Development of Membraneless Ethanol/O_2 Biofuel Cell

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Biofuel cell is a electrochemical device in which energy derived from chemical reactions is converted to electrical energy by means of the catalytic activity of living cells and or/ their enzymes. Bioanode are the electrodes of the biofuel cell where the fuel is utilized by enzymes to produce electrons and protons which are then utilized by enzymes of second electrode to reduce O_2 to H_2O.

The goal of this project has been to develop an ethanol/oxygen biofuel cell with an extended lifetime (>10 days) and high power density (>0.10mW/cm^2) that does not require the use of a polymer electrolyte membrane (PEM) as a separator between the anode and cathode compartments. To accomplish this task, both the anode and the cathode electrodes of the fuel cell have to employ biological catalysts (enzymes) instead of traditional fuel cell catalysts (Pt, Pd, Ru, etc.). Traditional precious metal catalysts are not selective catalysts. The anode and cathode catalysts can both catalyze the oxidation of the fuel and the reduction of oxygen. This ability to catalyze cross-reactions requires that the anode compartment be physically separated from the cathode compartment. Previously, our research group has developed an ethanol bioanode, which employs immobilized alcohol dehydrogenase and aldehyde dehydrogenase enzymes along with the coenzyme NAD^+ to catalyze the oxidation of ethanol to acetate[1]. This research described focuses on the development a biocathode by replacing the platinum catalyst at a traditional cathode with an enzymatic catalyst system. By having both the oxidation and the reduction kinetics governed by selective enzymatic catalysts, the system no longer needs a PEM separator membrane to separate the anode solution from the cathode solutions. The biocathode consists of carbon cloth coated with a modified Nafion membrane containing bilirubin and bilirubin oxidase. The coated carbon cloth is then soaked in 1mM $Ru(bpy)_3^{+2}$ to allow the redox mediator $Ru(bpy)_3^{+2}$ to preconcentrate in the membrane.

Preliminary data shows that maximum open circuit potential for membraneless biofuel is 0.51V with maximum current density of 2.04 mA/cm^2, and shows maximum power densities of 0.46mW/cm^2; while biofuel cell with a salt bridge gave maximum open circuit potential of 0.79V with current density of 1.1 mA/cm^2 and life time of about 20 days. Both biofuel cells were run in a phosphate buffer containing 1mM ethanol and 1mM NAD^+.

Since our biofuel cell employs biological catalyst (enzymes) instead of traditional fuel cell catalyst (heavy metals) it comes with several advantages such as they are less toxic and more suitable to physiological enviroment. Also, the technology of our biofuel cell can be employed in same manner for utilizing other types of fuel such as other type of alcohols, carbohydrates, amino acids, fatty acids. Another advantage comes from the use of specific system by which we can eliminate the polymer electrolyte membrane. In addition to that it gives possibilities for this biofuel cell to be further worked on for possible implantation in living organisms.

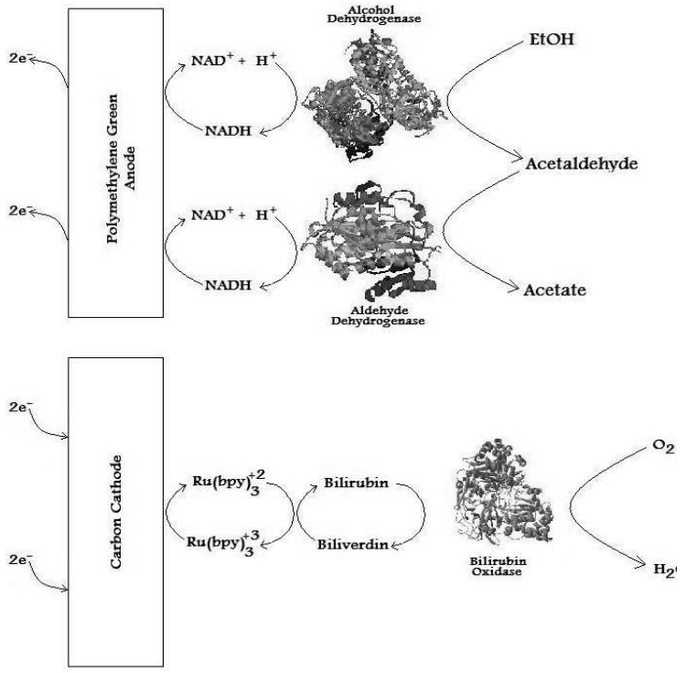

Figure 1: Schematic of the chemistry occurring at the biocathode and bioanode of the ethanol/oxygen biofuel cell.

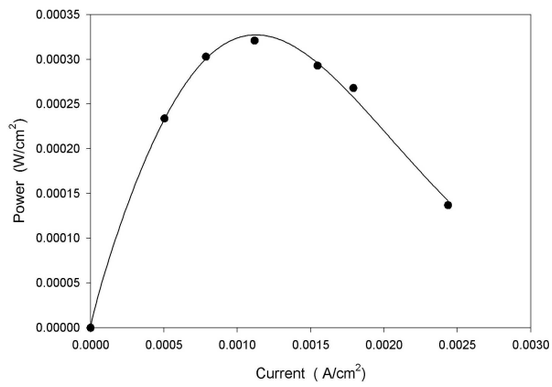

Figure 2: Representative power curve of a membraneless ethanol/oxygen biofuel cell in a 1mM ethanol and 1mM NAD^+ solution in pH 7.15 phosphate buffer at room temperature.

References

1. Moore, C.M., Akers, N.L. and Minteer, S.D. "Improving the Environment for Immobilized Dehydrogenase Enzyme by Modifying Nafion with Tetraalkylammonium Bromides." *Biomacromolecules* **in press** (2004).