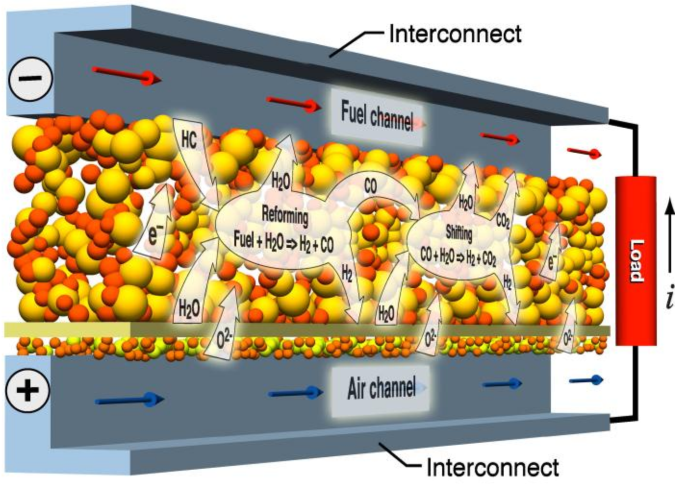
Solid Oxide Fuel Cells (SOFC)

Background: In the recent past fuel cells have gained the attention of scientists and engineers. They are ideal candidates for generating clean energy, a concept which is becoming increasingly important where global warming and related issues are of much concern. These chemical to electrical energy converting devices find application in numerous fields, from residential to space. Most of the fuel cells require H_2 as fuel, and hence the widespread use of these cells depends on the economic breakthrough of H_2 production and storage technologies. However, Solid Oxide Fuel Cells (SOFCs) are operated at higher temperature and, therefore, offer the possibility of running hydrocarbons on them with or without partial reforming. The efficiency and the performance of these cells depend on many operating parameters and the feed composition.



SOFC with direct internal reforming, courtesy of R. J. Kee

Project: Our research on fuel cells is focused on modeling of Solid Oxide Fuel Cells. Modeling of the processes within the cell is a challenging task since the cell performance is governed by the coupled interactions of mass transfer and heat transfer, chemistry, electrochemistry etc. Hence the approach adopted here is to couple the transport processes with detailed heterogeneous and electrochemistry. Furthermore the performance of the cell is also dependent of the flow configuration. Since planar SOFCs offer the possibility of three different flow configurations (co-current, counter-current and cross flow) it is important to study these effects on cell performance. The detailed chemistry within the anode of the cell is modeled by an elementary step surface reaction for Ni based catalysts. The electrochemistry is modeled by a modified Butler-Volmer formalism. However the electrochemistry model assumes that H_2 is the only electrochemically active species. Analyzing the temperature distribution within the cell is very important from chemical and mechanical point of view. Within a single channel level though one can study the temperature distribution under adiabatic conditions, in reality, however, the heat balances are much more complex, because the temperature boundary conditions are also dependent on the cell position within the stack. Nevertheless analysis on a single channel level can give instructive results on the variation of temperature within the cell due to endothermic reforming reactions and exothermic cell reactions.

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Selected publications: 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. Janardhanana, 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 Solid-Oxide Fuel Cell Stack. J. Power Sources, accepted