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Distinguished Seminar Speaker

The Potential and Potentials of Electrochemistry: From Nonequilibrium Thermodynamics to Energy, Electrosynthesis, and Electric Aviation

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Abstract: Electrochemistry is a way to break and form chemical bonds with voltage, and subsequently to regulate reactions by tuning electron chemical potential rather than by raising temperature or pressure. That capability has enormous potential to reshape chemical engineering, from electrified manufacturing and electrosynthesis to energy conversion and storage that could enable new performance regimes (high power and high energy) and emerging applications such as electric aviation. But the same feature that makes electrochemistry powerful, also creates a steep learning curve: electrochemistry relies on a family of distinct potentials that are not interchangeable, yet are often blurred together in practice. Such confusion may lead to wrong interpretations of measurements and wrong design choices.

This seminar first builds a practical map of the potentials in electrochemistry, including chemical potential, electrostatic potential, electrochemical potential, reduced electrochemical potential (voltage scale), electrode potential, and overpotential, including their physical significance and how they connect thermodynamics, transport, and kinetics. With that foundation, we advance the seminar with frontiers in energy and power, entailing ultrahigh-efficiency electricity generation, high-power/high-energy storage, and electrosynthesis routes relevant to GTL (gas-to-liquid), emphasizing how a rigorous “potential framework” can guide materials selection, stability, and system design to achieve record-breaking power density, stability, and energy conversion efficiency.

We then turn to the potential of electrochemistry by using nonequilibrium thermodynamics to move from equilibrium intuition to nonequilibrium reality: an area we have been working on for several years. In an active electrochemical system, interfacial, kinetic, and transport-related potential drops (including overpotentials, ohmic losses, and concentration polarization) often determine selectivity, efficiency, and durability. Within this framework, global nonequilibrium, together with the local thermodynamic equilibrium theorem, provides a basis for defining meaningful local state variables (e.g., chemical and electrochemical potentials) even under gradients, enabling quantitative treatment of the power-durability coupling in electrochemical environments.

Biography: Professor Xiao-Dong Zhou is the Connecticut Clean Energy Fund professor of Green Hydrogen and Fuel Cells, The Nicholas E. Madonna Chair in Sustainability, Director of the, Center for Clean Energy Engineering, and a Professor in Chemical and Biomolecular Engineering, Mechanical Engineering, and Materials Science and Engineering at University of Connecticut. He is a special advisor to UConn President Radenka Maric in Sustainability. Dr. Zhou received *J. B. Wagner Jr. Young Investigator Award* in 2007 from the Electrochemistry Society (ECS) - High Temperature Materials (HTM) Division. He is the recipient of 2011 US DOD – DARPA Young Faculty Award. He is a Fellow of the Electrochemical Society and Connecticut Academy of Science and Engineering. His research interests span theoretical and experimental studies of materials and interfaces for energy systems, including batteries, fuel cells, and electrolyzers.