Materials Innovation for Multivalent and Solid-state Batteries

Yan Yao

Professor of Electrical and Computer Engineering and Texas Center for Superconductivity
University of Houston, Houston, TX

Abstract: The global clean energy industry relies heavily on lithium-ion batteries. As electric vehicles and grid energy storage continue to gain market share, the United States is expected to increasingly rely on imported raw materials (nickel and lithium) for lithium-ion batteries due to the lack of domestic production. Therefore, innovative battery chemistry that goes beyond lithium-ion is needed, as well as the discovery and design of new materials that can be domestically produced to make safe, sustainable, fast-charging batteries at terawatt scale. In this seminar, I will begin with an overview of organic battery electrode materials made from abundant elements. I'll demonstrate how organic materials can offer unique advantages in magnesium and solid-state batteries. For Mg batteries, organic electrode materials address the challenge of sluggish divalent cation dissociation and diffusion through a heterogeneous enolization chemistry that involves carbonyl reduction. In solid-state batteries, soft organic crystals maintain intimate interfacial contact with solid electrolytes, even after thousands of cycles under low stacking pressure. I will also discuss a low-cost, easy-to-fabricate oxysulfide glass solid electrolyte that exhibits electrochemical stability against Na metal.

Bio: Dr. Yao is the Hugh Roy and Lillie Cranz Cullen Distinguished Professor at the University of Houston. He obtained B.S. and M.S. degrees from Fudan University, China, and Ph.D. degree in Materials Science and Engineering from UCLA in 2008 with Professor Yang Yang. After working in industry for two years and as a postdoc at Stanford University with Professor Yi Cui, he joined the Department of Electrical and Computer Engineering at University of Houston as an Assistant Professor in August 2012. He established an internationally recognized research program focusing on bridging electrochemistry with materials design and synthesis for beyond lithium-ion batteries, including aqueous organic batteries, magnesium batteries, and solid-state sodium batteries, which could have enormous impacts on environmental and energy sustainability.

Dr. Yao has published over 150 scientific articles and has been issued twelve US patents and established two startup companies. He serves as the Principal Investigator for several core battery programs in DOE. He has received numerous awards, including the Career Innovator Award (2024), Texas Academic Leadership Academy Fellow (2023), Senior Faculty Research Excellence Award from the University of Houston (2022), Highly Cited Researchers list by Clarivate Analytics (2021), Scialog Fellow on Advanced Energy Storage from Research Corporation (2017), and Office of Naval Research Young Investigator Award (2013). He is Fellow of the Royal Society of Chemistry (UK) and IAAM, and a senior member of both National Academy of Inventors (NAI) and the Institute of Electrical and Electronics Engineers (IEEE).