Microbes to Generate Electricity

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“The word “energy” incidentally equates with the Greek word for “challenge.” I think there is much to learn in thinking of our federal energy problem in that light,” says Thomas Carr. Energy needs around the world are rising at a pace yet unmatched by sustainable energy sources. Natural resources like oil will soon become scarce, and we need modifications in our current lifestyles if we wish to stretch the remaining oil reserves. Thus, all sorts of ideas and inventions for developing greener and more efficient methods of energy generation are increasingly being hailed across the globe.

One of such approaches, which can be seen as having tremendous potential, is the use of microbes for the production of electricity. The first report that bacteria can generate electricity appeared almost a hundred years ago, by Potter [1]. However, his work did not gain any major coverage at that time. It is only in recent years that this ability of microbes has been rediscovered. The reason for this renewed interest, as mentioned above, is the need for new resources of energy and better understanding of the microbial system in relation to the electron transport and eventually, the development of Microbial Fuel Cells. A Microbial Fuel Cell (MFC) is capable of generating electricity directly from a large variety of organic or inorganic compounds, using a microbe as a catalyst [2].

Conventionally, fuel cells convert chemical energy to electrical energy, by consumption of a fuel at the anode and an oxidant at the cathode. The electrons and protons

released travel through an external circuit, producing electricity (See equation below) [3, 4]. In MFCs, the anode and cathode are separated by an ion exchange membrane, and a solution consisting of organic matter and microbes is used as fuel [5] (Fig. 1).

However, efficiency is greatly lowered by the direct transfer of electrons from the microbe to anode. Therefore, in electrochemically inactive microbial cells, exogenous mediators like thionine, methyl viologen, humic acid etc. are used. These act as shuttles for electrons, diffusing to the anode, discharging electrons, and then diffusing back to bacterial cells. These mediators are, however, too expensive, and also toxic to the microorganisms [4]. Alternate solutions were needed.

These came in the form of discovery of certain bacteria, like *Shewanella oneidensis* and *Geobacter sulfurreducens*, which produce electrically conductive appendages (called bacterial nanowires) under anaerobic conditions. These nanowires facilitate direct transfer of electrons to the anode, hence greatly increasing efficiency and reducing significant costs [6]. Addition of toxic compounds to shuttle electrons has now been rendered unnecessary. Such Mediator-less Fuel cells can use a larger variety of organic matter as fuel. Moreover, studies show that flow of current increases as much as six times in the presence of other microorganisms, i.e. in a mixed culture [4].

Microbial fuel cells thus have the property of consuming almost any type of organic waste, and generating energy at the same time. Most of the substrates they use, like sugar and

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Fig. 1 A schematic representation of the MFC [4]. The cathode is exposed to air on one side, and the solution containing the biodegradable substrate is present on the other side. The anode chamber containing the bacteria is sealed off from oxygen

starch, are readily available, easy to store, dose and are greener than, for e.g., methanol [7]. This twin set of extraordinary uses, if perfected, may well resolve the energy crisis and waste disposal problems that the world currently faces.

Moreover, MFCs have many distinct advantages over the conventional fuel cells. For one, they have higher efficiency, and produce little pollution. Some MFCs can even produce hydrogen along with electricity, conveniently solving the hydrogen problem as well, in a process called electrohydrogenesis [8]. The MFCs may turn out to be highly effective as compared to conventional batteries, which need to be charged before usage, are environment unfriendly due to heavy metal content, and require electricity for powering them [7].

In the near future, MFCs may be developed to such a stage that they can give a reasonable and usable power output per unit the MFC volume. In such a viable scenario, a larger battery size could well be overlooked, provided the maintenance is easy and has a green and safe label. This eco-friendly fuel cell will then lead to several ground-breaking applications. As the amount of low-power devices implanted in the human body increases, the long term, stable power source used may well be the MFC. Photosynthesis could be used to produce electricity. During this process, carbohydrates like sucrose are produced, which travel through the plant sap. These plant saps could be harvested to provide a flow of fuel for MFCs, making an entire forest a power plant! Maple syrup plant saps have already been tested, and have yielded a conversion efficiency of 50 % [9]. The leftover minerals could be recycled to the trees or the plants. Another use could be construction of Bio-Sensors. As demonstrated in Mediator MFCs, bacteria have lower metabolic activity when inhibited by toxic compounds, leading to a lower rate of electron transfer to the

anode. An MFC may be constructed in such a manner that the bacteria in the anode are protected behind a membrane. In this setting, if a toxic compound diffuses through the membrane, there will be a measurable change in potential. These sensors could be used as indicators of toxicants in rivers, at entrance of wastewater treatment plants, to detect pollution or illegal dumping, or even for research in polluted areas [10, 11]. MFCs can even be used as an application to produce electricity from the seafloor. A potential difference can be generated by bacteria between sediment and the aqueous phase below [12]. Bacteria oxidize carbon present in the sediment to produce sulphide, which is then oxidized along with other organic matter by bacteria growing on to the anode. Accessibility is the only problem that might hamper the development of this technology [7].

As revolutionary as they might sound, it will still be some time before MFCs take the fuel cell industry by storm. For large scale applications, they still face important limitations. Initial investment costs for the entire setup are quite high. The aeration and recirculation required in the cathodic compartment consumes a considerable amount of electricity, larger than the energy produced. Moreover, a large amount of sludge is formed during anaerobic conversion, which requires additional treatment [7]. Efficiency in anaerobic digestion is low, as hydrolysis of most organic matters and hence their bioconversion into biofuels is almost never complete. With mediators, the efficiency is even lower, and in Mediator-less conditions, there are only a few bacteria which can conduct electrons.

MFC, as an energy-saving technology, may well wean us away from the dwindling oil resources. But there are many technical challenges that must be overcome before it can be used for renewable energy production. Nonetheless,

the technology might open the door to a new method for renewable and sustainable energy products.

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