IOWA STATE UNIVERSITY
Department of Mechanical Engineering

Microscale "Turbulence" induced by Electrochemical Interfaces

Ali Mani
Department of Mechanical Engineering
Stanford University

Seminar on September 20, 2016 at 11:00 am in 2004 Black
Seminar host: Shankar Subramaniam

Abstract
Electrochemical interfaces, e.g., the interface of an aqueous electrolyte with a charge selective surface such as an electrode or a membrane, are host to a range of physical phenomena involving ion-transport, electrostatic interactions, and fluid flow. The equations governing these disciplines are the Nernst-Plank, Poisson, and Navier-Stokes, which are well established for more than a century. Analytical solutions to these equations have contributed to the understanding of various interfacial phenomena such as electric double layers, electroosmosis, and diffusion boundary layers. However, only very recently direct numerical solutions to these equations have become available. Such simulations allow investigation of nonlinear modes of transport, and have revealed a wide range of highly complex dynamical responses. In this presentation, we consider voltage-driven ion transport from an aqueous electrolyte to an ion-selective membrane as a canonical setting with broad applications from electrodialysis for water purification to microfluidic-based lab-on-a-chip systems. We will present results from our numerical simulations demonstrating that, beyond a threshold voltage, such interfaces trigger hydrodynamic chaos with multi-scale vortices similar to turbulent boundary layers. Namely, structures with scales from sub-millimeter down to tens of nanometers can be formed as a natural result of these hydrodynamic effects. These flow structures are shown to impact mixing and enhance net ion transport well beyond nominal diffusion-controlled limiting currents. While predictions of these simulations are consistent with recent experimental observations, simulations allow for non-intrusive capture of fine spatiotemporal details in these flows. We will demonstrate the need for the development of specialized algorithms for computation of these systems, similar to the tools that have been traditionally used for the simulations of turbulent flows. Such calculations require resolving a wide range of scales using unsteady solvers and often require massively parallel computational resources. By presenting various examples, we will discuss how the development of high-fidelity computational tools can lead to fundamental understanding of complex effects in electrochemical interfaces and facilitate their design and optimization.

Dr. **Ashok Gadgil** has a doctorate in physics from UC Berkeley. He is Deputy for Science and Technology for the Energy Technology Area of Lawrence Berkeley National Laboratory, and a Professor of Civil and Environmental Engineering at UC Berkeley. He has substantial experience in technical, economic, and policy research on energy efficiency and its implementation — particularly in developing countries. For example, the utility-sponsored compact fluorescent lamp leasing programs that he pioneered are being successfully implemented by utilities in several east-European and developing countries. He has several patents and inventions to his credit, among them the "UV Waterworks," a technology to inexpensively disinfect drinking water in the developing countries, for which he received the Discover Award, as well as the Popular Science award for "Best of What is New". In recent years, he has worked on ways to inexpensively remove arsenic from Bangladesh drinking water, and on fuel-efficient stoves for Darfur. Among recent honors, Prof. Gadgil is elected a member of the National Academy of Engineering, recipient of the Zayed Future Energy Prize, and the Lemelson-MIT Lifetime Award for Innovation.

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.

www.me.iastate.edu