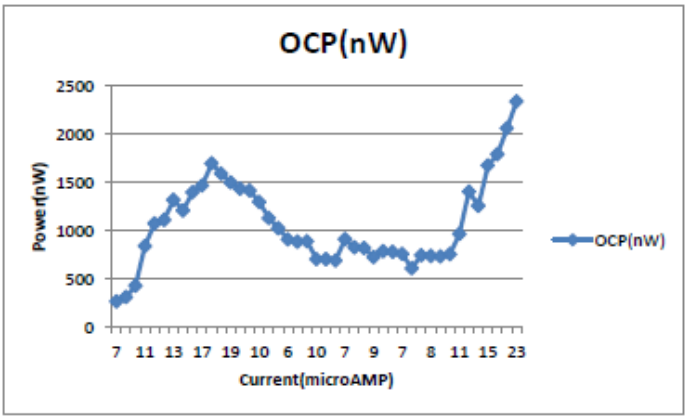
TABLE 3:- Voltage generation with increased anode surface area

TIME(hrs.)	VOLTAGE(V)	CURRENT(µA)	POWER(mW/m^2)
0	38.161	7	267.127
0.5	38.985	8	311.88
1	42.96	10	429.6
1.5	76.51	11	841.61
2	119.227	9	1073.043
2.5	141	9	1269
3	101.387	13	1318.031
3.5	80.757	15	1211.355
4	77.631	18	1397.358
4.5	86.265	17	1466.505
5	130.471	13	1696.123
5.5	113.56	14	1589.84
6	78.897	19	1499.043
6.5	79.665	18	1433.97
7	128.51	11	1413.61
7.5	129.6675	10	1296.675
8	125.681	9	1131.129
8.5	128.184	8	1025.472
9	151.61	6	909.66
9.5	126.56	7	885.92
10	111.234	8	889.872
10.5	70.5798	10	705.798
11	78.3467	9	705.1203
11.5	115.26	6	691.56
23	130.1114	7	910.7798
23.5	103.395	8	827.16
24	117.1971	7	820.3797
24.5	80.647	9	725.823
25	98.31	8	786.48
25.5	86.63	9	779.67
26	108.48	7	759.36

26.5	101.7	6	610.2
27	106.5428	7	745.7996
27.5	92.3775	8	739.02
28	73.224	10	732.24
28.5	84.072	9	756.648
29	87.7963	11	965.7593
29.5	108.15	13	1405.95
30	114.2363	11	1256.5993
30.5	111.666	15	1674.99
31	99.4965	18	1790.937
31.5	98.0947	21	2059.9887
32	101.7028	23	2339.1644

Figure 6:-Volatge & Current generated by Microbial Fuel Cell with increased anode surface area.





When anode surface area was increased from 55.25cm^2 to 221cm^2 then power delivered by MFC was increased by more than 10%. The maximum value of power generated by microbial fuel cell was increased from 2070.2nW to 2339.1644nW. However this increase in relatively less than caused by increased in cathode surface area.

5.5. Effect of cathode surface area

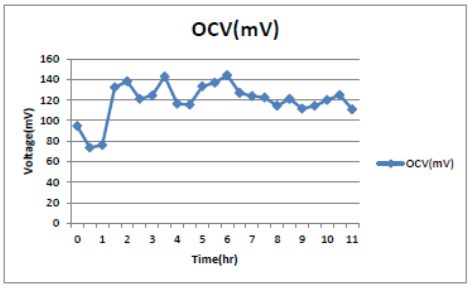
The effect of increased surface area on generation of electrical energy is shown in table 4 and the corresponding trend is depicted in figure 7

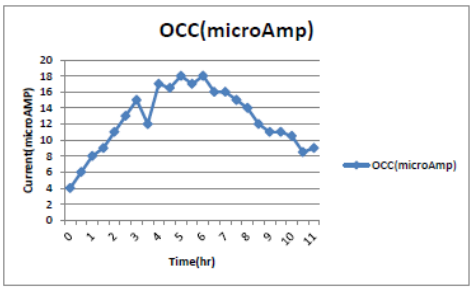
TABLE 4:- Voltage generation with increased cathode surface area

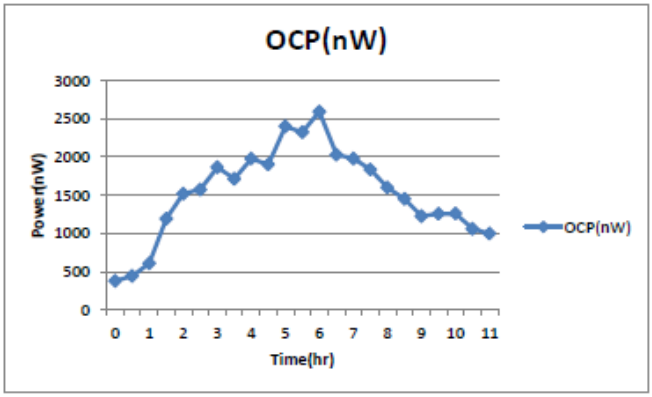
Time(hrs)	OCV(mV)	OCC(µA)	OCP(nW)
0	94.56	4	378.24
0.5	73.6	6	441.6
1	76.1	8	608.8
1.5	134	8	1072
2	138.2	11	1520.2
2.5	121.11	13	1574.43
3	124.4	15	1866
3.5	142.9	12	1714.8
4	116.38	17	1978.46
4.5	115.36	16.5	1903.44
5	133.4	18	2401.2
5.5	136.8	17	2325.6
6	144.2	18	2595.6
6.5	126.9	16	2030.4

7	123.8	16	1980.8
7.5	122.4	15	1836
8	114.4	14	1601.6
8.5	121	12	1452
9	111.6	11	1227.6
9.5	114.3	11	1257.3
10	120	10.5	1260
10.5	124.9	8.5	1061.65
11	110.9	9	998.1

Figure 7:- Voltage and Current generated by MFC having increased cathode surface area







When cathode surface area was increased from 55.25cm2 to 221cm2 then it was found that the value of generated power is increased by more than 50%.

5.6. Effect of chemical treatment of electrodes

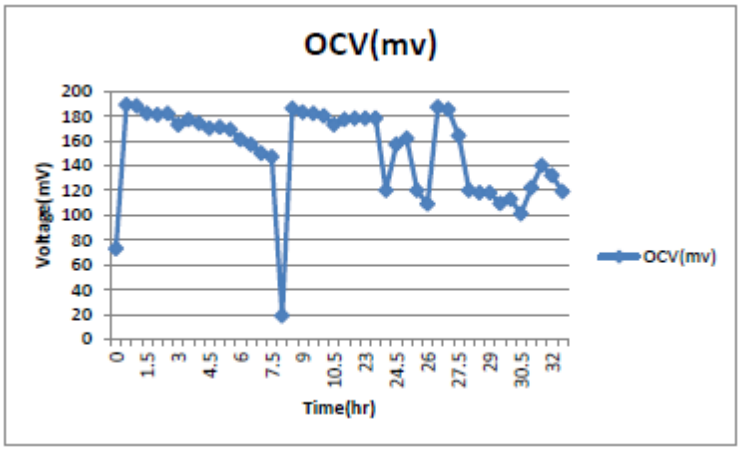
The effect of chemical treatment of electrodes on the generation of electrical energy is shown in table 5 and the corresponding trend is depicted in figure 8

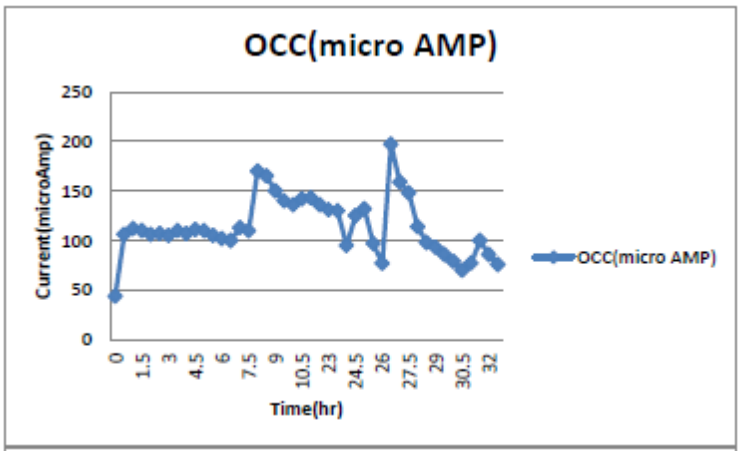
TABLE 5:- Voltage generation with chemically treated electrode

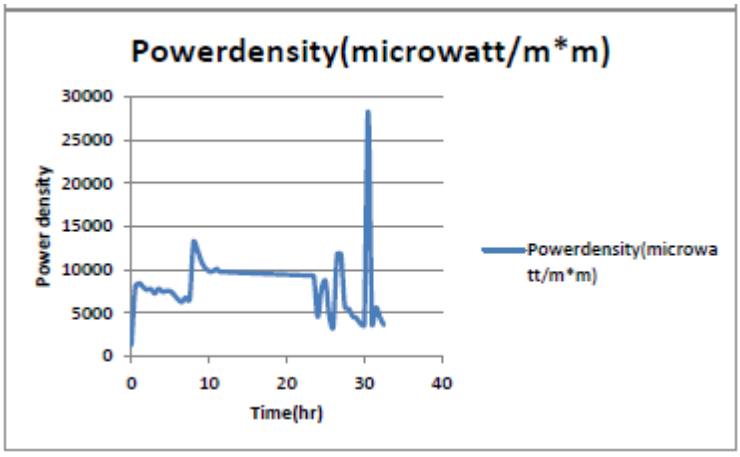
Time(hrs)	OCV(mv)	OCC(μA)	OCP(in nW)
0	73	44	3212
0.5	189	106	20034
1	188	112	21056
1.5	182	110	20020
2	181	106	19186
2.5	182	107	19474
3	173	105	18165
3.5	177	110	19470
4	174	107	18618
4.5	170	111	18870
5	171	110	18810
5.5	169	105	17745
6	161	102	16422
6.5	157	100	15700
7	150	113	16950
7.5	147	110	16170
8	19	170	32980
8.5	186	165	30690
9	183	150	27450
9.5	182	140	25480
10	180	136	24480
10.5	173	142	24566
11	177	143	25311
11.5	178	136	24408
23	178	131	23318
23.5	178	130	23140
24	120	95	11400
24.5	157	125	19625
25	162	132	21684
25.5	120	97	11640
26	109	77	8393
26.5	187	197	29359
27	185	159	29415

27.5	164	148	14272
28	120	114	13680
28.5	118	98	11564
29	118	93	10974
29.5	109.5	86	9417
30	112.9	79	8919.1
30.5	101.2	70	70684
31	122.2	77	9409.4
31.5	140	100	14000
32	132	86	11352
32.5	119	76	9044

Figure 8:- Voltage and current generated by MFC having chemically treaded electrode.







Due to this there is a huge invrease inthe generated current as well as generated power. The maximum value of generated power was found to be 32980nW having the corresponding current of 170µA.

5.7. Formation of Chitosan membrane: Chitosan membrane was formed by by completely dissolving 3gm chitosan powder in 100ml of 3% acetic acid. When chitosan completely get dissolved in acetic acid then the solution was poured in a petridis and heated at 60°C for 24hrs.

Figure 9 : chitosan membrane sheet

5.8. Characterisation of Chit-membrane

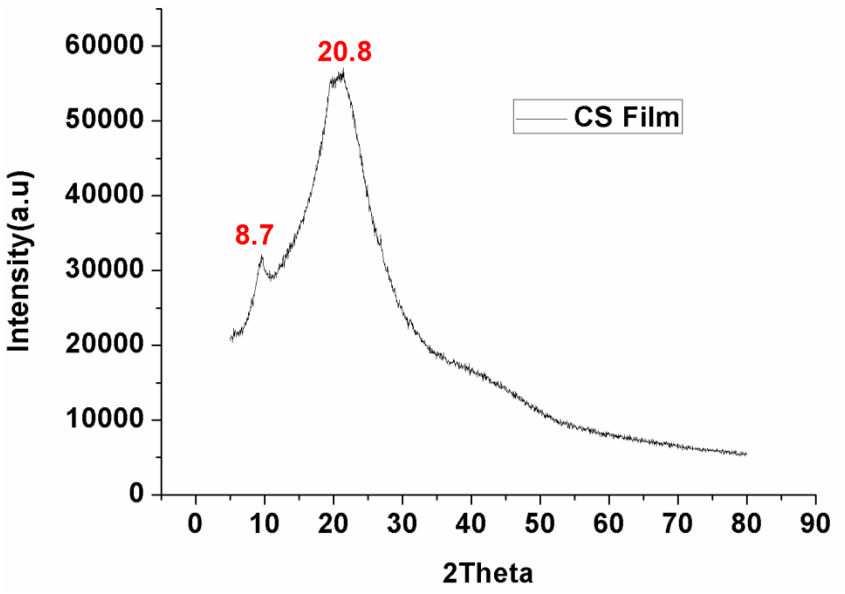


FIGURE 10:- XRD spectrum of Chitosan film

There are two characterestic peaks one at 2Θ=8.7 and another at 2Θ =20.8 which correspond to 020 and 110 planes.

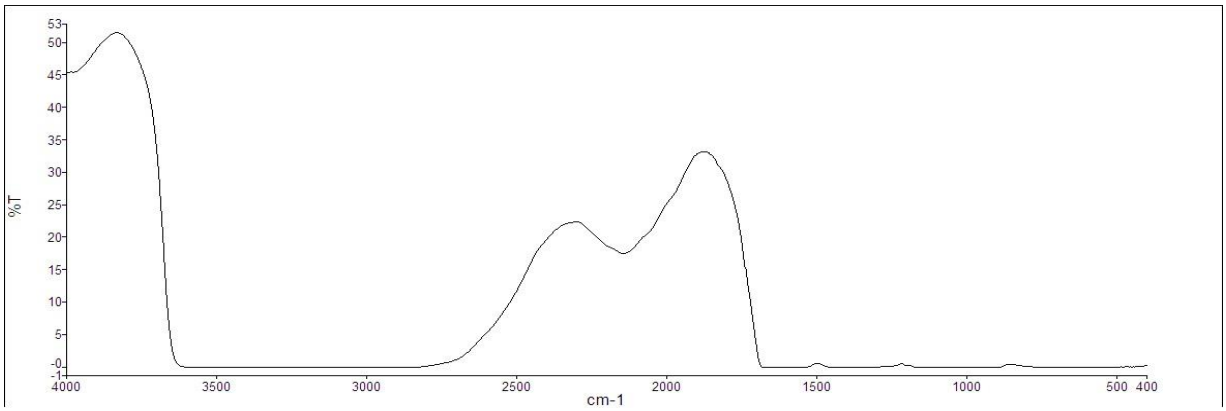


FIGURE 11:- FTIR spectrum of Chitosan film

The intense broadband in the greater vitality space assigned to stretching vibration of hydroxyl group of chitosan, water and amino group which are present in chitosan membrane. However the

occurrence of bending vibration of CH_2 is observed just below 1500cm^{-1} while strong absorption peak of carbonyl stretching of amide was observed at 1652cm^{-1}.

6. CONCLUSION

This project was done to generate electricity from rice water which is considered as waste and to analyse the effect of various parameter (cathode and anode surface area, silver nanoparticle incorporated in salt bridge, chemical treatment of electrodes) on voltage and current generation of microbial fuel cell. Furthermore, to find an alternative of conventional proton exchange membrane.

In the first phase a H-shaped microbial fuel cell was constructed. In the second phase sample (rice water) was collected from MSS hall of residence, NIT Rourkela. In the third phase microbial fuel cell is operated in different conditions as mentioned earlier.

It was found that when microbial fuel cell is operated in simple condition then generated current has a very low value (in the range of 0.01µA). But when silver nanoparticle is incorporated with salt bridge the maximum value of generated current was increased from 0.011µA to 10µA. However when anode surface area was increased from 55.25cm^2 to 221cm^2 the generated power got increased by more than 10%, but if we increase the cathode surface area from 55.25cm^2 to 221cm^2 then the generated power get increased by more than 50%. Furthermore when electrodes was chemically treated prior to the operation then maximum value of generated current and power get increased to 197µA and 32980nW respectively.

Since convention proton exchange membrane used in microbial fuel cell is expensive hence chitosan membrane was prepared which can be used as separator in microbial fuel cell. Chitosan membrane is cheaper than nafion membrane and have lower impedance than salt bridge. In the last phase characterization of chitosan membrane was done.

Thus MFC is a self-sufficient system which can produce electricity from organic waste or biomass. When these organic materials are oxidized by microorganisms then it does not supply net carbon dioxide to the environment and unlike hydrogen fuel cells, there is no requirement for

wide pre-handing out of the fuel or for costly catalysts. With the suitable optimization, microbial fuel cells might be able to power an extensive collection of broadly used procedure. For example, there is current research on the future for powering self-feeding robots and even vehicles in this way. However, considerable optimization of microbial fuel cells will be required for most applications.

7. REFERENCES

- Abassi, S.A. and Abassi, T. Biomass energy and environmental impacts associated with its production and utilization. Renew. Ener. (2010). Rev., 14:919-937.
- Allen R.M., Bennetto H.P. Microbial fuel cells: electricity production from carbohydrates. Appl Biochem Biotechnol, (1993). 39-40:27-40.
- Allen, R. M. and P. H. Bennetto "Microbial Fuel-Cells: Electricity Production from Carbohydrates." Applied Biochemistry and Biotechnology, (1993). 39/40: 27-40.
- Amann,C.A Alternate fuels and power systems in the long term.Int.J.vehicle.Des, (1996).,17:510-517.
- Bennetto, P. H., J. L. Stirling, et al. "Anodic Reactions in Microbial Fuel Cells." Biotechnology and Bioengineering, (1983). 25(2): 559-568.
- Bond DR, Holmes DE, Tender LM and Lovley DR Electrode-reducing microorganisms that harvest energy from marine sediments. Science, (2002). 295 483-485.
- Bond, D. R. and Lovley, D. R. Electricity production by Geobacter sulfurreducens attached to electrodes. Environmental Science and Technology, (2003). 69(3), 1548–1555.
- Booki , M., Chenga, S.,Bruse, E. and Logana, BElectricity generation using membrane and salt bridge microbial fuel cells. Water. Resear, (2005), 39 :1675-1686.
- Bullen,R.A., T. C. Arnot, et al. "Biofuel Cells and their Development."Biosensors and Bioelectronics, (2006). 21(11): 2015.
- Cahyani, Farida Nur and Markx, Gerard The Generation of Electricity in Microbial Fuel Cell (MFC) Using Artificial Waste Water as a Fuel and Pseudomonas aeruginosa as Micro Organism. Gelagar, (2008) 19 (2). ISSN 0853-2850
- Chang, R. Physical chemistry with application to biological systems, 2nd ed. Macmillan Publishing, New York, N.Y. 1981.

- Chaudhuri, S. K. and D. R. Lovley "Electricity Generation by Direct Oxidation of Glucose in Mediatorless Microbial Fuel Cells." Nature Biotechnology, (2003). 21(10):1229.
- Clauwaert, P., D. van der Ha, et al. "Open Air Biocathode Enables Effective Electricity Generation with Microbial Fuel Cells." Environmental Science and Technology, (2007). 41(21): 7564-7569.
- Cohen, B. The Bacterial Culture as an Electrical Half-Cell. Thirty-second Annual Meeting of the Society of American Bacteriologists, (1931).
- Das,D and Veziroglu,T.NHydrogen production by biological process: a survey on literature. Int. J. Hydrogen Ener, (2001).,26;13-58.
- Delaney GM, Bennetto HP, Mason JR, Roller, SD, Stirling JL and Thurston CF Electron-transfer coupling in microbial fuel cells. 2. Performance of fuel cells containing selected microorganism-mediator substrate combinations. Journal of Chemical Technology and Biotechnology, (1984). 34B 13–27.
- Du, Z., Li, H. and Gu, TA state of art review on microbial fuel cells: A promising technology for wastewater treatment and bioenergy. Biotechnol. Advances, (2007), 25;464-482.
- Habermann, W. and Pommer, E.HBiological fuel cells with sulphide storage capacity. Appl. Microbial. Biotechnol, (1991). 35:128-135.
- He, Z. and Largus T. Angenent "Application of Bacterial Biocathodes in Microbial Fuel Cells." Electroanalysis, (2006). 18(19-20): 2009-2015.
- 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, 2009. 43, 1648–1654.
- Hernandez , M.E and Newman, D.KExtracellular electron transfer. Cell. Mol. Life Sci. (2001).,58:1562-1571.

- In S. Kim, Kyu-Jung Chae, Mi-Jin Choi, and Willy Verstraete. Microbial Fuel Cells: Recent Advances, Bacterial Communities and Application Beyond Electricity Generation. Environ. Eng. Res. Vol. 13, 2008.No. 2, pp. 51~65, Korean Society of Environmental Engineers .
- Kim, B. H., H. J. Kim, et al. "Direct Electrode Reaction of Fe(III)-Reducing Bacterium, Shewanella putrefaciens." Journal of Microbiology and Biotechnology 9: (1999). 127-131.
- Kosaric N and Velikonja J., Liquid and gaseous fuels from biotechnology: challenge and Opportunities. FEMS Microbiology, (1995). Reviews 16: 111-142.
- Lane, N. "Microbiology: Batteries Not Included, What Can't Bacteria Do?" Nature, (2006). 441(7091): 274.
- Liu, H. and B. E. Logan "Electricity Generation Using an Air-Cathode Single Chamber Microbial Fuel Cell in the Presence and Absence of a Proton Exchange Membrane." Environmental Science and Technology, (2004). 38(14): 4040-4046.
- Liu, H., R. Ramnarayanan, et al. "Production of Electricity during Wastewater Treatment Using a Single Chamber Microbial Fuel Cell." Environmental Science and Technology, (2004). 38(7): 2281-2285.
- Logan, B. E. Exoelectrogenic bacteria that power microbial fuel cells. Nature 2009. 7:375–381.
- Logan, B. E. and Regan, J. M., Electricity-producing bacterial communities in microbial fuel cells. Trends in Microbiology, (2006). 14(12), 512-518.
- Logan, B. E., B. Hamelers, et al. "Microbial Fuel Cells: Methodology and Technology." Environmental Science and Technology, (2006). 40(17): 5181-5192.
- Logan,B.E Biologically extracting energy from wastewater: Biohydrogen production and microbial fuel cells. Environmental Science and Technology, (2004). 38 :160-167

- Min, B. and B. E. Logan "Continuous Electricity Generation from Domestic Wastewater and Organic Substrates in a Flat Plate Microbial Fuel Cell."Environmental Science and Technology, (2004). 38(21): 5809-5814.

  Min, B., J. Kim, et al. "Electricity Generation from Swine Wastewater using Microbial Fuel Cells." Water Research, (2005). 39(20): 4961.
- Nicholls, D. G. Bioenergetics – An Introduction to the chemiosmotic theory. London: Academic Press. (1982).
- Park, D.H. and Zeikus, J.G. Improved fuel cell and electrode designs for producing electricity from microbial degradation. Biotechnol. Bioeng, (2003).,81:348-355.
- Potter, M. C. "Electrical Effects Accompanying the Decomposition of Organic Compounds." (1911), 84(571): 260-276.
- Rabaey, K. and W.Verstraete (2005). "Microbial Fuel Cells: Novel Biotechnology for Energy Generation." Trends in Biotechnology 23(6): 291.
- Rabaey, K., Boon, N., Siciliano, D., Verhaege, M. and Verstraete, W. (2004). Biofuel cells select for microbial consortia that self-mediate electron transfer. Applied and Environmental Microbiology, 70(9), 5373-5382.
- Rabaey, K., G. Lissens, et al. "A Microbial Fuel Cell Capable of Converting Glucose to Electricity at High Rate and Efficiency." Biotechnology Letters, (2003). 25(18): 1531
- Rakesh Reddy N, Nirmal Raman K, Ajay Babu OK and Muralidharan A Potential stage in wastewater treatment for generation of bioelectricity using MFC, Current Research Topics in Applied Microbiology and Microbial Biotechnology 1, (2007). 322326.
- Rao JR, Richter GJ, Vonsturm F, Weidlich E Performance of glucose electrodes and characteristics of different biofuel cell constructions. *Bioelectrochem. Bioenerg.* (1976) 3: 139–150.

- Reguera, G., Nevin, K. P., Nicoll, J. S., Covalla, S. F., Woodard, T. L. and Lovley, D. R. Biofilm and nanowire production leads to increased current in Geobacter sulfurreducens fuel cells. Applied and Environmental Microbiology, (2006). 72(11), 7345-7348.
- Rismani Yazdi, h.,Carver,S.M., Christy,A.D. and Tuovinen,O.H.(2008). Cathodic limitation in microbial fuel cells:an overview.J.Power Sources.,180:683-694.
- Schroder U, Nieber J and Scholz F, A generation of microbial fuel cells with current output boosted by more than one order of magnitude. Angew Chem, (2003). 115:2986–2989
- Scott, K., Murano, C., A study of a microbial fuel cell battery using manure sludge waste. J. Chem. Technol. Biotechnol, 2007. 82, 809–817.
- Sisler, F. D. "Electrical energy from Biochemical Fuel Cells." New Scientist, (1961). 12: 110-111.
- Sisler, F. D. "Electrical Energy from Microbiological Processes." Journal of the Washington Academy of Sciences 52: 181-187. Strik, D.P.B.T.B., Hamelers, H.V.M., Snel, J.F.H., Buisman, C.J.N., 2008a. Green electricity production with living plants and bacteria in a fuel cell. Int. J. Energy Res, (1962). 32 (9), 870–876.
- Suzanne T Read, Paritam Dutta, Phillip L Bond, Jürg Keller and Korneel Rabaey. Initial development and structure of biofilms on microbial fuel cell anodes. *BMC Microbiology* 2010, 10:98
- Thauer, R. K., K. Jungermann, and K. Decker. Energy conservation I chemotrophic anaerobic bacteria. Bacteriol, 1977. Rev. 41:100–180.
- Vandevivere, P. and Verstraete, W. Environmental applications. In Basic biotechnology (Ratledge, C. and Kristiansen, B., eds), (2001) pp. 531–557, Cambridge University Press
- Venkata ,M.S., Saravan ,R., Veer Raghuvulu, S., Mohanakrishna , G. and Sharma, P.NBioelectricity production from wastewater treatment in dual chambered microbial fuel cell

(MFC) using selectively enriched mixed micro flora; effect of catholyte. Bioresource. Technology, (2007), 45:34-44.