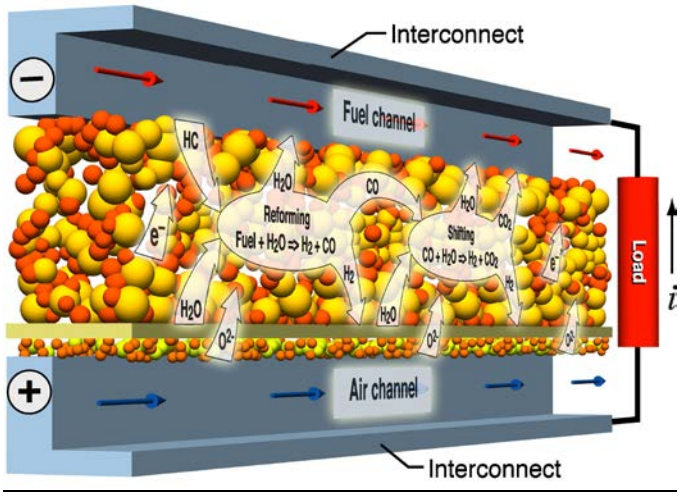
Solid Oxide Fuel Cells (SOFC): Direct internal reforming

Background: In the recent past, fuel cells have gained considerable 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 great concern. These chemical to electrical energy converting devices find application in numerous fields, from commercial/residential to aerospace. 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) operate at relatively higher temperatures and, therefore, offer the possibility of operation on hydrocarbons with or without partial reforming. The efficiency and performance of these cells depend on many operating parameters and feed compositions.



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

Project: Our research on fuel cells focuses on the 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 and heat transfer, chemistry, electrochemistry etc. Hence, the approach adopted here is to couple the transport processes with detailed heterogeneous chemistry and electrochemistry. Furthermore, the performance of the cell is also dependent on 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 using a modified Butler-Volmer formalism. However, the electrochemistry model assumes H_2 as the only electrochemically active species. Analyzing the temperature distribution within the cell is very important from a chemical and mechanical point of view. Although one can study the temperature distribution at a single channel level under adiabatic conditions, in reality, the heat balances are much more complex, because the temperature boundary conditions are also dependent on the cell position within the stack. Nevertheless, analysis at 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.

Co-workers: Vikram Menon, Steffen Tischer

Collaboration: V. M. Janardhanan, IIT Hyderabad/India, H. Zhu and R.J. Kee, Colorado School of Mines/USA

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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. 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