Grand Challenge for Bio Fuel Cells – Electron Transportation Path

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The breakdown of organic substances to retrieve energy is a naturally occurring process in nature. Metabolism is the routine by which living systems extract energy from carbohydrates through a series of enzymatic redox reactions. In a microbial fuel cell, microorganisms are used as the catalysts that break down organic fuels to provide electrical energy. In principle, the application space of microbial fuel cells is similar to that of hydrogen or methanol fuel cells and ranges from portable electronics to automobiles. The ultimate cost of materials and fabrication for appropriate performance will dictate which markets could be targeted. Microbial fuel cells offer the advantages over hydrogen fuel cells of using inexpensive bacteria as the catalyst and liquid or solid simple sugars as the fuel.

Experimentally, some organisms have repeatedly demonstrated an energy conversion efficiency exceeding 90% on an electrode surface. However, the development of bio fuel cells has been hindered by the very low energy transfer efficiency in the set up of artificial engineering environment. Some of the key energy loss mechanisms include dioxygen (O_2) in liquid solution which is a strong oxidant and easily combines with e^- and H^+ to yield H_2O, the diffusion of electron from inside to the external environment and the diffusion of electrons in the solution to the electrode. Other energy conversion and efficiency issues include a number of fundamental yet unanswered performance questions: specific requirements for optimized bacteria-electrode connectivity and geometrical effects, the volumetric limit of catalyst loading and its relationship with power density, and the rate limiting step in the system. Quantifying these issues would provide insight on the fundamental sciences in the output capacity of microbial fuel cells as well as commercial feasibility as power sources for electronic devices.

Our current efforts target a new class of MEMS microbial fuel cells based on the electrode-exoelectrogenic bacteria interface. Experimental results show several key advancements in 1) longer lifetime for at least 7 days of operation, 2) natural cell division process with increased electrical outputs, and 3) better fuel cell efficiency due to the electrode-exoelectrogenic bacteria interface. By adopting exoelectrogenic bacteria, or micro-organisms that can completely break down the chemical energy in alcohols into electrons and can grow their own “organic nanowires” to connect to electrodes for enhanced efficiency, many of the aforementioned bottlenecks could be resolved. As such, we believe this fuel cell represents a step forward moving toward practical applications of microbial fuel cells. On the fundamental scientific side, we are pursuing direct measurements of electron transfer in these fuel cells and hope to answer and target some of the most basic energy transfer questions, including efficiency and electron transfer paths.