Parametric Study of Electrolyte-Supported Planar Button Solid Oxide Fuel Cell

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Abstract

Fuel cells are devices that convert chemical energy of a fuel into electrical energy through electrochemical processes. One of the types of fuel cell is the Solid Oxide Fuel Cell (SOFC) that uses solid ceramics for electrolytes. Numerical simulation involves constructing a mathematical model of the SOFC and use of specifically designed software programs that allows the user to manipulate the model to evaluate the system performance under various configurations. High fidelity modeling allows testing and development of new materials, fuels, geometries, and operating conditions with a low cost. In addition, it is possible to measure internal variables which are experimentally difficult if not impossible to measure and study the effects of different operating parameters on power generated, efficiency and current distribution. COMSOL Multiphysics is a Finite Element Method (FEM) based software that facilitates such analysis. This paper will present the model developed in COMSOL of an electrolyte-supported planar button SOFC and a summary of the parametric study done for the same model. The parameters that will be studied are anode and cathode exchange current density, anode and cathode specific surface area, anode and cathode porosity and permeability, and electrolyte conductivity and inlet flow velocity. The whole modeling process, from creating the geometry, meshing, solving and post-processing, was all carried out in COMSOL Multiphysics 4.2a using the Batteries and Fuel Cells Module. The geometry, dimensions, and materials used can be seen in Figure 1. Tetrahedral elements were used for the meshing process. The nodes that were used included: the secondary current distribution node to solve for charge conservation and the nonlinear Butler-Volmer equations, transport of concentrated species node for solving the Maxwell-Stefan diffusion equations and free & porous media flow node for solving the Brinkman continuity and momentum equations. The solver used was MUMPS: a MUltifrontal Massively Parallel sparse direct Solver. After the model was built it was validated against experimental results [1, 2]. Preliminary results show that the significant parameters that affect the performance of the cell include exchange current density at the cathode and anode (Figure 4), specific surface area of the anode and cathode (Figure 2) and electrolyte conductivity (Figure 3). On comparing the effect of the exchange current density at anode with the parametric study done by Akhtar et al. [3], it can be seen that the results are in agreement although the type of SOFC is different. Increasing the specific surface area facilitates more reaction site [Triple Phase Boundaries (TPB)] and hence increases the current and power density. Higher electrolyte conductivity results in lower ohmic losses. Using the results obtained, researchers can focus their attention on optimizing the parameters that significantly affect cell performance. This is the advantage of modeling a fuel cell; it supports and forwards the commitment of building high performance fuel cells.

Reference

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2. William J. Sembler, Sunil Kumar, Optimization of a Single-Cell Solid-Oxide Fuel Cell Using Computational Fluid Dynamics, Journal of Fuel Cell Science and Technology, April 2011, Vol. 8.
3. Naveed Akhtar et al., A parametric analysis of a micro-tubular, single-chamber solid oxide fuel cell, International Journal of Hydrogen Energy, 36 (2011) 765-772.

Figures used in the abstract

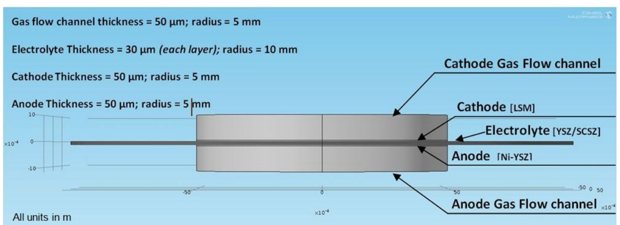

Figure 1: Electrolyte-Supported Planar Button SOFC geometry with the dimensions and materials used.

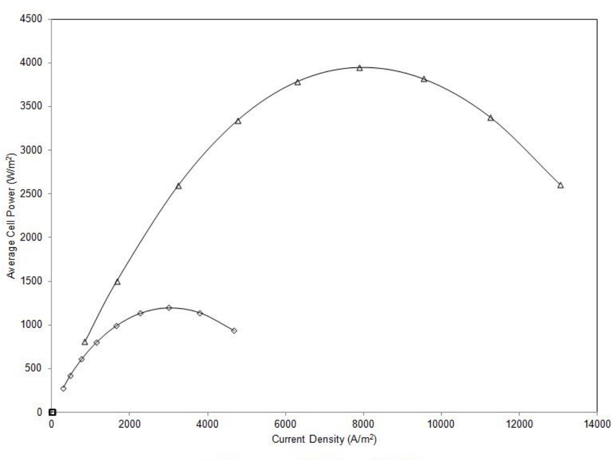

Figure 2: Effect of cathode specific surface area on the performance of the SOFC.

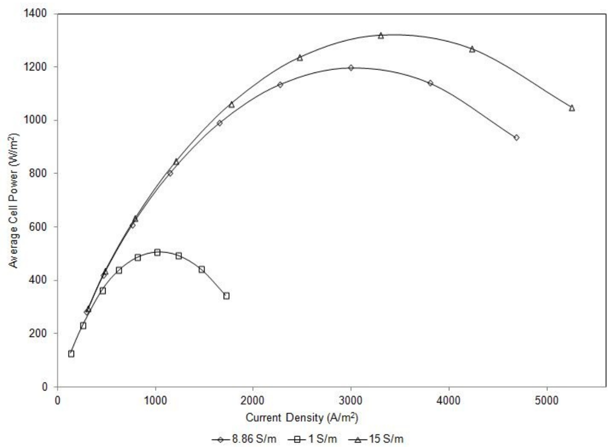

Figure 3: Effect of electrolyte conductivity on the performance of the SOFC.

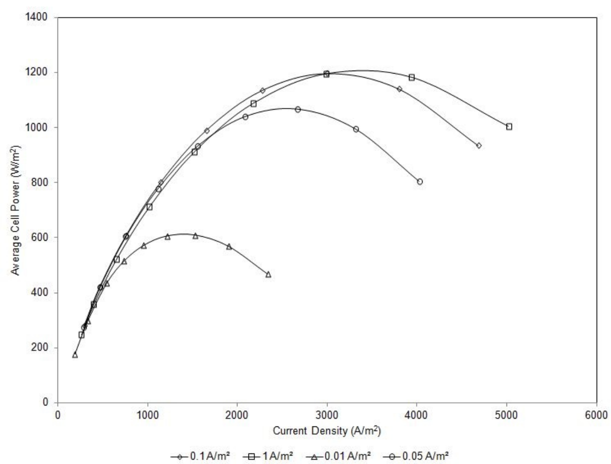

Figure 4: Effect of anode exchange current density on the performance of the SOFC.