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SIMULATIONS OF DIMENSIONAL EFFECTS IN SOLID OXIDE FUEL CELLS

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ABSTRACT

A fuel cell produces electricity and heat through an electrochemical energy conversion process that converts hydrogen and oxygen into water. The environmental impact is one to two orders of magnitude lower than in conventional systems because of their very low level of pollutant emissions.The prediction of fuel cell performance is one of the most challenging problems in fuel cell research.The objective of this study is to develop simulations of various two-dimensional models of SOFC(Solid Oxide Fuel Cell) and understand the effects of channel dimensions and channel geometry on the electrochemical performance and overall power dissipation for a planar SOFC. FEMLAB, a multi-physics solver is used to perform the simulations.

Typically, a fuel cell consists a cathode,anode, electrolyte and bipolar plates as shown in Figures 1. In the cathode side flow path oxygen from the air flows through the cathode, and methane (a fuel gas containing hydrogen) flows past the anode side gas flow path. Oxygen ions that are negatively charged move through the electrolyte and react with the hydrogen for the formation of water. This produced water again reacts with the methane fuel to form carbon dioxide and hydrogen. By this electrochemical reaction electrons generates and supplies electric power to load connected to the fuel cell. Figure 2 shows the channel with rectangular protrusions to improve chemical reactions and performance.

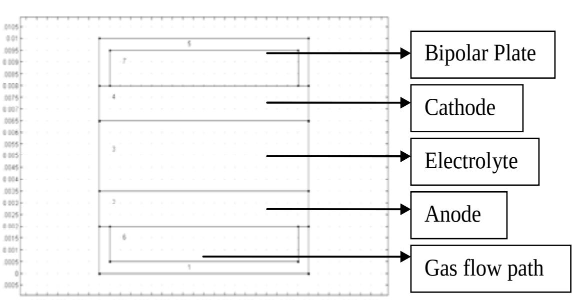


Figure 1 2D-Model of a SOFC (1cm*1cm cell)

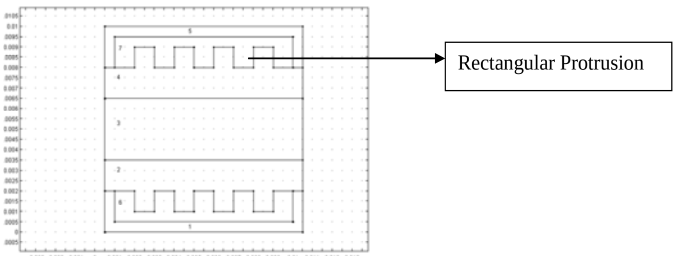


Figure 2 Model of Solid Oxide Fuel Cell with rectangular protrusion over cathode and anode surface (1cm*1cm cell)

Dimension	***1cm*1cm Cell***	***3cm*3cm Cell***	***5cm*5cm Cell***
Cell width and height	1 cm	3 cm	5 cm
Gas channel width	0.9 mm	2.7 cm	4.5 cm
Bipolar plate thickness	0.5 mm	1.5 mm	2.5 mm
Gas channel height	1.0 mm	3.0 mm	5.0 mm
Anode/Cathode thickness	1.5 mm	4.5 mm	7.5 mm
Electrolyte thickness	4 mm	12 mm	20 mm

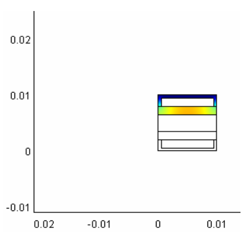
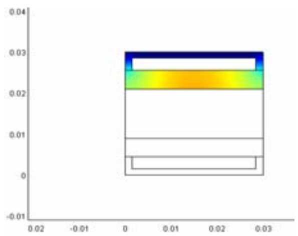
Table 1 Cell dimensions

RESULTS

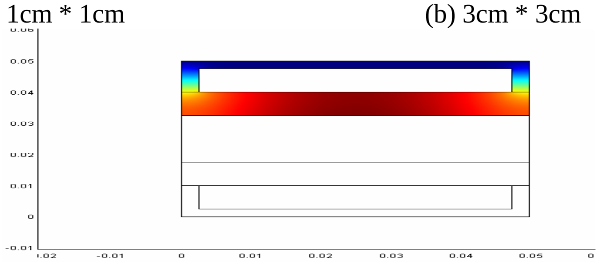
The results for various electrochemical properties are observed for each cell size as a contour display of variation along the cell walls. The results are observed for higher convective flux , concentration, concentration gradient and diffusive flux for all three different cells.In every region of larger cell sizes especially the 5 cm*5cm cell indicates higher performance.

Electronic potential distribution is the most important factor in the design of a fuel cell. After completion of the chemical reaction, this is the output from the cell. Higher electron potential distribution in different regions, are indicative of higher power production. Figure 3 show that the larger (5cm*5cm) cell gives higher potential distribution than the other two types of cell. As for electron as well as current flow a higher potential region on one side of the cell and a lower potential region on another side of the cell are needed for a high performance cell. In considering potential on the anode side, the design that gives the lowest potential distribution on the anode side is indicative of better performance. Figure 4 show that the larger cell (5cm*5cm) cell gives us the desired lowest potential distribution.

Ultimately, the fuel cell performance is purely gauged by the overall current density and associated power production. Figures 5 and 6 show the performance curves of the three cell sizes and the 1cc*1cm cell with rectangular protrusions. They clearly show that the bigger cell provides higher power output.The protrusions enhance convective flux as is typical in most enhanced heat transfer channels resulting in increased rate of chemical reaction leading to increased power production.

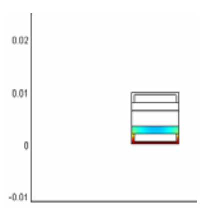
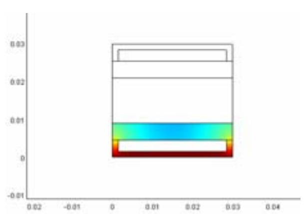



(a) 1cm * 1cm (b) 3cm * 3cm

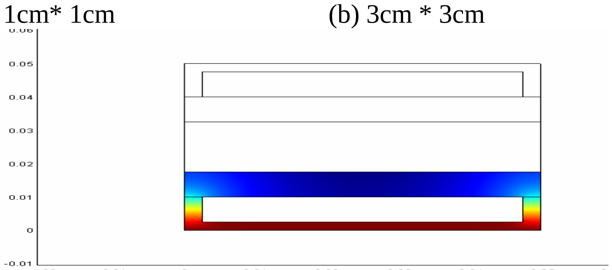


(c) 5cm * 5cm

Figure 3 Electronic potential distributions on Cathode side

(a) 1cm* 1cm (b) 3cm * 3cm



(c) 5cm * 5cm

Figure 4 Electronic potential distributions on Anode side

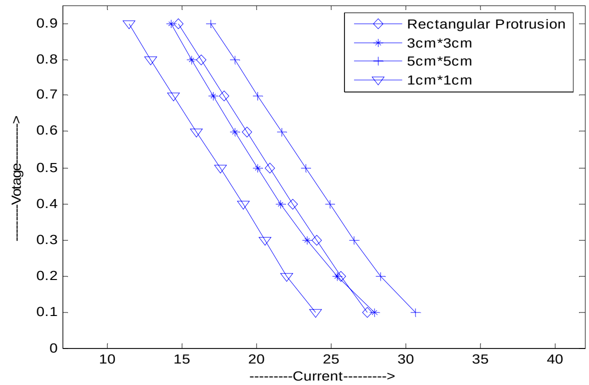


Figure 5 Current(Amp/m^2) vs. Voltage(volt) relation

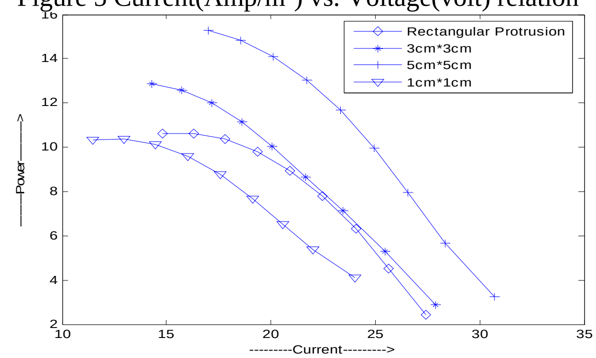


Figure 6 Power(watt) vs. Current (Amp/m^2) relation

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