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Meet the Faculty Candidate

Engineering polymer materials for the energy-water nexus: new chemistries, in-situ diagnostics, and directed self-assembly

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Polymer electrolyte membranes (PEMs) are found at the heart of membrane electrode assemblies (MEAs) and they are central to the performance of electrochemical energy conversion and storage devices in polymer electrolyte fuel cells, water electrolyzers, flow batteries, supercapacitors, and reverse electrodialysis. They are also essential to electrodialysis processes used for water desalination and purifying industrial effluent streams. Two of the most stringent requirements for PEMs are exceptional ionic conductivity, which is paramount to device efficiency, and longevity. This poster will cover research strategies for addressing PEM chemical stability and ionic conductivity through i.) the synthesis of new PEM chemistries, ii.) elucidating material performance and degradation in electrochemical systems using *in-situ* diagnostics, and iii.) the adoption of block copolymer directed self-assembly (DSA) for creating ordered, periodic architectures with high degree of functionality. These strategies will be illustrated through three different case studies. The first two parts of the poster stem from my Ph.D. work with Professor Vijay Ramani at the Illinois Institute of Technology, while the latter part highlights my current postdoc work with Professor Nealey at the University of Chicago.

Part 1 of the poster describes the use of a micro, *in-situ* bifurcated optical fluorescence probe for monitoring the reactive oxygen species (ROS) generation in an operating PEM fuel cell. Chemical degradation of the proton exchange membrane observed by fluorescence response correlated with the macroscopic fluoride ion flux rate collected from the water emanating from the fuel cell. The latter technique substantiated the accuracy of the *in-situ* probe for real-time monitoring of PEM degradation. This part of the poster will also describe mitigation of reactive oxygen species degradation through the incorporation of mixed-metal oxide nanoparticles that scavenge the free radicals in the PEM.

In part 2, the chemical and mechanical stability of anion exchange polymer electrolyte membranes (AEMs) for alkaline fuel cells and water electrolyzers and redox flow batteries will be highlighted. Understanding AEM alkaline stability will be demonstrated through a best practices approach that leverages multidimensional NMR spectroscopy, membrane mechanical analysis, examination of AEM electrochemical cell stability using a variety of electroanalytical techniques, and post-mortem NMR analysis of MEAs. Additionally, chemical structure-property relationships for mitigating chemical degradation of AEMs in alkaline electrochemical systems will be given.

The final part of the poster will showcase research for improving PEM conductivity by orienting periodic, ion-conducting domains in diblock copolymer electrolytes perpendicular to electrode surfaces using DSA. Other extensions of this powerful technique, such as creating periodic patterned arrays of electrocatalyst nanoparticles and fabrication of miniaturized electrochemical devices (e.g., micro-supercapacitors) will be disseminated.

My future academic career seeks to compliment my background in electrochemical engineering and polymer chemistry from my Ph.D training with polymer physics and lithography/nanolithography learned in my postdoc work. From my point of view, amalgamating these different skill sets will lead to new classes of functional and resilient materials for the energy-water nexus and efficient micro-electrochemical systems for portable consumer products. The independent, academic program I am aim to build will cut across a multitude of different disciplines spanning the fields of chemical engineering, materials science, physics, chemistry, and mechanical engineering. My vision is to construct a team with students and research professionals with diverse backgrounds in addition to fostering collaborative alliances with researchers worldwide.