Constructing COMSOL Models of a Bacteriological Fuel Cell

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Abstract

We have started constructing preliminary design COMSOL models of a bacteriologically driven 'fuel cell' that is intended to process waste products, such as carbon dioxide and brine, from a crewed vehicle. In early stage of modeling, this complex system is reduced to two chambers, each with an electrode, that are separated by a membrane that passes only cations. The setup is crudely illustrated in Figure 1, which shows the two chambers along with the electrodes. The membrane is ~100 microns thick and is barely visible. The spatial scale is meters, and the colors correspond to the density of H+. The protons are produced on the anode (the left electrode), transported through the membrane into the right chamber, and combine at the cathode to produce hydrogen gas that is vented. The chambers are filled with a salt-water mix appropriate for the culturing of methanogens. COMSOL will be used to model this system in ever-increasing detail, using the secondary current distribution, concentrated species transport, and free media flow physics nodes. Initial models will involve only water electrolysis, but eventually the production of methane from carbon dioxide and derived species will be included. Since pH will be the eventual observable, the flux of cations through the membrane needs to be tracked; this is done with a flux boundary for the species transport. The COMSOL model will be used to predict the production rate of methane, given experimentally derived reaction rates for the bacteria-coated electrodes. Potential differences, pH, concentrations of salts, carbon dioxide content, flow rates, and temperatures all impact performance; COMSOL will be used to explore this complex parameter space to determine an optimum bacteriologically driven 'fuel cell' design.

Figures used in the abstract

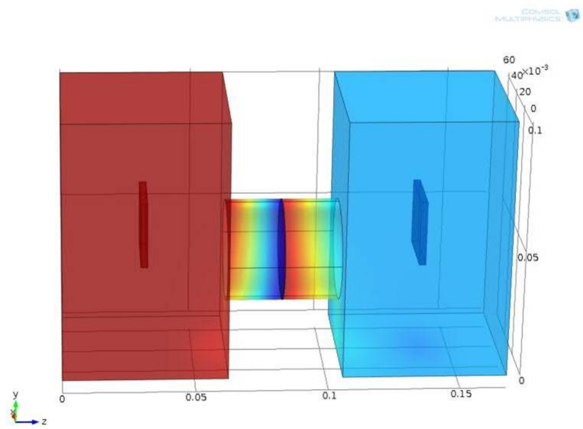

Figure 1: Mock-up of the fuel-cell setup showing the migration of protons from the anode (left) to the cathode (right). Higher H+ density is in red, while lower density is in blue.