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Energy Harvesting from Sediment Microbial Fuel Cell Using Different Electrodes

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Abstract : The consumption rate of energy around the world is rising on each successive day. In this result, Non-renewable sources of energy are ended at a fast rate. Sediment Microbial fuel cell (SMFC) aimed to deliver opportunities to generate pollution-free, cost-effective sustainable energy from sediment. The potential generated by the SMFC, microbes existing in the sediment. In this research, test the different electrode material in SMFC and here find the zinc and copper is the best material for SMFC which generate the maximum voltage across the electrode. Here maximum generated voltage and current of SMFC for steady state operating condition, with a copper anode and zinc cathode were 1.160V and 0.301mA and maximum power was 3.491mW. SMFC is gifted for long-term operation, sustainable low-cost green electricity harvest and stable power generation. SMFC can be used as a renewable power source as a remote environmental monitoring.
Keywords : Sediment microbial fuel cell, Energy harvesting, Voltage, Copper, Zinc, Graphite.

Introduction:-

Sediment Microbial fuel cell is the eco-friendly type of renewable sources of energy and capacity to rectify the disadvantages involve with the generation and utilization of the fossil fuels. At present-day many researchers are working on different renewable energy sources likes' thermoelectric energy, solar cells, piezoelectric, geothermal and wind. All these sources can't be used anywhere that doesn't have suitable geological types. SMFC is a new innovation that is suitable for the entire geographical situation. SMFC convert biochemical energy into electricity without creates any type of pollution in environment[1]. In recent years, the advance of the microbial fuel cell (MFC) in bio-electrochemical study deals a new kind of innovation that converts biochemical energy into electricity using microbes present in substance[2]. Some of the researchers have used the SMFC for powering temperature sensor, remote sensors and electrical equipment for environmental observing[3, 4]. The electrolyte in SMFC was used the soil of ponds, canals, and sea under water and generate power for a long time without any maintenance5. There several advantages of using SMFCs, it is not generating toxic wastes, any preservation required, and long-term energy harvesting as well as wastewater treatment. Whereas commercial batteries generally are not working for a long time and replacement are required [3,4,5,7].

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The organic compounds in the sediment have several types of electro-genic bacteria across the anode surface. Electro-genic bacteria likeGeobacter sulfurreducens[8,9],Rhodoferax ferrireducens[10], Shewanella putrefaciens[11], Clostridium spp. and Bradyrhizobiumspp.[12], which oxidized organic substance andproduce electrons and protons[14]. SMFC has two chambers, anode chamber, and the cathode chamber, anode are placed in electrolyte present in anode chamber while the cathode suspended in water present in the cathode chamber.A copper wire was connected across the anode and cathode by which electrons travel from anode chamber to cathode chamberand recognized by an electron acceptor in the cathode chamber, where they condense oxygen[15]. Open circuit voltage analysis of the redox process between anode and cathode was 0.7V to 0.8V[16]. Figure1 show schematic detail of sediment microbial fuel cell. The most impartment components in the microbial fuel cell are the anode and cathode which affect internal resistance, microbial connection, electron transference and amount of electrode surface reactions[17]. Different electrode materials have different physical and chemical properties so these effects vary withelectrode materials used.The aim of this research works to generate maximum voltage by SMFC using different electrode material. In this paper, observed copper anode and zinc cathode generate a higher voltage in compare to graphite rod anode and zinc cathode electrodes.

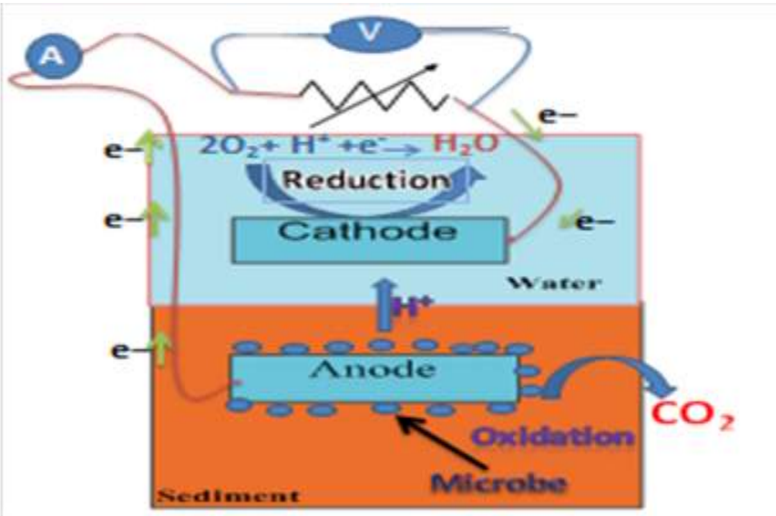

Figure 1:- Schematic details of sediment microbial fuel cell.

2:- Materials and methods

2.1:- Raw Materials

SMFC was developed by collecting electrolyte material as sediment from Ganga river of Phaphamau, Allahabad, U.P, India. SMFC was reserved at room temperature 28^0Cfor the whole experiment. This experiment was performed in the electrical laboratory at Department of Electrical Engineering, MNNIT Allahabad, UP, India for 30 days.

2.2:- Sediment microbial fuel cells assembly

SMFCs were constructed in twocylindrical plastic bottles (1000mL) for this experiment and sediment used as electrolyte both SMFCs. Zinc cathode andthe copper anode ware used for sediment microbial fuel cell (SMFC1) and Zinc cathode, graphite rod anode was used for sediment microbial fuel cell (SMFC2). Figure 2 shows the photo ofSMFC1 and SMFC2 which are used in thelaboratory for this experiment. Copper (7.5cm height, 2.5cm width and 2mm thickness) as anode and Zinc plate (7.5cm ×2.5cm × 2mm,height,widthand thickness) as cathode ware used in SMFC1 shown in figure 3. Zinc plate (7.5cm × 2.5cm × 2mm,height, width and thickness) as cathode and graphite rod (10cm height and 350mm thickness) as anode ware used in SMFC2 shown in figure 4. Sediment was placed in half of the cylindrical plastic bottle and the other halfoccupied with water in both the SMFCs.About 600gram of the electrolyte was used and sealed with a plastic cap to simulate an anaerobic conditionin both SMFCs. Zinc cathode washold in the water and the copper anode was employed into the soilof SMFC1. Graphite rod anode wasemployed into sediment and zinc cathode washold in the water column of SMFC2. Anode and cathode wereattached by a copper wire ($1.5mm^2$) withan external load. Neither the anode nor cathode material participates in electrochemical reactions. As a result; neither the anode nor cathode material was consumed in SMFCs operation. So anode and cathode material sustained for a long time in the substrate.

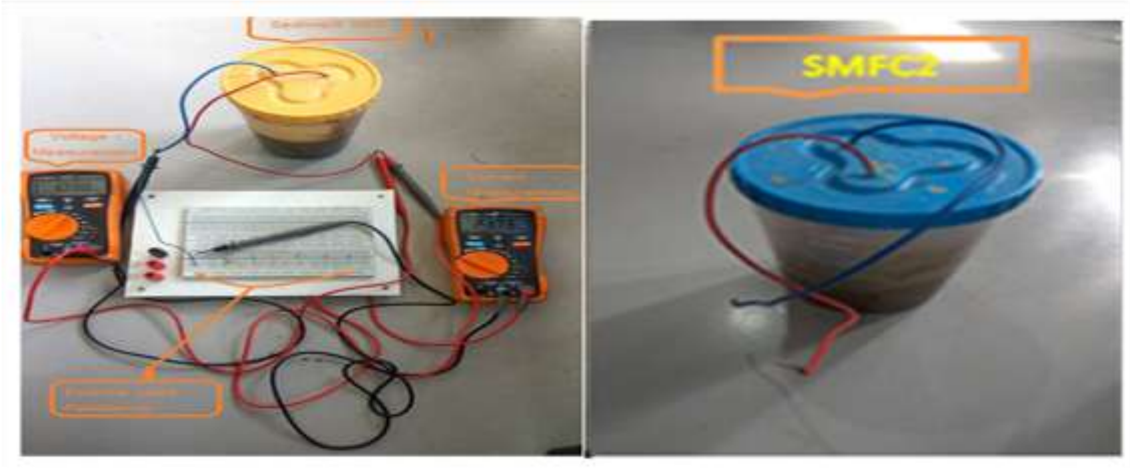

Figure 2:- Experimental setup of SMFC1 and SMFC2.

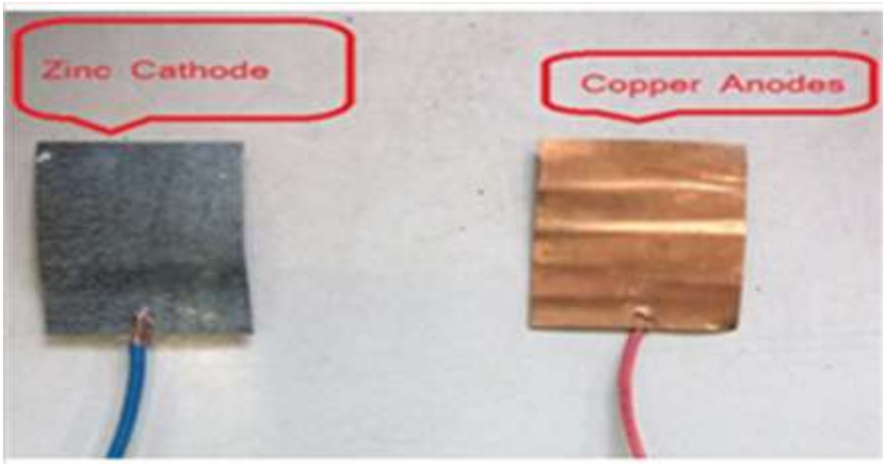

Figure 3:-Copper anode and zinc cathode used in SMFC1.

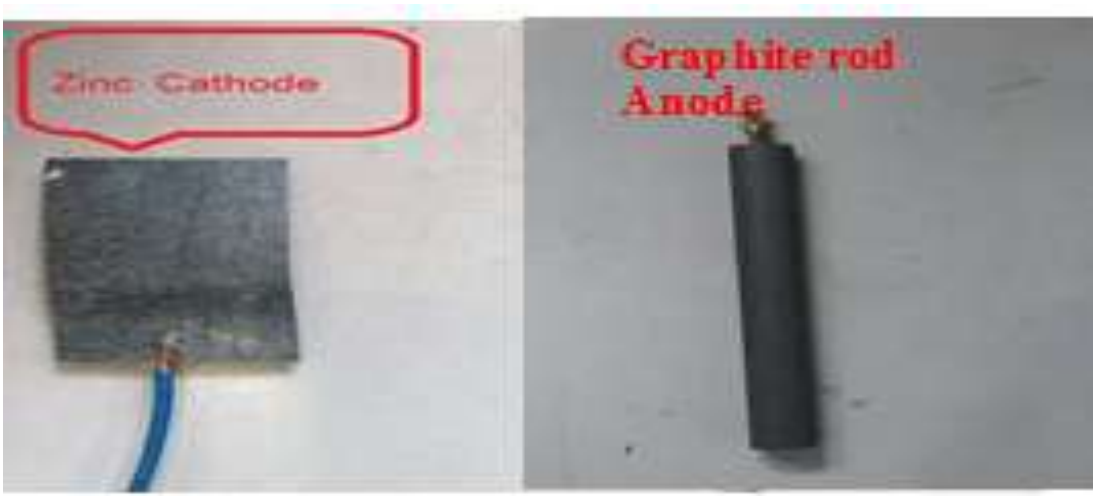

Figure 4:-Graphite rod anode and zinc cathode used in SMFC2.

2.3:- Electrical measurement and analysis

Digital multi-meters (Agilent U1232A)are connected for measurement the voltage and current at a specific time. The power output was calculated by measuring voltage and current the across load resistor. Experimentally, inthe direction offinding the polarization curve by manipulating the load resistance was changed from 47Ω, to 147Ω, to 214Ω, to 327Ω, to 475Ω, to 687Ω, to 735Ω, to 835Ω and 987Ω manually.The digital multi-meterswere connected to SMFC through anode and cathode shown in Figure 1.

The voltage (V_O) and current (I_O)of the SMFCs recorded voltage every 60 secby varying external resistance (R_o). Where, voltage (V_O) measured in$V$ andcurrent (I_O)in mA.

Power (P_{ou}) was calculated[18]by $P_{ou} = I_o \times V_o$, Where P_{ou} measured in mW. The current density was deliberate as $I_{de} = I_o/A$, where A signifies anode projected surface area in cm^2 and current density I_{de} in $mA.m^{-2}$. Power density P_{de} is the division of power and projected surface area of anode and P_{de} was measured in$mW.m^{-2}$. In this experiment projected anode surface area was 0.339m^2 which used to estimate current density and power density for both SMFCs.

3:- Experimental results and discussion

3.1:- SMFC Start- up and Operation

Copper and graphite were used as anodes with only zinc as cathode material in the SMFCs. Choice of Electrode material is so important that figure out the performance of SMFC as various material generated different electrical energy and potential.A multitude of organics are present in sediment electrolyte which is responsible for power generation and the voltage was observed in this experiment for 30 days both SMFCs shown in Figure 5.In the 30 days observation, we find that maximum energy harvested from using zinc cathode and copper anode in thecompare to zinc cathode and the graphite anode. Voltage is continuously increased for first some days due to chemical reaction inspirer to the microbial growth taking effectin the electron and proton production and after some days a steady state voltage was obtained. This behavior of SMFCs was altered from other commercial cells. At beginning day, open circuit voltage of SMFC1 and SMFC2 was measured as 0.644V was 6.34V respectively. Power generation of both SMFCscontinuouslyincreaseand next some days a study state voltage 1.160V and 0.931V was found SMFC1 and SMFC2 respectively. Both SMFCs ware generate different power due to having different electrode properties. Copper has standard electrode potential (Eo) value which is higher than Zinc with +0.337 V and -0.763 V respectively that means copper and zinc electrode materialcan generate the maximum electrical voltage.

S.S.Uddin et al. (2016) examined duel chamber microbial fuel cell 5.78 mili-amperes and 6.046 mili-watts were obtained using copper sulphate as the electron acceptor and 1.515 mili-amperes and 1.944 mili-watts were obtained using potassium permanganate as electron acceptor[19]. In this research, maximum generated open circuit voltage and current of SMFC1 was 1.160V and 0.301mA with SMFC1. Maximum generated open circuit voltage and the current was 0.931V and 0.201mA with SMFC2. Maximum power generated by SMFC2 and SMFC2 ware 3.491mW and 2.991mW respectively for steady state operating condition.

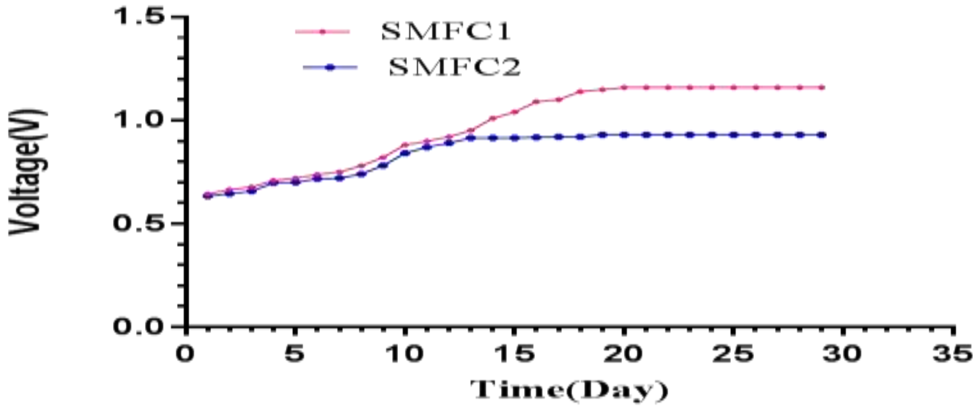

Figure 5:- Obtained voltage of SMFC1 and SMFC2.

3.2:- Polarization curves for SMFC

Polarization curves explain the electrical performance of microbial fuel cell. Polarization curves of sediment microbial fuel cell with copper anode and zinc cathode (SMFC1) shown in Figure 6. Polarization curves of sediment microbial fuel cell with the graphite anode and zinc cathode (SMFC2) shown in Figure 7. When the cell reached the first stable current densityvs. voltage Characteristics and current densityvs. power density characteristics were obtained in lab experiments by changing the load resistance. The maximum current density was obtained 8.871mA.m^{-2} for the steady phase in SMFC1. As shown in Figure 6, by increasing the resistance, the output current decreased. The polarization curve drowns by calculating the current density and power density at various resistances (47Ω-987Ω). The current was monitoring by changing the load resistance whenSMFCsachieved the peak voltage.

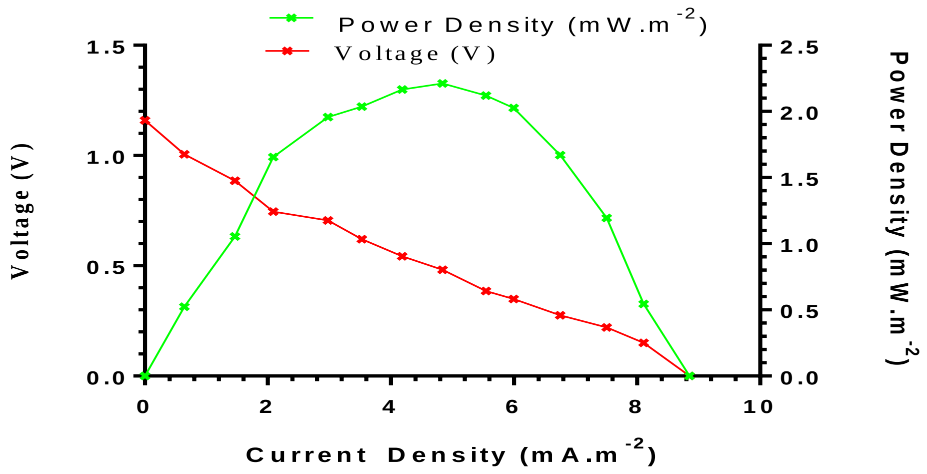

Figure 6:- Polarization curve of SMFC1.

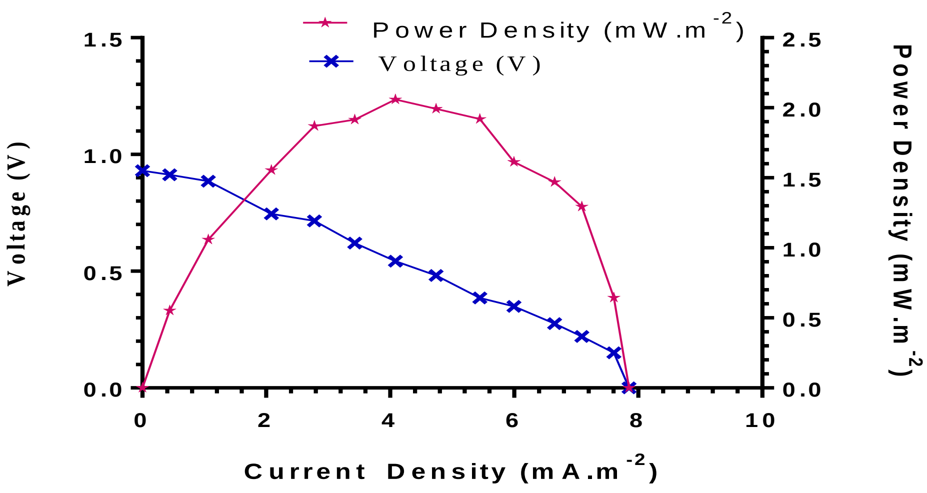

Figure 7:- Polarization curve of SMFC2.

A typical polarization power curvesare shownin figure 6 and figure 7 that were drown by the experimental data. The curve wasshowed a maximum power density 2.36mW.m^{-2}at current density 4.185mA.m^{-2}in SMFC1 and 2.070mW.m^{-2} at current density 3.427mA.m^{-2} in SMFC2. Voltage is continuously falling with growing in current density and power density first rises then falls, which are typical behavior of microbial fuel cell. Power density 0.644mW.m^{-2} and 0.540mW.m^{-2} was examined at higher resistance 987Ω for SMFC1 and SMFC2 respectively. In this experiment, we observed that SMFC1 shows best electrical characteristic as compared to SMFC2.our study important to use of sediment microbial fuel cell energy harvesting. In the future, I will design boost converter for such low voltage sediment microbial fuel cells.

Table I shows the maximum voltage generation from sediment microbial fuel cell using different electrode material. The different researcher was developed SMFCs using different electrode material and examined the voltage for a long time. In this work, voltage generates by using copper anode and zinc cathode which is maximum in compression to other researchers SMFCs technology.

Table I. Maximum voltage generation from SMFCwith different electrode material.

Anode	Cathode	Open circuit voltage (V)	Operation Time(days)	Reference
Graphite anode	Carbon fiber	0.400	120	[20]
Graphite fiber	Graphite fiber	0.664	60	[21]
Carbon felt	Carbon felt	0.158	6	[22]
Graphite felt	Iron	0.431	70	[23]
Iron	Graphite felt	0.645	70	[23]
Carbon cloth	Carbon cloth	0.250	35	[24]
Copper	Zinc	1.160	30	This work
Graphite	Zinc	0.931	30	

4: Conclusion

Sediment microbial fuel cell is showing the future renewable energy source. The present study verified the performance of SMFC for different electron acceptor. This mediator-less SMFCs with the copper anode and zinc cathode generate higher output power and cheaper microbial fuel cell in compression to membrane microbial fuel cell. In this research, bioelectricity was positively produced from sediment in the field of SMFC innovation. The copper anode and zinc cathode generate maximum power and stable for a long time. This SMFC was eco-friendly and cost-effective due to the utilization of sediment as a substrate which is obtained free from nature. SMFC can be utilized as a sustainable power source for powering electronic devices, remote environmental observing and led lighting etc.

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