

## Electricity Generation from Mediator-Less MFC with Consortia of Carbon-Zinc Electrodes and CNT Doped PEM

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### Abstract:

Microbial fuel cell is an applied aspect of microbes, i.e., using bacteria to generate electricity. It uses carbon source like sugars or any other organic waste. Bacteria like *E. coli*, *Pseudomonas methanica*, *Pseudomonas fluorescence*, *Pseudomonas putida*, *Proteus vulgaris*, *Bacillus subtilis* and many more that lives at anode are able to consume sugars under anaerobic conditions. They then release protons while depositing electrons externally on anode. Electrons and protons combine with an oxidant at cathode. In this process electricity is generated with carbon dioxide and other useful by products. Apparatus containing two electrodes viz. Carbon and Zinc electrodes, carbon nanotube doped proton exchange membrane and multi-meter for visualization of results by using *E. coli* culture was used. Microbial fuel cell was allowed to stand for three days, with the increase in incubation period the output voltage increases from nil to 1.23V. And on successive incubation the decline in the output was detected. Utmost voltage output recovered was 1.23V whereas the current being 8.04-8.08mA on the third day of incubation. With the increase in incubation it can be interpreted as some of the factor becoming limiting for further increment in the voltage was hindered. Recent research is based upon the increasing efficacy of microbes to produce electricity with enhancing production at commercial scale. Since it is a rechargeable approach it can be recharged by changing its culture media. Since it does not have any moving mechanical part, it can be used in remote areas as power supplement with no noise pollution as such.

### Introduction:

Some of the reduced fermentation products or microbially reduced artificial mediators can abiotically react with electrodes to yield a small electrical current. This type of metabolism does not typically result in an efficient conversion of organic compounds to electricity because only some

metabolic end products will react with electrodes, and the microorganisms only incompletely oxidize their organic fuels. A new form of microbial respiration has recently been discovered in which microorganisms conserve energy to support growth by oxidizing organic compounds to carbon dioxide with direct quantitative electron transfer to electrodes. These organisms, termed electricigens, offer the possibility of efficiently converting organic compounds into electricity in self-sustaining systems with long-term stability<sup>[1]</sup>. Haacke and Klein have shown that electrical currents in plants are essentially a manifestation of vital phenomena, and that differences in electric potential are connected both with respiration and carbon assimilation<sup>[2]</sup>.

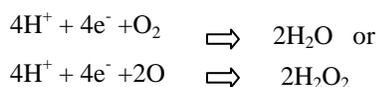
The idea of using microbial cells in an attempt to produce electricity was first conceived at the turn of the nineteenth century. M.C. Potter (1911) was the first to perform work on the subject in 1911<sup>[8]</sup>. Potter managed to generate electricity from *E. coli*, but the work was not to receive any major coverage. In 1931, however, Barnet Cohen drew more attention to the area when he created a number of microbial half fuel cells that, when connected in series, were capable of producing over 35 volts, though only with a current of 2 milliamps.

Carbon nanotubes (CNTs) have recently emerged as the wonder materials of the new century and are being considered for a whole host of applications ranging from large scale structures in automobiles to nanometer scale electronics. This includes significant features of electrical transport, which impact interpretation of measurements and suitability in advanced electronics.

The aim of this review is to study for the generation of good amount of electricity by the use of complete anaerobic chamber and CNT-doped polycarbonate proton exchange membrane as this would allow more efficient electron transfer and better current yield.

### Materials and Methods:

A microbial fuel cell (MFC) is a device that converts chemical energy with the aid of the catalytic reaction of microorganism. An MFC consists of anode and cathode separated by a proton exchange membrane or a salt bridge for the connection between the two compartments. In the anode compartment of an MFC microorganisms oxidize fuel (substrate) generating electrons and protons. The proton and electrons are transferred to the cathode compartment, the protons through the membrane or the salt bridge and the electrons through the external circuit. They are consumed reducing oxidant at the cathode, usually oxygen supplied by aeration;



Electrons may or may not be transferred from the normal microbial electron transport systems to the electrode due to the non-conductive nature of the cell surface structure. Electrochemical mediators were employed to render electrode. The mediators are usually toxic phenolic compounds. Therefore, the long-term operation of mediated MFCs cannot be achieved with limited commercial applications although MFCs can be used for various purposes including biosensors and electricity generation.

Previous studies showed that an MFC could be operated without mediators using an electrochemically active bacteria to transfer electrons to the electrode (electrons are carried directly from the bacterial respiratory enzyme to the electrode).

The bacterial cells in the anode of MFC consumed substrate as they transferred electrons directly to the electrode. In the subsequent studies it has been shown that electrochemically active microbes can be enriched using a fuel cell type electrochemical cell. Several steps have been identified as the limiting steps on a mediator-less MFC. They are fuel oxidation at anode, electron transfer from microbial cells to anode, resistance of the circuit, proton transfer through the membrane and oxygen reduction at the cathode.

The aim of this review, in addition to enumerating the electrical properties of CNT derived structures, is to encourage the integration of a diverse set of

electrical phenomena into a multifunctional CNT based device. As large scale assembly of CNT's is impressive and would be challenging to the system of device to encourage more power production with less of substrates.

In a mediator-less MFC, as in other MFCs, the membrane separates the anode from the cathode and the membrane functions as an electrolyte that plays the role of an electronic insulator and allows protons to move through. These functions of the membrane are believed to be indispensable in the operation of an MFC.

In this study attempts were made to develop a mediator-less MFC with using a CNT-doped membrane. Membranes are the most characteristic and functional part for the construction of an MFC.

**Fig 1: Microbial Fuel cell**



Apparatus showing two divided chambers, a carbon and a zinc electrode, on left side it is a CNT- doped proton exchange membrane. The apparatus is anaerobic with the facility of both inlet and outlet.

### Construction of Microbial fuel cell:

Microbial fuel cell works on the capacity of micro organisms to convert carbohydrate substrate into microbe specific by-products and simultaneously producing electrons which help in electricity production. MFC consists of two different chambers Namely – Anodic chamber and Cathodic chamber Both the chambers in previous review were partitioned by a salt bridge consisting of agar-agar and kitchen salt. But now, for better efficiency and

better output current two approaches are followed: The first being the use of poly carbonate proton exchange membrane doped [Fig.1] with Carbon Nanotubes but as these being very delicate and soft, second approach is the use of fibre proton exchange membrane doped with Carbon Nanotubes, these

**Results and Discussion:**

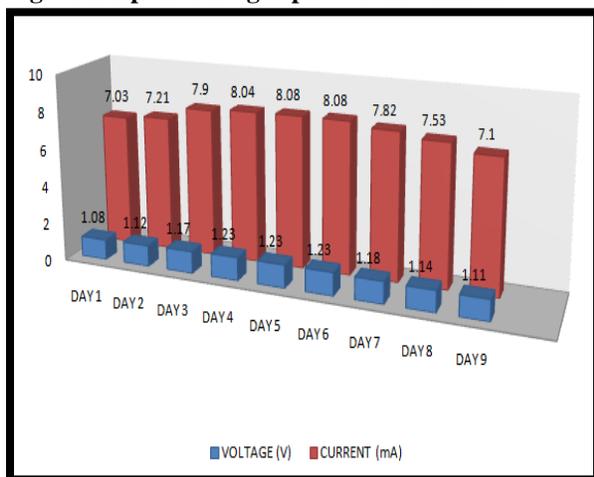
Present study carried out using bacterial cell suspension culture growing in nutrient medium containing substrate, supersaturated solution of electrolyte in cathodic chamber and seperated by CNT-proton exchange membrane. With the use of CNT-proton exchange membrane, carbon and zinc electrodes and no mediator as well with *E. coli* bacteria an output of maximum of 1.23 volts and current being maximum of 8.08 milliamperes was received.

**Table 1: Observations:**

OBSERVING DAY	VOLTAGE (V)	CURRENT (mA)
DAY 1	1.08	7.03
DAY 2	1.12	7.21
DAY 3	1.17	7.90
DAY 4	1.23	8.04
DAY 5	1.23	8.08
DAY 6	1.23	8.08
DAY 7	1.18	7.82
DAY 8	1.14	7.53
DAY 9	1.11	7.10

The table above shows the number of experimental days, the voltage and the current obtained.

**Fig. 2: Graph showing experimental results.**



having much more strength and little tough. From the anodic half consisting of bacteria and their substrates (in anaerobic conditions) electrons flow to cathodic chamber (aerobic conditions) consisting of the electrolytic solution through an external electrical connection maintained by the wires.

The graph is showing the output voltage and current (mA) obtained during the course of experiment.

Results of previous studies conducted with an MFC equipped with agar salt-bridge, carbon rods with no mediator and using *E.coli* and *Pseudomonas fluorescense* were as follows.

A carbon nanotube (CNT)/polyaniline (PANI) composite is evaluated as an anode material for high-power microbial fuel cells (MFCs). Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) are employed to characterize the chemical composition and morphology of plain PANI and the CNT/PANI composite. The electrocatalytic behaviour of the composite anode is investigated by means of electrochemical impedance spectroscopy (EIS) and discharge experiments. The current generation profile and constant current discharge curves of anodes made from plain PANI, 1 wt.% and 20 wt.% CNT in CNT–PANI composites reveal that the performance of the composite anodes is superior. The 20 wt.% CNT composite anode has the highest electrochemical activity and its maximum power density is 42 mW m<sup>-2</sup> with *Escherichia coli* as the microbial catalyst. In comparison with the reported performance of different anodes used in *E. coli*-based MFCs, the CNT/PANI composite anode is excellent and is promising for MFC applications<sup>[12]</sup>.

Microbial fuel cells (MFCs) are devices that exploit microbial catabolic activities to generate electricity from a variety of materials, including complex organic waste and renewable biomass. These sources provide MFCs with a great advantage over chemical fuel cells that can utilize only purified reactive fuels (e.g., hydrogen). A developing primary application of MFCs is its use in the production of sustainable bioenergy, e.g., organic waste treatment coupled with electricity generation, although further technical developments are necessary for its practical use. In this article, recent advances in MFC technologies that can become fundamentals for future practical MFC developments are summarized. Results of recent studies suggest that MFCs will be of practical use in the near future and will become a preferred option among sustainable bioenergy processes<sup>[11]</sup>.

Microbial fuel cells (MFCs) are typically designed as a two-chamber system with the bacteria in the anode chamber separated from the cathode chamber by a polymeric proton exchange membrane (PEM). Most MFCs use aqueous cathodes where water is bubbled with air to provide dissolved oxygen to electrode. To increase energy output and reduce the cost of MFCs, we examined power generation in an air-cathode MFC containing carbon electrodes in the presence and absence of a polymeric proton exchange membrane (PEM). Bacteria present in domestic wastewater were used as the biocatalyst, and glucose and wastewater were tested as substrates. Power density was found to be much greater than typically reported for aqueous-cathode MFCs, reaching a maximum of  $262 \pm 10 \text{ mW/m}^2$  ( $6.6 \pm 0.3 \text{ mW/L}$ ; liquid volume) using glucose<sup>[6]</sup>.

**Table 2:** Microbes showing voltage output by using substrate with specific electrodes.

The above table is showing different microbes with using dextrose as substrate and the different voltage outputs obtained.

Microbes	Substrate	Mediator	Anode	Voltage
<i>E. coli</i>	Dextrose	-	Carbon rod	0.40 V
<i>Pseudomonas fluorescense</i>	Dextrose	-	Carbon rod	0.32V
<i>E. coli</i> + <i>P. fluorescense</i>	Dextrose	-	Carbon rod	0.54 V

So, this is kind of a novel approach to generate rechargeable electricity through live cell preparation that serves as a new dimension for the future as an alternate of energy. An identification of specific group of microbial cell lines that may offer optimal quantum of energy that can be further employed is required.

**Conclusion:**

Microbial fuel is different from that of better known conventional cells as conventional cells requires expensive catalyst to promote oxidation of electron donors. They also cannot be operated at room temperatures and are highly explosive and toxic. Also

they have a complex and regulated distribution system whereas microbial fuel cells uses naturally occurring microbes to catalyze the oxidation of fuel, also can be operated at room temperature. As microbial fuel cells uses environment friendly microorganisms and there is no use of any toxic product and also no complex and regulated system exist, so microbial fuel cells are attractive power source in remote areas and besides only providing electricity also provides with other by-products like manure, biogas, etc. Also, there is no sound generation so no sound pollution as such. With Carbon Nanotubes an MFC works with better and much more efficiency with the same substrate and same micro-organism. So, with more development in the same, one can see the bright future especially with all villages getting lighted and kids studying under lamps.

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