UNIVERSITY OF CALIFORNIA, IRVINE

Department of Materials Science and Engineering

Towards High-Energy and High-Power Electrochemical Energy Storage Through Electrolyte Convection

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Abstract: Ubiquitous in portable electronics and emergent in transportation and grid applications, lithium (Li)-ion batteries represent the state-of-the-art in electrochemical energy storage technology due to their energy density, efficiency, and cycle life. While the past decade has seen a steady decline in battery price and concomitant increase in energy density, current Li-ion batteries are still unable to meet the often-incongruous requirements of emerging applications, which often call for both high-energy and high-power capabilities (e.g., long driving range *and* fast charging in electric vehicles). A common limitation under such operating conditions is electrolyte transport, where a spatial gradient in salt concentration develops across the electrochemical cell. Such concentration extremes contribute to numerous failure modes in batteries including Li metal plating and dendrite growth, salt precipitation, and electrolyte degradation. These processes can also lead to increases in heat generation, which, if uncontrolled, can lead to thermal runaway, constraining cell design and necessitating advanced battery management systems. While significant research efforts have been dedicated to advancing innovative new electrode materials and electrolyte formulations with improved property profiles, decidedly fewer efforts contemplate re-engineering the cell format to support the heat and mass transfer conditions necessary for higher-performing energy storage.

Here, I will present on convection-enhanced electrochemical energy storage as a means of enabling high power operation without sacrificing accessible capacity. In this configuration, the spatial gradients formed during discharge/charge operation are overcome by forced electrolyte convection through the porous electrodes and separator. This approach has several important potential advantages over traditional cell formats including: (1) electrodes with an increased and controllable range of operation, (2) improved battery safety and maintenance, (3) simplifications to manufacturing, and, ultimately, (4) reduced system costs. Importantly, this may also unlock opportunities in materials research, including compounds whose characteristics properties do not perfectly align with application needs (e.g., electrolytes with low diffusion coefficients, low-capacity, high-rate active materials). Given the novelty of this approach and the breadth of the parameter space involved, this presentation will emphasize mathematical models that simulate dynamic behavior of the cell over a range of conditions to elucidate the fundamental relationships that connect constituent materials properties to electrochemical performance.

Bio: Fikile Brushett is an Associate Professor in the Department of Chemical Engineering at the Massachusetts Institute of Technology where he holds the Cecil and Ida Green Career Development Chair. Before joining the Institute, he received his Ph.D. in Chemical Engineering from the University of Illinois at Urbana-Champaign and performed postdoctoral work in the electrochemical energy storage group at Argonne National Laboratory. His research group seeks to advance the science and engineering of electrochemical technologies that enable a sustainable energy economy. He is especially interested in the fundamental processes that define the performance, cost, and lifetime of present day and future electrochemical systems. His group currently works on rechargeable batteries for grid energy storage and electrochemical processes for carbon management. He also serves as the Research Integration Co-Lead for the Joint Center for Energy Storage Research, a DOE-funded Energy Innovation Hub.