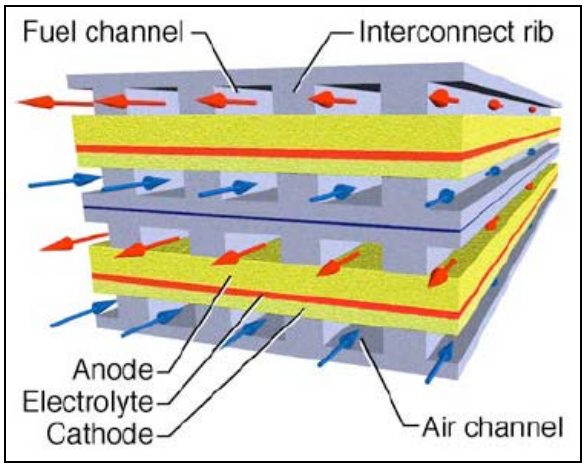
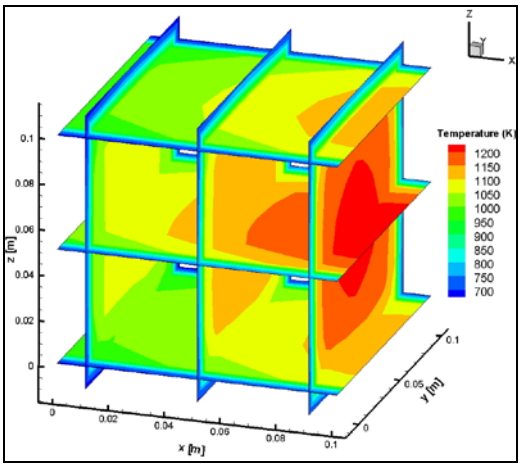
Solid Oxide Fuel Cells (SOFC): Transients in SOFC stacks

Background: Solid-oxide fuel cells (SOFCs) have gained substantial interest in recent time as high efficiency electrical sources. A unique combination of advantages such as high reaction kinetics, poison tolerance, utilization of inexpensive catalysts, high power density, fuel flexibility and low emissions have helped SOFCs find application in the automobile industry or in stationary/distributed power plants as auxiliary power units (APUs). These applications experience fluctuating loads, which inevitably results in the variable consumption of electrical power over time. To understand and overcome the challenges posed by SOFC technology, one has to understand the complex fundamental and functional interactions between various internal multi-physics based processes in addition to the transient responses. Transient behavior affects the system heat transfer, which then dominates the dynamics of electrochemical reactions occurring at the three-phase boundary (TPB), reforming/shift reactions, and gas-phase reactant temperatures.



SOFC stack, courtesy R. J. Kee



Steady-state internal temperature distribution of the 3D stack at different surface planes

Project: The timescales of various processes such as kinetics, diffusion, and heat transfer occurring in an SOFC stack are different from each other, and the heat transfer process has a higher time constant compared to the rest of the processes. Therefore, it is quite rational to assume all processes but heat transfer to be in steady-state. The approach is based on decoupling the solid phase temperature from that of the fluid phase, to develop the transient stack model, which solves the unsteady 2-D or 3-D heat conduction problem. A recently developed cluster algorithm is used that divides unit cells into clusters according to the differences in their local temperature profiles, and is based on the assumption that all cells with similar temperature profiles behave identically, in order to significantly reduce computation time. All unit cells of one cluster are then represented by one cell, for which in-depth simulation is carried out. The simulation applies detailed models for electro-chemical conversion at the three-phase boundary, an elementary heterogeneous reaction mechanism for the thermo-catalytic anode chemistry, the Dusty Gas Model to account for multi-component diffusion, and a plug flow model for flow through the channels.

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Selected publications: S. Tischer, O. Deutschmann, Catal. Today 105 (2005) 407; H. Zhu, R. J. Kee, V.M. Janardhanan, O. Deutschmann, D. Goodwin, J. Electrochem. Soc. 152 (2005) A2427; E. Hecht, G.K. Gupta, H. Zhu. A.M. Dean, R.J. Kee, L. Maier, O. Deutschmann. Appl. Catal. A: Gen. 295 (2005) 40; V.M. Janardhanan, O. Deutschmann. Chem. Eng. Sci. 62 (2007) 5473; V.M. Janardhanan, V. Heuveline, O. Deutschmann. J. Power Sources 178 (2008) 368; V.M. Janardhanan, O. Deutschmann. Electrochim. Acta (2011), doi:10.1016/j.electacta.2011.08.038; V. Menon, V.M. Janardhanan, S. Tischer, O. Deutschmann. A Novel Approach to Model the Transient Behavior of Solid-Oxide Fuel Cell Stacks. J. Power Sources, doi:10.1016/j.jpowsour.2012.03.114