University of Nebraska Lincoln | NEBRASKA CENTER FOR ENERGY SCIENCES RESEARCH

Cycle 11
January 2017

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Storing Renewable Energy for Nebraska and Beyond Using Vanadium Flow Batteries

Abstract.

The United States energy consumption is predicted to increase 56% by 2040. Renewable-energy based upon wind and solar may help us meet future energy demands with economical and scalable energy storage using a vanadium redox flow batteries (VRB) (Fig. 1). A VRB uses V^{2+}/V^{3+} redox couples at the negative electrode, and VO^{2+}/VO_2^{+} electrochemical reactions at the positive electrode to store and release energy. This proposed research effort will couple experimental materials research with computational methods in order to direct multi-block poly(phenylene) ionomer design and VRB function. Advanced materials are necessary in order to create materials that simultaneously provide high proton conductivity, excellent chemical stability, low areal and internal electrical resistivity, superior physical properties, and selective proton transport versus vanadium ions. The material challenge is related to uncoupling these compositionally dependent properties and ion transport. Computational modeling offers a unique tool to delineate these effects in order to focus upon the phenomenon. This will greatly complement experiments by providing atomic-scale insights into the underlying mechanisms corresponding to structure, transport, and function. The proposed work has the potential to advance the basic science associated with ionomer composition, morphology, ion transport, and VRB energy storage. Although a multitude of ionomer membranes have been analyzed, an in-depth evaluation of compositional dependencies, energy capacity, and durability are lacking. These efforts are needed in order to develop selective ionomers using composition and spatial distribution of functional groups for reliable and scalable energy storage. This proposed research will create fundamental knowledge linked to nanostructured ionomer design. These results are necessary in order to advance new battery concepts for Nebraska and our Nation as it begins to adopt greater renewable-energy technologies.