Finite element analysis approach for optimization of enzyme activity for enzymatic bio-fuel cell

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Introduction

Enzymatic biofuel cells (EBFCs) are miniature implantable power sources, which use enzymes as catalysts to perform redox reaction with biological fuels such as glucose. In this study, we focused on a three dimensional EBFC chip with highly dense micro-electrode arrays, fabricated by carbon-microelectromechanical system (C-MEMS) techniques. Glucose oxidase (GOx) is immobilized on anodes for the oxidation of glucose from blood, and laccase is immobilized on cathodes for the reduction of dissolved oxygen in the body. We mainly focus on two critical parameters related to the biofuel cells efficiency: one is the direct electron transfer between enzyme and electrode, and another one is how to generate maximum current density or power density.

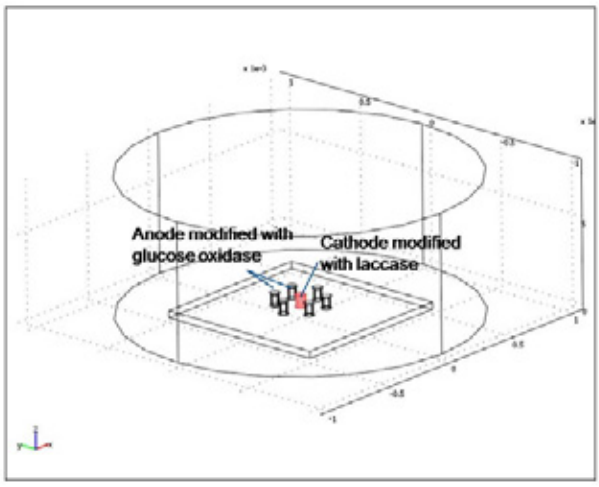

Figure 1: A schematic 3-D model of a biofuel cell

The Figure 1 is the simulation geometry for a 3-D model of an EBFC. In the center there is one cathode, immobilized with laccase, and there are six anodes, immobilized with glucose oxidase, surrounding the cathode.

Use of COMSOL Multiphysics

In our 2-D model design, we use the Michaelis–Menten enzyme kinetics theory in *convection and diffusion module*, to work out the relationship between electrode dimensions and enzyme reaction rate, based on direct electron transfer.

In the 3-D model design, having an unequal number of anodes and cathodes on the chip, we study the kinetics of electron transfer and power density, by incorporating Nernst potential theory in *Conductive Media DC module*.

Results:

From our initial results of 2-D model, the reaction rates of enzyme on the electrodes reach the maximum when the distance between anode and cathode is around 1.5 times as the height of electrodes.