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Analysis of Sediment-Microbial Fuel Cell Power Production in Series and Parallel Configurations

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ABSTRACT

Renewable power from sediment microbial fuel cells (SMFCs) are prospect to utilize and to operate low power devices like remote sensor etc., in the area where operation of low power devices is needed in regular human life. To scale-up the size we think of increasing the electrode surface area but it results in decreasing power density, which demonstrate that SMFCs find it difficult to scale-up with size. Development of different approaches to increase the power generation from sediment MFCs is to be needed as to scale-up the MFC. Two arrangements have been tried to check the different possible results. Series arrangement shows voltage scale-up, and peak voltage was recorded at 54.5 mV. Parallel arrangement shows peak current at 187.2 µA with an external resistor of 47 Ω. To obtain polarization curve several resistors ranging from 47-4700 Ω can be used. Graphene, a flat monolayer of carbon molecules firmly stuffed into a two-dimensional (2D) honeycomb cross section, was used in the present work in the form of graphene disks as anode and cathode, connected to a load. Smaller-sized individually operated SMFCs connected to a power management system that electrically isolates the anodes and cathodes, have been used in this study.

INTRODUCTION

The exploration of alternate energy resources and how it works is as important as the search for new medical treatments, because ultimately all these valuable advances rest on an understanding of basic laws that govern everything in nature. Microbial fuel cell (MFC) research is curiosity-driven science and is a valuable pursuit, and this is why we must continue our journey in this field. There is no magic trigger that can end energy conversion crisis immediately, while coal, oil and natural gas are the main methods for energy production today, it however, cannot be in the future. Developing methods that will not leak CO_2 into the atmosphere at an average rate of more than 1% over centuries will be critical (Lewis & Nocera 2006). This requires the entire global community to be equally committed and effective in carbon capture and sequestration.

In microbial fuel cells bacteria act as a catalyst and oxidize the organic matter and inorganic matter to produce electricity (Rao et al. 1976, Davis & Yarbrough 1962). These are an older invention than the battery. The electrons produced by microbes from the substrate are transferred to the anode, which is the negative terminal and onto the cathode, which is the positive terminal. These are linked by conductive materials with a load (resistor). Electrons can be transferred by using electron mediators into the anode (Rabaey et al. 2004, Rabaey & Verstraete 2005), usage of direct membrane electron transfer has also been shown in studies (Rabaey et al. 2004) or by use of nanowires (Gorby et al. 2006, Reguera et al. 2005). It can be speculated that further undiscovered means can also facilitate such processes.

Sediment-MFC (SMFC) systems can be constructed by placing one electrode into a sediment rich organic matter (it can be soil itself), while the other electrode exposed to air from one side, electricity can be generated to power small scale low utility energy devices such as biosensors (Reimers et al. 2001). Some studies have used graphite disks as electrodes (Bond et al. 2002, Reimers et al. 2001), however, platinum based electrodes have also been used (Tender et al. 2002). Sediments have also been placed into the traditional H-shaped two chambered system to investigate the growth of bacteria and bioelectricity production (Bond et al. 2002). SMFCs have attracted the attention of many researchers because of their moderate functioning parameters and ability to use a range of biodegradable substrates like river water, acetate, starch (Loloei et al. 2017) and simple mud itself.

MATERIALS AND METHODS

Shewanella spp. and *Geobacter* spp. are the two species of bacteria present in soil capable of producing electricity. These are also capable of metabolizing mineral compounds (such as iron, lead etc.) in the soil, so when the soil samples are put back to the environment no harm is done to the ecology as well. Soil can be blended with kitchen waste, compost or any rich organic matter and when placed between the electrochemical cells (anode and cathode, made from graphene), have demonstrated that such systems can produce sufficient power (Donovan et al. 2013, Dewan et al. 2008). The schematics of how the setup works is shown in Fig. 1

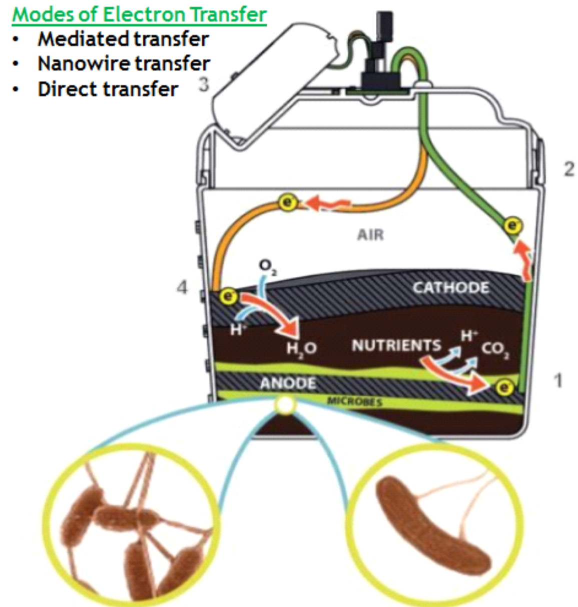

Fig. 1: Mechanism for SMFC, at point 1, biofilm is formed by the bacteria, and as they consume organic matter, electrons are released, which travel through the anode wire at point 2, and reaches the load at 3, after which they are accepted at the cathode and reduced at point 4.

For scaling up sediment microbial fuel cells, different stack approaches are needed. So two approaches were tested, one is series arrangement and second is parallel arrangement. Three sediment MFCs were kept in series by connecting anode of one MFC to the cathode of another MFC using titanium wires, in which end connection is connected to hacker board. In series stack approach, the current flowing in whole circuit is same and the potential difference of each anode and cathode is different. These three voltages (potential differences) add up to give the final output voltage.

Soil taken for fabrication of these three MFC's was from a barren land and no additional substrate was added. Each MFC had a total soil sample of about 174.80 grams, with the sample below anode having an average weight of 83 grams and for the cathode of about 91 grams. Total soil sample of these three was around 524.5 grams. The location from where the soil sample was taken is at latitude 30°31'65" N and longitude 78°03'22"E. Fig. 2 shows the series arrangement setup for the same.

Fig. 2: Three MFCs connected in series.

Studies on parallel arrangement of three MFC's in which three anodes and three cathodes are connected parallel and end connection is connected to the resistor of resistance 47 Ω, in parallel stack approach, the potential difference of each cathode and anode of these three MFCs remain same and current from each MFCs get summed up.

Present system has produced peak voltage of 54.5 mV in series arrangement and peak current of 187.2 μA, but the overall cost of setting up each assembly using the graphene electrodes is significantly high. This spectacular disparity has to be bridged; presently the study involves finding the optimal feedstock in terms of soil, and its utilization as a bioremediation tool. Then further, this optimal feed with specified proportion of organic matter will be kept as a constant for future research.

Microbial fuel cell demonstrates the capability of the soil microbes to produce voltage in a higher range and if this is allowed to continue (say for a month), there can be some remarkable current produced from the system which we can then speculate to help run/charge less energy intensive devices in rural areas where electricity is still not available. While the setup was expected to yield significant result, it has yielded low output power, the following is assessed to be the reason for the same:

a. The process inside the vessel can result in steady formation of water, if the cathode gets submerged in water, it will cause low power, so making modification in the system, and investment is required in such.

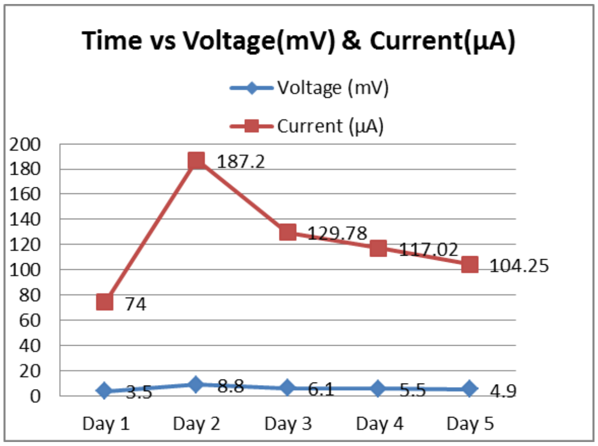

Fig. 3: Variation of voltage and current with time.

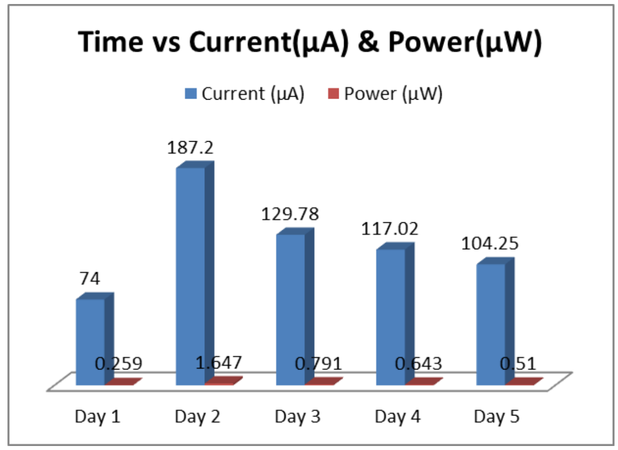

Fig. 4: Variation of current and power generated with time.

Table 1: Three different MFCs voltages (potential differences) and final output voltage.

Time	MFC 1 Voltage (mV)	MFC 2 Voltage (mV)	MFC 3 Voltage (mV)	Output Voltage (mV)
Day 1	27	14.7	12.2	53.9
Day 2	26.2	12.3	16	54.5
Day 3	24.8	10.6	16.1	51.5
Day 4	23.8	11.7	13.6	49.1
Day 5	22.3	12.6	10.7	45.6
Day 6	22	13.4	9.5	44.9
Day 7	20.4	12.6	8.5	41.5
Day 8	10.6	2	8.6	21.2

Table 2: Voltage across resistance, current and power generated for parallel connection.

Time	Voltage (mV)	Resistance (Ω)	Current (μA)	Power (μW)
Day 1	3.5	47	74	0.259
Day 2	8.8	47	187.2	1.647
Day 3	6.1	47	129.78	0.791
Day 4	5.5	47	117.02	0.643
Day 5	4.9	47	104.25	0.51

b. Large air bubbles should not be present inside the system in the soil
c. Starting the initial process takes a lot of time (3-7 days), but once a good microbial community is established, the system works well.

RESULTS AND DISCUSSION

Power output is low due to some reason, it may be air gaps inside the systems or water formation or may be any other reasons. The same is shown in Fig. 3 and Fig. 4 respectively.

Scale-up of MFCs work is in progress and power developed can be increased when soil added with organic wastes.

According to one study (Ewing et al. 2014), power density of the scale-up is similar in starting like single equivalent MFC but after some days power outsource of scale-up will be high when power density of single equivalent is going down. Tables 1 and 2 shows the overall power output for the s-MFCs.

The power generation of the scale-up MFC system would be expected approximately 65% higher than the single equivalent.

CONCLUSION

The overall cost of setting up each assembly or arrangement using the graphene makes it an expensive prospect and this spectacular disparity has to be bridged. Presently the study involves finding the optimal feedstock in terms of soil, kitchen waste and other organic matter which are locally sourced in a village area. Then further, this optimal feed with specified proportion of organic matter will be kept as a constant for future research. The process of generating electricity from sMFCs can also improve the soil, thus the soil after use can be a good carbon sink. If implemented on a large scale, the technology holds advantage of generating power anywhere where the soil is rich in bacteria and also it can be implemented in small villages to make them self-sustainable by the microbial fuel cell based micro-grids.

REFERENCES

Bond, D.R., Holmes, D.E., Tender, L.M. and Lovley, D.R. 2002. Electrode-reducing microorganisms that harvest energy from marine sediments. Science, 295(5554): 483-485.

Davis, John B. and Harold, F. Yarbrough 1962. Preliminary experiments on a microbial fuel cell. Science, 137(3530): 615-616.

Dewan, Alim, Haluk, Beyenal and Zbigniew, Lewandowski 2008. Scaling up microbial fuel cells. Environmental Science & Technology, 42(20): 7643-7648.

Donovan, C., Dewan, A., Heo, D., Lewandowski, Z. and Beyenal, H. 2013. Sediment microbial fuel cell powering a submersible ultrasonic receiver: new approach to remote monitoring. Journal of Power Sources, 233: 79-85.

Ewing, T., Ha, P.T., Babauta, J.T., Tang, N.T., Heo, D. and Beyenal, H. 2014. Scale-up of sediment microbial fuel cells. Journal of Power Sources, 272: 311-319.

Gorby, Y.A., Yanina, S., McLean, J.S., Rosso, K.M., Moyles, D., Dohnalkova, A., Beveridge, T.J., Chang, I.S., Kim, B.H., Kim, K.S. and Culley, D.E. 2006. Electrically conductive bacterial nanowires produced by Shewanellaoneidensis strain MR-1 and other microorganisms. Proceedings of the National Academy of Sciences, 103(30): 11358-11363.

Lewis, Nathan S. and Daniel, G. Nocera 2006. Powering the planet: chemical challenges in solar energy utilization. Proceedings of the National Academy of Sciences, 103(43): 15729-15735.

Loloei, M., Rezaee, A., Roohaghdam, A.S. and Aliofkhazraei, M. 2017. Conductive microbial cellulose as a novel biocathode for Cr(VI) bioreduction. Carbohydrate Polymers, 162(2017): 56-61.

Rabaey, K., Boon, N., Siciliano, S.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, Korneel and Willy, Verstraete 2005. Microbial fuel cells: novel biotechnology for energy generation. Trends in Biotechnology, 23(6): 291-298.

Rao, J.R., Richter, G.J., Von Sturm, F. and Weidlich, E. 1976. The performance of glucose electrodes and the characteristics of different biofuel cell constructions. Bioelectro-chemistry and Bioenergetics, 3(1): 139-150.

Reimers, C.E., Tender, L.M., Fertig, S. and Wang, W. 2001. Harvesting energy from the marine sediment, water interface. Environmental Science & Technology, 35(1): 192-195.

Reguera, G., McCarthy, K.D., Mehta, T., Nicoll, J.S., Tuominen, M.T. and Lovley, D.R. 2005. Extracellular electron transfer via microbial nanowires. Nature, 435(7045): 1098-1101.