Multiphysics Simulation of a Circular-Planar Anode-Supported Solid Oxide Fuel Cell

Keyvan Daneshvar[1], Alessandro Fantino[1], Cinzia Cristiani[1], Giovanni Dotelli[1], Renato Pelosato[1], Massimo Santarelli[2]

[1]Politecnico di Milano, Dipartimento di Chimica, Materiali e Ingegneria Chimica "G. Natta", Milano, Italy
[2]Politecnico di Torino, Dipartimento di Energetica, Torino, Italy

Abstract

In this paper a 2D isothermal axisymmetric model of an anode-supported Solid Oxide Fuel Cell (SOFC) has been developed. Also a parametric analysis to find the effect of important parameters on the cell performance has been done. The geometry of the model with its mesh is illustrated in the (Figure 1). The meshing process has been done based on the importance of cell components and considering the low thickness of Positive Electrolyte Negative (PEN) structure of the cell in comparison with the dimensions of fuel and air channels. This simulation has been carried out at 1 atm and 1073 K, but has a potential to run in different ranges of pressure and temperature which could be tested in parametric analysis part. Also it is possible to trace the effect of cell length and PEN thickness on the cell performance by parametric study. The PEN materials are traditional ones: Ni-YSZ/YSZ/LSM-YSZ as anode, electrolyte and cathode respectively, but also model could use different material library, if it is needed in the future modeling. Of course with changing the materials, different specifications should be used in the new simulation. The developed model includes the following processes: electronic and ionic charge balance (Ohm's law), Butler-Volmer charge transfer kinetics, flow distribution in gas channels (Navier-Stokes), flow in the porous gas diffusion electrodes (GDEs) (Brinkman equations), mass balances in gas phase in both fuel and air channels and porous electrodes (Maxwell-Stefan diffusion and convection). So all forms of polarizations have been included in the simulation process. The simulation has been performed with the COMSOL Multiphysics software. Among the results of the simulation process, the most important ones are polarization and power density versus current density curves that show a good agreement with the experimental data (Figure 2). Because of multiphysics nature of the model, so far three different physics: secondary current distribution, transport of concentrated species and free and porous media flow have been applied in the simulation and some more modules such as heat transfer, chemical reaction engineering and CFD should be added to model to complete the other aspects of the simulation. Some other results of the present model are: electrolyte potential and current density profiles, mass fraction profiles of water vapor, oxygen and nitrogen in the cathode and air channel, mass fraction profiles of hydrogen and water vapor in the anode and fuel channel (Figure 3) and the 3D velocity and pressure profiles in the channels and PEN structure (Figure 4). Moreover, some improvements are expected in the next steps of modeling due to the extension of the model from 2D axisymmetric towards 3D geometry. Also a parametric study on the role of

material properties on cell efficiency will be carried out in the future.

Reference

1. Vinod M. Janardhanan, Olaf Deutschmann, CFD analysis of a solid oxide fuel cell with internal reforming: Coupled interactions of transport, heterogeneous catalysis and electrochemical processes, Journal of Power Sources, 162, 1192-1202 (2006).
2. Yixiang Shi, Ningsheng Cai et al, Numerical modeling of an anode-supported SOFC button cell considering anode surface reaction, Journal of Power Sources,164,639-648 (2007).
3. Yuanyuan Xie, Xingjian Xue, Multi-scale electrochemical reaction anode model for solid oxide fuel cells, Journal of Power Sources,209, 81– 89 (2012).

Figures used in the abstract

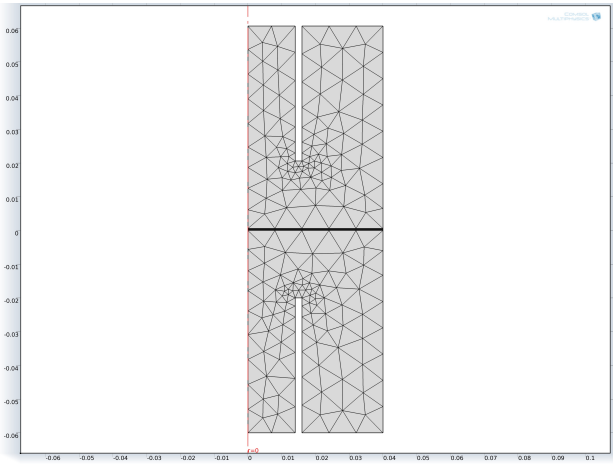

Figure 1: 2D axisymmetric geometry of the setup with its mesh.

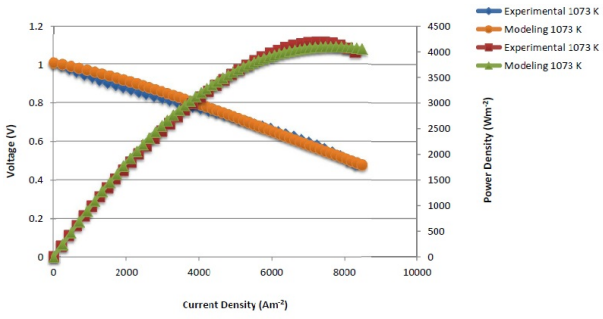

Figure 2: Polarization and power density vs current density curves.

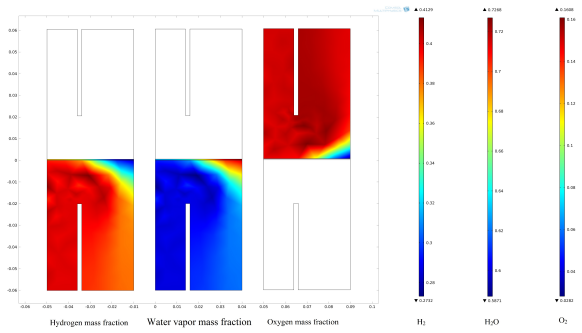

Figure 3: Hydrogen, water vapor and oxygen mass fraction profiles.

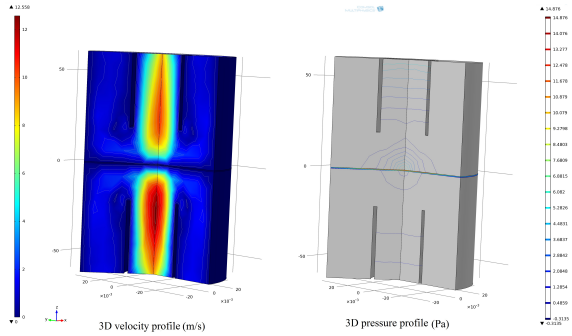

Figure 4: 3D profiles of velocity and pressure.