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Building Microbial Fuel Cells, Structure and Components

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Abstract: Production of electricity by microorganisms is a new interesting subject which has received high attention by researchers, industries and NASA. In Microbial fuel cells (MFC) electricity is generated *via* microbial activities. It is proposed that waste materials as sewage, food leftovers and basically all sorts of biodegradable organic matters have the capability to be used in MFC. These devices are harmless to the environment. Basically wide range of bacteria can be used as candidates in MFC. Basic structure, mechanism of action, types of microorganisms and chemical reactions are discussed in this paper.

Key words: Microbial Fuel cells, biological fuel cells, exchange membrane, mediator

INTRODUCTION

In recent years research activity in fuel cell technology has increased remarkably. Great expectations are directed to fuel cells because of the forthcoming depletion of Earth's fossil fuel resources. Also, drilling and mining, transportation and use of fossil fuels cause environmental risks. A biological fuel cell is a device that directly converts biochemical energy into electricity[1,2]. A fuel cell generates electricity by a chemical reaction. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the cathode and anode. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other and a catalyst, which speeds the reactions at the electrodes. Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, namely water. There are several kinds of fuel cells and each operates a bit differently. But in general terms, hydrogen atoms enter a fuel cell at the anode where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized," and carry a positive electrical charge. The negatively charged electrons provide the current through wires to do work. If Alternating Current (AC) is needed, the DC output of the fuel cell must be routed through a conversion device called an inverter[3].

MATERIALS AND METHODS

Preparation of Components: Every fuel cell has two electrodes, one positive and one negative, called, respectively, the cathode and anode. The reactions that produce electricity take place at the electrodes. Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other and a catalyst, which speeds the reactions at the electrodes. Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, namely water[3]. One of the simplest forms of fuel cells components are: a large glass boiling tube, the electrodes are made from carbon rods large if possible which can be scavenged from old dry batteries. Although inert metals can be used, most common ones (copper. iron. zinc, aluminum) should be avoided, as they may give rise to spurious generation of current from electrochemical dissolution of the metal. The oxidizing solution (catholyte) is a solution of potassium or sodium ferricyanide. 0.01-0.10 M, in potassium phosphate buffer (anywhere in the region of pH 7). One electrode is immersed in this solution to form the oxidizing half-cell. The separation of the anode and cathode solutions is achieved with the aid of a length of tubular dialysis membrane (The membrane is of course permeable to ions, including the oxidant; the separation of the two halves is therefore only temporary, but is adequate for a demonstration which can be completed in 30 min or so.) The bag contains the second electrode immersed in pH 7 buffer containing the micro-organisms, the mediator and a small amount of glucose. *E. coli* is a very suitable organism and its use is permitted by school safety regulations in most countries. (*Proteus vulgaris* is excellent, but may not be permitted, as some strains are pathogenic.). Other bacterial species that used in MFCs are sited in many references[4,5] and recently three species

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of bacteria- *Pseudomonas aeruginosa, Enterococcus faccium, Alcaligenes faecalis* are used as combining together[6]. Ordinary yeast may be used. The amount of micro- organism required is upwards of 50 mg (dry wt.) per ml - sufficient to give a turbid (watery milk-white) suspension. Suitable redox mediators a thionine or methylene blue. These substances resemble dyestuffs and although water-soluble[1].

Analysis of Mode of Action of MFCs: When living creatures metabolize food to provide them with energy, they are trapping the energy of oxidation of energy-rich (electron-rich) substances liberated, from carbohydrates for example, in reactions such as:

$$C_6H_{12}O_6 + 6O_2 ? 6CO_2 + 6H_2O \quad (1)$$

In the living cell this process is of course a complex one involving many enzyme-catalysted reactions. It progresses through a series of intermediates (*e.g., NADH quinones*) involving successive oxidation-reduction changes and in this respect resembles an electro chemical process; it is an example of "cold combustion". The energetics of metabolism are of fundamental importance in areas such as nutrition and have inspired evocative labels such as the fire of life, but that fire is one that proceeds at body temperature. In normal microbial catabolism, a substrate such as a carbohydrate is oxidized initially without participation of oxygen when its electrons are released by enzymatic reactions. The electrons are stored as intermediates which become reduced and in this state they are used to fuel the reactions which provide the living cell with energy for maintenance and growth via bio-synthetic reactions. The ultimate electron sink is molecular oxygen (dioxygen). To an electrochemist, a simplified representation of the charge separation involved in the oxidation of glucose by a whole bacterial cell would be as follows:

$$C_6H_{12}O_6 + 6H_2O ? 6CO_2 + 24H^+ + 24e^- \quad (2)$$

The large harvest of electrons is stored as reduced intermediates, but the eventual terminus in the respiratory chain is oxygen:

$$6O_2 + 24H^+ + 24e^- ? 12H_2O \quad (3)$$

Inspection shows that equations (2) and (3) combine to give the same result as equation (1)[1]. General characteristics and differences between of chemical and biological fuel cell are represented in Table 1.

Table1: General characteristics of chemical and biological fuel cell

Items	Fuel cell chemical	Fuel cell biological
Catalyst	Noble Metals	Microorganism / enzyme
pH	Acidic Solution (pH<1)	Neutral Solution pH 7.0-9.0
Temperature	over 200°C	Room Temperature 22-25°C
Electrolyte	Phosphoric –acid	Phosphate Solution
Capacity	High	Low
Efficiency	40-60%	Over 40%
Fuel Type	Natural gas , H_2, etc.	Any Carbohydrates and hydrocarbons

RESULTS AND DISCUSSION

Microbial electrochemistry provides many opportunities for promoting an approach in interdisciplinary science areas including microbiology, chemistry, physics, space engineering and more. Simple experiments to demonstrate microbial generation of electricity is described which can be carried out with relative unsophisticated equipment leading to future plans when fossil energies would deplete. NASA is considering it for future space research [7]. However, the electrical response of micro- organisms can be used to construct analytical biosensors. Improvements in the power and energy yields might be efficiently performed to subsidize or parallel use with common energy sources. Applications of MFC in biotechnology, biomass conversion and environmental science are of future goals. Waste products or crude biomass, such as lactose or sucrose molasses are promising substrates to feed future MFC plants [8]. In comparison with internal combustion engines, this type of energy is more environmentally safe. Hopefully, optimization of thermodynamics and mechanical engineering principles used in MFC would lead to advanced progress in this field in near future.

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