UC San Diego
JACOBS SCHOOL OF ENGINEERING
Aiiso Yufeng Li Family Department of Chemical and Nano Engineering

Aiiso Yufeng Li Family Department of Chemical and Nano Engineering

Department Seminar

Wednesday, October 22, 2025
11:00am – 12:pm PT
SME 248

Dr. Tao Gao, PhD

"Physical Insights into Critical Phenomena in Electrochemical Systems for Next-Generation Energy Storage and Beyond"

Assistant Professor
Department of Chemical Engineering
University of Utah

Abstract: Electrochemical systems play a vital role in diverse applications, including energy storage and advanced manufacturing. A deep physical understanding of thermodynamics, kinetics, and transport phenomena in these systems is essential for rational design and engineering—both to enhance performance and reduce cost in electrochemical technologies, and to improve efficiency and scalability in electrochemical processes.

In the first part of this talk, I will discuss the electrochemical reduction of transition metal cations (M^{2+}) in aqueous electrolytes—an area with significant implications for low-cost battery technologies and sustainable ironmaking. A long-standing observation in the field is that electrolyte composition has a strong influence on the Faradaic efficiency of these reactions. Our recent studies reveal that this enhancement is not only due to the commonly cited suppression of water reduction reactivity (H_2O/H_2), but also stems from changes in the intrinsic reactivity of the metal cation redox couple (M^{2+}/M), driven by strong ion–ion interactions. We derived a chemistry-agnostic physical model that captures this behavior and quantitatively predicts the thermodynamic shifts of transition metal redox potential across a wide range of electrolyte compositions and for various transition metals.

In the second part of the talk, I will turn to lithium plating—a critical phenomenon that dictates the cycle life, safety, fast-charging capability, and low-temperature performance of lithium-based batteries. I will first address long-standing ambiguities surrounding the onset mechanism of lithium plating in conventional lithium-ion batteries, examine the physical principles that govern lithium morphology in lithium metal batteries.

Together, these two case studies highlight how mechanistic and physical-model-based approaches can guide new pathways for electrolyte design and performance optimization in electrochemical systems.

Bio: Dr. Gao obtained his BS/MS from Tsinghua University, PhD from University of Maryland, College Park with Prof. Chunsheng Wang, and postdoc training from MIT with Prof. Martin Bazant. He is currently an assistant professor at the Department of Chemical Engineering, University of Utah, and the PI of the Multi-scale Electrochemical Engineering (ME2) Lab. His lab studies electrochemical technologies/processes for energy and manufacturing applications, including rechargeable batteries, electrolytic ironmaking, critical material extraction, etc. He has published over 80 papers in journals including Science, Nature Communication, Joule, etc. He has an H-index of 60, with a total citation of more than 22, 000. He is the recipient of NSF CAREER Award (2025), Highly Cited Researcher Recognition by Clarivate (2022-2024), the Emerging investigator Award by Journal of Material Chemistry (2023), the American Chemical Society (ACS) Energy and Fuel Division Early Career Investigator Award (2022), the Rising Star of Science Award by research.com (2022), and Dean's Dissertation Fellowship at University of Maryland (2016).

Seminar Host: Zheng Chen