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Graphene-based Microbial Fuel Cell Studies with Starch in sub-Himalayan Soils

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Abstract

Microbial fuel cells with graphene based cathode and anode is the study of interest. Present work shows the capacity of sub-himalayan soil of Dehradun region of Uttarakhand, India holds potential to cater to power production from soil and organic waste matter. This can be speculated to power less energy intensive devices at the smallest level. Peak voltage of 0.69 V and current density datas are reported.Renewable energy utilization with such samples represents a sustainable usage. The soil bacterias are capable to metabolize the metal substances in the soil through symbiosis. Electric bacteria create conductive pili called nanowires enabling them to transfer electron and this can be utilized effectively.Direct electron transfer mechanisms have been investigated for this work. The biofilm developed by soil bacterias represent the central idea in making value from waste matter.

Keywords: *fuel cell, soil microbes, graphene, organic wastes.*

1. Introduction

In a microbial fuel cell (MFC), microorganisms i.e. bacteria oxidize prganic matter, producing protons and electrons. Protons diffuse through the electrolyte towards the cathode and the electrons travel around a circuit, where a load is connected and into the cathode, producing the current. At the cathode, species such as oxygen reacts with the electrons and protons to form a reduced compound, such as water. Bacteria that can convert organic matter in the soil to electricity are mainly from the Proteobacteria phylum: Shewanella (Family: Shewanellaceae) and Geobacter (Family: Geobaceraceae). Shewanella appeared in a comic book as "Shewy, the Electric Bacterium" in educational kits that are available for students and hobbyists to understand how microbes contribute to charge density in the soil by giving out electrons after consuming organic matter from it [1].

This work is taken into account because it shows that the electrogenic bacterium which may add power to a microbial fuel cell exist in Uttarakhand i.e. Indian soil yet. Through our investigation we've opened a field of study that can focus on potentialities to experiment and collect additional knowledge regarding the soil within the mountain range ranges of Uttarakhand, the existing facility of the MFC are often hyperbolic by putting the MFC (stacked approach). Renewable and clean energy area units are one in every of society's greatest wants. The direct conversion of organic touch onelectricity exploitation bacteria is feasible in MFC; use of compost will be something that can be reviewed in other literatures such as the works of Barua et al [2]. Costly and poisonouschemicals weren't required for mediate electron transfer. Such technology has the likelihood to be used even for rural and concrete waste management which has cleanup of stream, production of electricity at the same time.

There is no writing accessible on this point for the soil of Uttarakhand, or entirely the mud in this area. There was some collaboration with partners from a government based research organization known as FRI (Forest Research Institute) and Wadia Institute of Himalayan Geology, and it is seen that they have information on soil profiles however no studies on microbial profile of the soil. This gives the task an additional importance as it would add to expand the circle of learning of the soil as far as power generation limit of microorganisms is concerned (assuming any).

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2. Research Method

Graphene based anode and cathode were used, attached with titanium wires to the load. The load circuit has flexibility; it can be used to power an LED using a capacitor and further if significant power is obtained it can power more small scale devices. The anode is designed to maximize active surface area to foster a healthy community of microbes. When the Anode is placed within the system, electricity-generating microbes will develop on its surface, shuttling electrons to its surface and driving the power generation process. The cathode is designed for maximum active surface area for the cathodic reaction to take place. At the Cathode, oxygen and protons interact with the electrons being generated by microbes at the Anode, forming water. This completes the circuit of the Microbial Fuel Cell, and allows electrical current to be generated.

Figure 1. The graphene based anode on the right and cathode on the left

The above given system can be used in any geometry of construction which will consist of a closed chamber, and electronics to connect the wires. Material for both anode and cathode are high surface area graphite fiber felt. The anode has a thickness of 0.5 cms and cathode of 1 cms. The diameter of the fiber for anode is 8 cms and for the cathode is 8.5 cms. The vessel will be topped off with a particular amount of soil the anode will be put in the mud where the microorganism species can develop, while the cathode will be on top of the dirt layer presenting it to oxygen in the space between the compartment cover and the felt. Both cathode and anode are made of graphene associated with titanium wires.

The geographical location of the study is given in Table 1, and calculations are based on Ohms Law, voltage is measured using multimeter and same is used to calculate power using the resistors. From Ohms law: V= I.R and further the power calculation is given by P = V.I combining the two equations power can be obtained as P = V2/R. There are two layers of sample in the existing system, as sediment MFCs have the anode submerged in the sample, so the sample below anode is approximately 84 gms and the sample between anode and cathode is 92 gms. Such is maintained simply for convenience purposes and not any technical dilemmas. The sample used is the local soil sample from the sub-himalayan terrain and starch has been added to it to act as a substrate for the soil microbes, for the overall sample 5 gm starch in dissolved in 100 ml water has been added. Such proportion is added purely on the basis of convenience.

Table 1. Geographical location of area from where soil samples are taken

Name	Bidholi, Uttarakhand, India
Type	Locality
Latitude	30.3165
Longitude	78.0322
State	Uttarakhand
District	Dehradun

3. Results and Analysis

Compared to other alternative energy systems such as solar and wind MFC is a low power system due to its thermodynamic limitation. The theoretical anode and cathode potentials calculated by Nernst equation are -0.3 V (vs. NHE) and 0.8 V (vs. NHE), respectively, when starch servers as the electron donor and oxygen serve as the electron acceptor. Therefore, the theoretical voltage across the two electrodes is 0.8 V - (-0.3 V) = 1.1 V. Further, the system was incorporated with an LED, to check for power, if voltage levels crossed 0.45 Volts, the LED will start to blink. Such was observed and given in figure 2 is the graph for Power developed over time for the system.

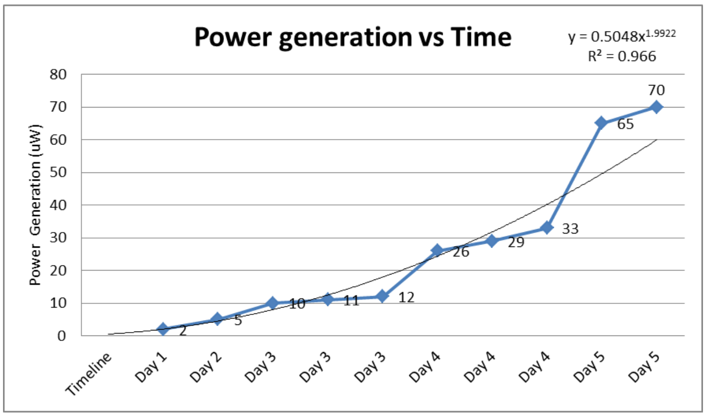

Figure 2. Power stabilized near 70 (uW) and significant growth as observed during day 4 and day 5

After the power production stabilized, the study was further conducted for a temperature sensor and the MFC system was able to power the sensor as well as shown in figure 3. Same phenomena in different capacities have been reported by other researchers, such as by placing one electrode into a marine sediment rich in organic matter and sulfides, and the other in the overlying oxic water, electricity can be generated at sufficient levels to power some marine devices [3, 4]. This study has used Graphite based electrodes although platinum mesh electrodes have also been used, as some studies have shown [5].

Figure 3. Temperature sensor being powered by the Microbial Fuel Cell

This also shows that experimentations have been performed at room temperature (24-27°C) and accordingly data has been generated. One study has shown the use of sediments into H-tube configured two-chamber systems to allow investigation of the bacterial community [6]. In energy harvesting systems, capacitors are widely used as either final energy storage before utilization or transitional energy storage during energy extraction. Different arrangements of multiple capacitors in the circuit can manipulate outputs of current, voltage, and power from MFCs. To date five charging/discharging techniques have been reported: direct charging, intermittent energy harvesting (IEH, also known as intermittent charging (IC)), alternate charging and discharging (ACD), charging capacitors in parallel while discharging in series and charging capacitive electrodes [7-10]. Present system reported in this work has experimented with direct charging capacitors.

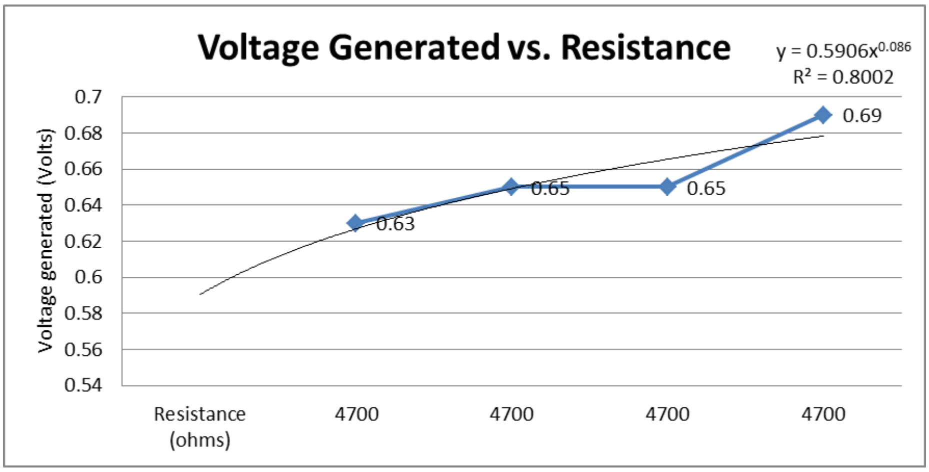

Figure 4. Keeping resistance of 4700 ohms peak voltage across the terminals was achieved of 0.69 V

Table 2. Current Generation for the soil sample with Starch

Resistance (R)	Voltage (V)	Current (milliAmp)
4700	0.63	0.134
2200	0.62	0.281
220	0.38	1.727
100	0.52	5.2
47	0.42	8.936

Since the direct energy production from MFCs is generally not sufficient for practical applications, various circuit topologies have been developed to interface MFCs with electronic loads and given below is the voltage and current density mapping for this work. The voltage output can be increased when charging an array of capacitors connected in parallel and then discharging them in series. By using two groups of capacitors with alternative charging and discharging sequence, Moreover, this approach does not require a minimum input voltage threshold, so voltage can be increased without using initial boost. It also effectively alleviated voltage reversal problem with negligible energy losses in the circuit. However, external energy supplied to control relay switches was not considered in the energy calculation.

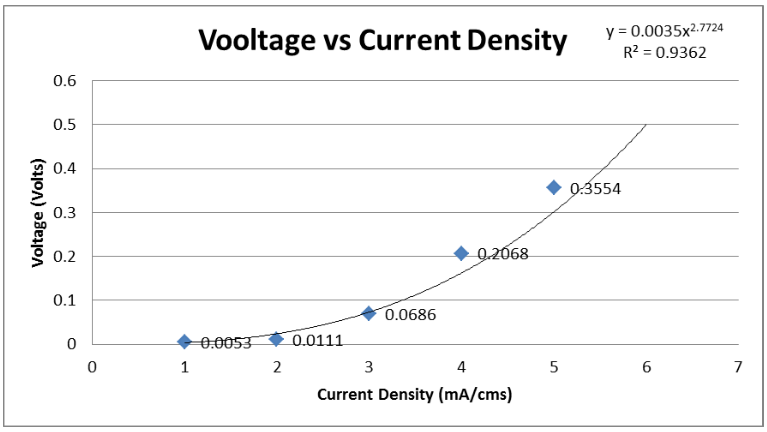

Figure 5. Vooltage vs Current Density

Creating custom fitted vitality collecting frameworks including MPP (Maximum Power Point) following and power administration frameworks are critical for MFC scale-up and genuine application. Such framework for the most part made out of various electronic components, for example, off-the-rack capacitors, rechargeable batteries, charge pumps, and boost converters, however these electronics are not intended for MFC conditions so the proficiency is low and introductory voltage supports are required. Altered reaping frameworks have been accounted for by a few groups, yet there is exceptionally constrained information base for this critical area of research, since it requires comprehension of power electronics, hardware, and programing, which is not, gave in conventional ecological science and designing training.

4. Conclusion

The generation of practically usable power is a critical milestone for further MFC development and application, and how to effectively and efficiently harvest and utilize MFC's energy remains a key challenge. This work discusses the method and systems that have been developed for MFC energy extraction and conditions for practical usein sub Himalayan soils of Uttarakhand in India, but it is very clear that more work needs to be done to optimize the design, improve harvesting efficiency, and reduce the cost. We consider this is a main bottleneck for MFC application and should be a new frontier of MFC research.

Acknowledgement

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References

[1] Hofstetter T, K Pecherl, RP Schwarzenbach. Bioavailability of Clay- Adsorbed U (VI) to Shewanella putrefacien. *Environ. Sci. Technol*. 2002; 36: 1734-1741.
[2] Amann, Rudolf I, Wolfgang Ludwig, and Karl-Heinz Schleifer. Phylogenetic identification and in situ detection of individual microbial cells without cultivation. *Microbiological reviews*. 1995; 59(1): 143-169.
[3] Reimers CE, Tender LM, Fertig S, Wang W. Harvesting energy from the marine sediment-water interface. *Environ.Sci. Technol*. 2001; 35: 192-195.
[4] Tender LM, Reimers CE, Stecher HA, Holmes DE, Bond DR, Lowy DA, Pilobello K, Fertig SJ, Lovley DR. Harnessing microbially generated power on the seafloor. *Nat. Biotechnol.* 2002; 20: 821-825.
[5] Hasvold Ø, Henriksen H, Melvaer E, Citi G, Johansen BØ, Kjønigsen T, Galetti R. Sea-water battery for subsea control systems. *J. Power Sources*. 1997; 65: 253-261.
[6] Bond DR, Holmes DE, Tender LM, Lovley DR. Electrodereducing microorganisms that harvest energy from marine sediments. *Science.* 2002; 295: 483-485.

[7] Dewan A, Beyenal H, Lewandowski Z. Intermittent energy harvesting improves the performance of microbial fuel cells. *Environ. Sci. Technol*. 2009; 43(12): 4600-4605.
[8] Grondin F, Perrier M, Tartakovsky B. Microbial fuel cell operation with intermittent connection of the electrical load. *J. Power Sources*. 2012; 208(15): 18-23.
[9] Liang P, Wu W, Wei J, Yuan L, Xia X, Huang X. Alternate charging and discharging of capacitor to enhance the electron production of bioelectrochemical systems. *Environ. Sci. Technol*. 2011; 45(15): 6647-6653.
[10] Deeke A, Sleutels TH, Hamelers HVM, Buisman CJN. Capacitive bioanodes enablerenewable energy storage in microbial fuel cells. *Environ. Sci. Technol*. 2012; 46(6): 3554-3560.