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COMPARATIVE STUDIES ON DIFFERENT ELECTRODES TO IMPROVE PERFORMANCE OF MICROBIAL FUEL CELLS (MFC)

Shakunthala C[1], Dr.Surekha Manoj[2]
[1]Research Scholar, Department of Electrical & Electronics Engineering
VidyaVikas Institute of Engineering and Technology, Mysuru-570028, Karnataka, India

[2]Professor and Head, Department of Electrical & Electronics Engineering
VidyaVikas Institute of Engineering and Technology, Mysuru-570028, Karnataka, India

Abstract
The main objective of this paper is to study the performance of the various combinations of electrodes for soil and cow dung slurry substrates which plays an important role in the Microbial Fuel Cells (MFC) for the generation of electricity. The present work is an experimentalstudy concerned with selection of the electrodes for the best performance of an MFC. The various combinations of anode/cathode materials like copper, zinc, aluminium, for MFCs has been systematically studied along with different substrate like cow dung, soil, and out of which Al/Al and Cu/Zngave higher voltage output.
Keywords: Microbial fuel cell (MFC); Membranes, Mediators, Substrate, Electrodes.

1. INTRODUCTION
Recently, the world is facing energy crisis for non-renewable resources and hence, there is a scope of searching for high efficient energy transformations and way to utilize the alternate energy sources.Fuel cells are one of the promising technologies in the research. Among electrochemical cells, MFCs are special types of biofuel cells, producing electric power by utilizing microorganisms.Microbial Fuel Cell (MFC) has great interest as a future unconventional energy production where employ microbes to generate electricity from biological reaction of organic and inorganic substances [1]. These materials are converted into electricity in the anode of MFC by microbial metabolic activity[2]. Single Chambered Microbial Fuel Cell (SC-MFC) has an anodic chamber which is linked to a porous air exposed cathode separated by a gas diffusion layer or a Proton Exchange Membrane (PEM). Electrons are transferred to porous cathode to complete circuit. Limited requirement of periodic recharging with an oxidative media and aeration makes SC-MFC system more versatile.
The anode electrode of SC-MFC is important in attempt to determine the efficient microorganisms, those can offer the highest rate of oxidation or able to extract the highest number of electron rate per plant of the substrate [3],study the effectiveness of mediators [4], select more effective electrode materials [5], determine the most efficient anodic reactions, those producing the highest number of electron rate per unit weight of the reactant [6]. Specific bacteria, including Geobacteraceae, were enriched on the anode where organic matter was oxidized and electrons were directly transferred to the anode under anaerobic conditions [7]. Bacteria capable of electricity generation from advanceddomestic wastewater [8], ocean sediments [7], animal wastes [9], and anaerobic sewage sludge [10]. Several factors affect MFC performance including the microbial inoculum, chemical substrate (fuel), electrode materials, cell internal and external resistance, solution ionic strength, and electrode spacing, type of proton exchange material [11].
In anode chamber, decomposition of organic substrates by microorganisms generates electrons (e-) and protons (H+) that are transferred to cathode through proper circuit and membrane, respectively. Organic substrates are utilized by microbes as energy sources; outcome of this process is the release of high-energy electrons that are transferred to electron acceptors. However, in anaerobic condition due to the absence of such electron acceptor in the anodic chamber of MFC, microorganisms shuttle electron onto the anode surface. As a result, the electrons will transfer through the external circuit, which results on the generation of electric power [12]. There are two main steps involved in power generation. In the first step, organic matter will be degraded in the absence of oxygen i.e., removal of electrons from organic matter (oxidation) in anodic chamber; in the second step, transferring of electrons to the electron acceptor, such as oxygen present in the cathodic chamber. In anaerobic condition certain bacteria can transfer electrons to a carbon electrode (anode). The electrons then move across a conductor at a specific resistance (resistor) to the cathode, where they combine with protons and oxygen to form water. Further, these electrons flow from anode to the cathode, which induces current and voltage to produce electricity. Bacteria are used in MFC to generate electricity while achieving

biodegradation of organic matters present in the wastewaters. Biodegradable organic rich waters (municipal solid waste, industrial and agriculture wastewaters) are ideal as a sustainable energy sources for the generation of electricity [12].

One of the limiting factors to use MFC is the high cost of materials which are used in the construction of MFC such as electrodes and proton exchange membrane which is nafion membrane so attempts are made to replace these costly membranes with the low cost earthen pots, cheaper stainless steel mesh as a cathode material and graphite plate as anode [13]. Microbial fuel cell is an ideal way of producing electricity as it uses renewable source as a substrate and treats the waste [12].

In this study various combinations of electrodes were used for the best performance of an MFC using cow-dung and soil as a substrate.

2.MATERIALS AND METHODS:

2.1 Model 1: Soil based MFC

The principle on which bacteria can generate electricity in soil is nothing but the soil bacteria eat what is in the soil, such as microscopic nutrients and sugars, and in turn produce electrons by its respiration metabolism that are released back to soil. Electrons are sub automatic particles that have a negative electric charge. These electrons can be harnessed and can be used to generate electricity.

Single Chambered Microbial Fuel Cell (SC-MFC) was constructed using a plastic container approximately 5lt capacity containing aluminium electrode for both anode and cathode have the thickness of 18mm. 30mm thickness copper wire is used for connection. In 5lt capacity of small containerfilled the soil till 5cm from bottom level and then placed the aluminium electrode (which acts as anode). After placing this electrode again filled the soil till 19cm from bottom level and then placed another aluminium electrode (which acts as cathode). Solder the wire to both electrodes before placing them suitably such that the wires should be externally available. The experimental model is as shown in Fig 1.

Fig 1: Model of soil based MFC

2.2 Model 2:Cow Dung Based MFC

MFC can use microbes from the cow dung to generate electricity. These bacteria, known as electrogenicbacteria include bacillus,cornynebacterium, actobacillus, streptococcus, pseudomonas, Nacordia, Mucor, and rhizopus.The principle on which bacteria can generate electricity in biomass (cow dung) ,i.e. bacteria present in cow dung consumes microscopic nutrients and sugars, and in turn produce electrons by its respiration metabolism that are released back to biomass content. Electrons are sub automatic particles that have a negative electric charge. These electrons can be harnessed and can be used to generate electricity.

Single Chambered Microbial Fuel Cell (SC-MFC) was constructed using a plastic container approximately 6lt capacity containing aluminium electrode for both anode and cathode have the thickness of 18mm. 30mm thickness copper wire is used for connection. In 6lt capacity of small container filled the soil till 6cm from bottom level and then placed the copper electrode (which acts as anode). After placing this electrode again fill the soil till 21cm from bottom level and then placed aluminium electrode (which acts as cathode). Solder the wire to both electrodes before placing them suitably such that the wires should be externally available. The experimental model is as shown in figure 2.

Fig 2: Model of Cow dung based MFC

Community of electricity generating microbes will develop on surface of anode in a matter of days. These bacteria have unique metabolic abilities which enable them for respiration the sugar and nutrients within the soil and cow dung and deposit electrons on to the anode as a part of the natural metabolism. Protons and carbon dioxide are released into soil and cow dung as a metabolic by product and diffused towards cathode. Once the electrons' are transferred to the anode then theses' electrons travels through connecting wires through the soil and cow dung based MFC circuitry to the cathode. While electron passing through the circuitry the current which is produced measure in a multi-meter giving a visible indication that the microbes are healthy. At the cathode the electrons interacts with oxygen in air as well as proton which is coming from the anode to form water. The carbon dioxide originating from the anode is released into the air and this cycle continues till the nutrients get depleted.

The same experiment is repeated using same SC-MFC for set of electrodes like Cu/Cu, Zn/Zn, Cu/Al and Cu/Zn for soil based MFC and Al/Al, Cu/Cu, Zn/Zn and Cu/Zn for cow dung based MFC.

3. RESULTS AND DISCUSSION

Cow dung has high concentration of organic matter and other trace elements which are required for growth of mixed culture of organisms. It contains around 60 species of bacteria some of them are bacillus, cornynebacterium, lactobacillus, streptococcus, pseudomonas, Nacordia, Mucor, and rhizopus. After 14 days there is a sudden decrease in voltage probably due to combined effect of depletion of nutrients, interaction and release of toxins from other species (Figure - 2). As shown in figure - 3, four combinations of electrodes i.e., Cu/Zn, Al/SS, C/C, and SS/SS, gave the higher voltage compared to other combination of electrodes which we have studied. From the above observations (Figure – 4) 4 high voltage producing combination of electrodes

were selected and these showed initially a high voltage and gradually decreased to zero because of depletion in nutrients and interaction in mixed cultures by producing some sort of toxins which may prevent the growth of microbes responsible for electron generation. From this study Cu/Zn was selected as the most efficient and consistent electrode and will be used in our further studies which is on modifications of the electrode surface

Microbial fuel cell (MFC) can generate electrical energy through the metabolic activity of the bacteria. The system is able to transform chemical energy into electrical energy. The amount of electrical energy generated is determined by the level of activity of microorganisms in generating electrons and protons.

In India we will get the nutritious soil in all agriculture fields and in rural areas. In India about 40-45% we have nutritious land so with the use of this nutritious, soil as technology proposed by M.Potter we would able to generate power with the help of soil. This is also termed as mud watt. So with this ideology we conducted various experiments on soil based MFC and the result and discussion is as below.

The relationship between voltage and duration of the observation of the resulting electricity of various modeling that we executed are shown below.

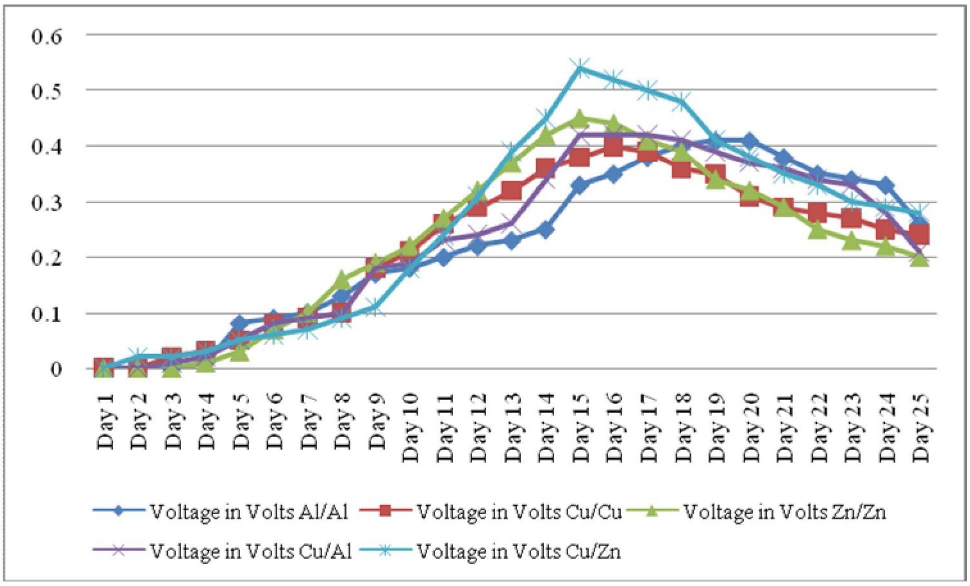

Fig 4: Generation of Voltage for Soil Based MFC before addition of Glucose

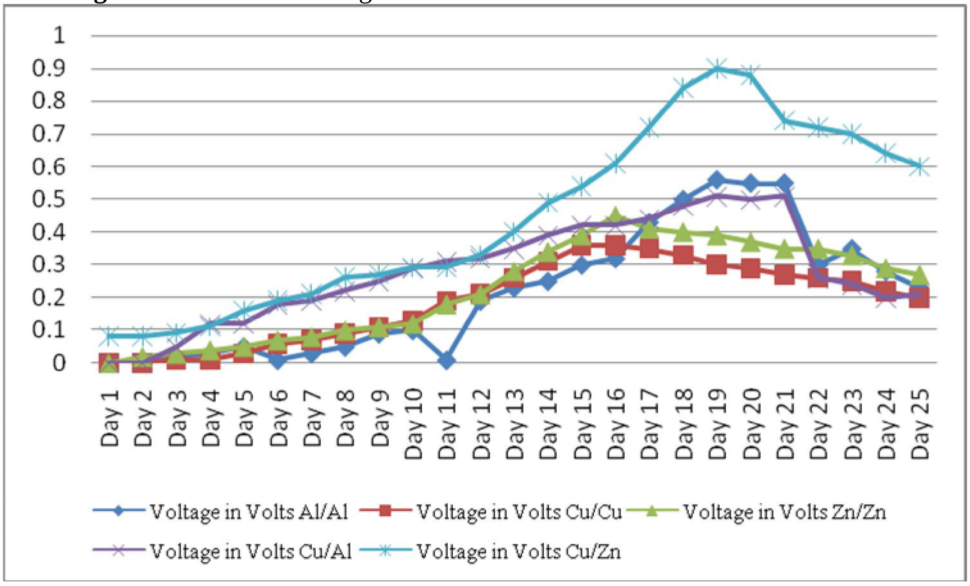

Fig 5: Generation of Voltage for Soil Based MFC after addition of Nutrients

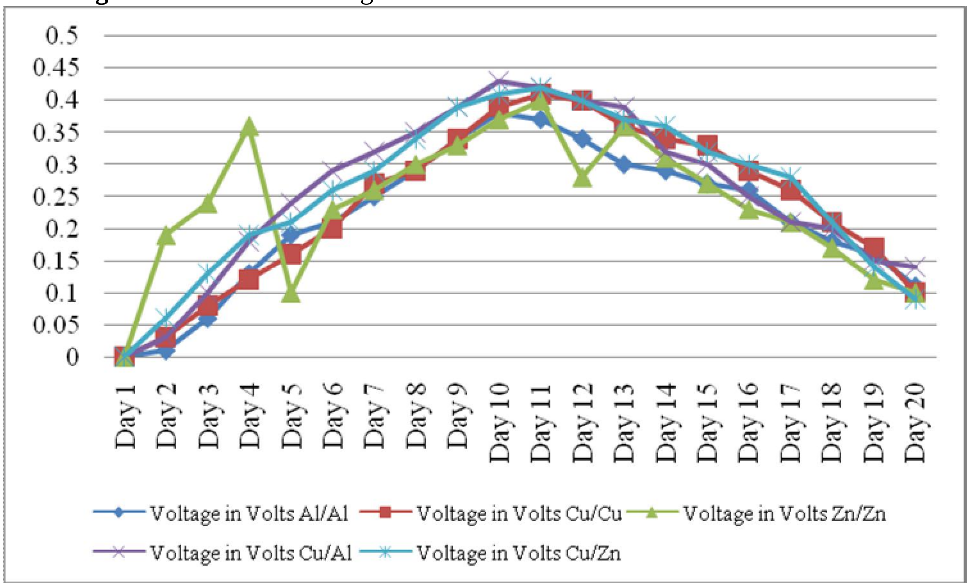

Fig 6: Generation of Voltage for Cow dung Based MFC before addition of Nutrients

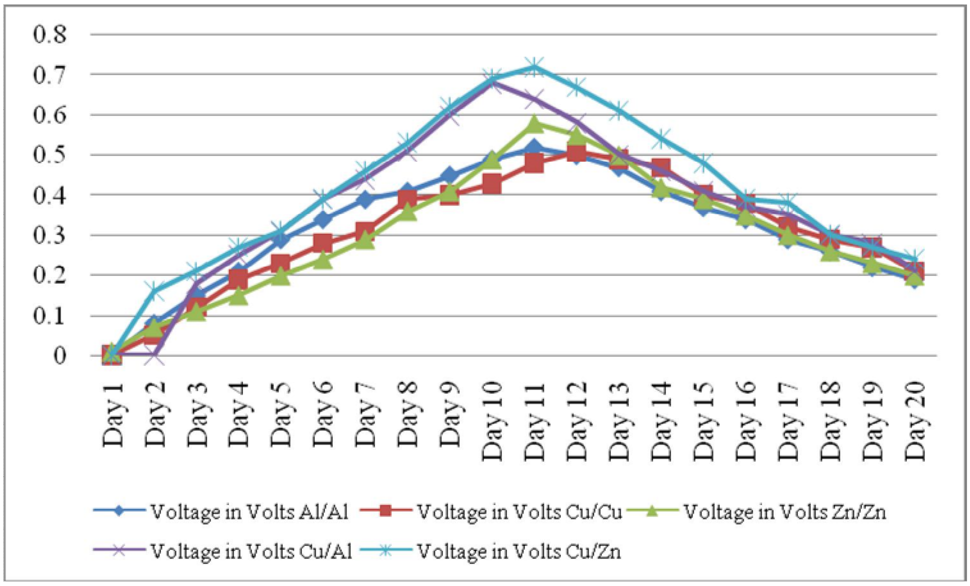

Fig 7: Generation of Voltage for Cow Dung Based MFC After addition of Nutrients

As per experimental results, soil based SC-MFC is one of the best modelsafter addition of nutrients with best results. From experimental study on soil based SC-MFC, the voltage is improved for Al/Al electrode as days increased to 0.56Vi.e. on 19th day after that it starts decreasing is as shown in figure 5. After 16, 15, 17, 15 days there is a sudden decrease in voltage for Cu/Cu, Zn/Zn, Cu/Al, Cu/Zn electrode set respectively, probably due to combined effect of depletion of nutrients, interaction and release of toxins from other species as shown in figure 5.Out of five combinations of electrodes i.e. Al/Al, Cu/Al and Cu/Zn gave the higher voltage compared to other set of electrodes which is studied. Figure 4 shows that results of soil based SC-MFC before addition of nutrients. In that maximum generated voltage for Al/Al, Cu/Cu, Zn/Zn, Cu/Al and Cu/Zn is 0.41V, 0.4V, 0.45V, 0.42V and 0.54V respectively after that it start decreasing. For this model using Zn/Zn and Cu/Zn as anode and cathode can get maximum voltage. Form this study for soil based SC-MFC Cu/Zn was selected as the most efficient and reliable electrode for both before and after addition of nutrients and will be used in further studies which is on modifications of the electrode surface to enhance the generated voltage. From this study it is observed that as electrode spacing increases, voltage production varies.

Cow dung has high concentration of organic matter and other trace elements which are required for growth of mixed culture of organisms. It contains around 60 species of bacteria some of them are bacillus, cornynebacterium, lactobacillus, streptococcus, pseudomonas, Nacordia, Mucor, and rhizopus. After 11 days there is a sudden decrease in voltage probably due to combined effect of depletion of nutrients, interaction and release of toxins from other species.

Figure 2 shows 50% dilution of normal cow dung was used for studies in the SC-MFC for same set of electrodes like Al/Al, Cu/Cu, Zn/Zn, Cu/Al, and Cu/Zn. The maximum voltage form these set of electrodes is 0.72V for Cu/Zn electrode after addition of nutrients improved output voltage was recorded and is as shown in figure 6. When glucose is added to experimental set up, it gives carbohydrates and nutrients to bacteria for their respiration process in which metabolism takes place giving protons and electrons from which improved voltage can be obtained. But 0.42V for before addition of nutrients to Cu/Zn electrode set was recorded and is as shown in figure 7.

4. CONCLUSION

The present study establishes the usage of soil and cow dung as the organic fuel for different set of electrodes like Al/Al, Cu/Cu, Zn/Zn, Cu/Al, and Cu/Zn and its bacteria as biocatalyst for the production of bioelectricity. Soil based MFC gave the best results, since the soil has high concentration of organic matter and other trace elements after addition of glucose which are required for growth of mixed culture of organisms. The different combinations of electrodes were used and found that Cu/Zn gave the best and reliable results for both soil and cow dung based MFC. It demonstrated that different electrodes exhibited different behaviours. From the perspective of current development, the exploration of electrode materials will be more important and attractive as a reasonable price and excellent performance will greatly expand the application of MFCs. The study also recommends the further tuning of the technology for the better usage of the waste towards the commercial utilization for the generation of alternate energy to sustain the demand of future.

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