Inexpensive Flow Batteries Based on Organic Redox Couples

Bo Yang, Lena Hoober-Burkhardt, G. K. Surya Prakash, and S. R. Narayanan*
Loker Hydrocarbon Institute, Department of Chemistry, University of Southern California, Los Angeles, CA 90089

Batteries for large-scale energy storage must be inexpensive, robust, environmentally friendly and sustainable. None of today's mature battery technologies meet all these requirements. Our goal is to provide a transformational solution to this challenge. To this end, we have focused on developing an aqueous flow battery that uses organic redox couples that have the potential to meet the demanding cost, durability, eco-friendliness, and sustainability requirements for grid-scale electrical energy storage. In this battery two different aqueous solutions of organic redox substances such as "quinones" are circulated past electrodes. The positive and negative electrodes are separated by a polymer electrolyte membrane. By choosing the appropriate quinone compounds a redox potential as high as 1.0 V can be achieved. One of the advantages of this organic redox flow battery is that it does not need any heavy metals such as vanadium, chromium or zinc. Additionally, the volatile organic solvents such as those used in lithium batteries are avoided.

While redox properties of a variety of organic compounds such as quinones have been known to electrochemists for many years, hardly a handful of these couples have been exploited in batteries. To our knowledge none of these couples have been considered for a large-scale, inexpensive and eco-friendly energy storage system. The quinones have a charge capacity in the range of 200-490 Ah/kg, and cost about $5-10/kg or $10-20/kWh, leaving ample scope for achieving the DOE-mandated target of $100/kWh for the entire battery system.

In preliminary results we have shown that quinones exhibit good reversibility in acidic media. An example of this is seen in the cyclic voltammogram of anthraquinone sulfonic acid (Figure 1). An organic redox flow battery using two different quinones shows sustained cyclability at high charge and discharge rates (Figure 2).

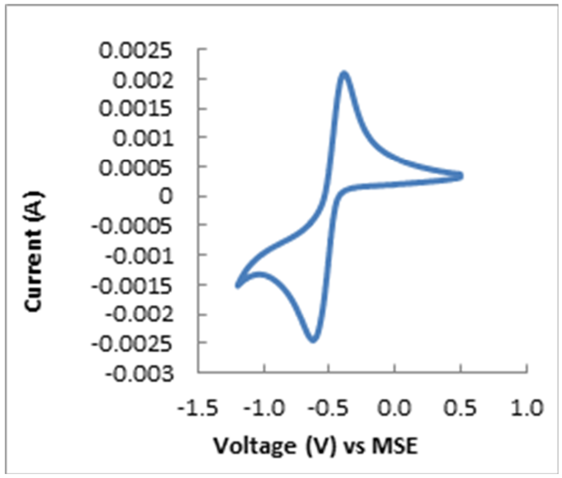

Figure 1: Cyclic voltammogram of 10 mM anthraquinone sulfonic acid at a scan rate of 50 mV/s at a glassy carbon electrode. Electrode potentials measured vs. a mercury sulfate reference electrode (MSE).

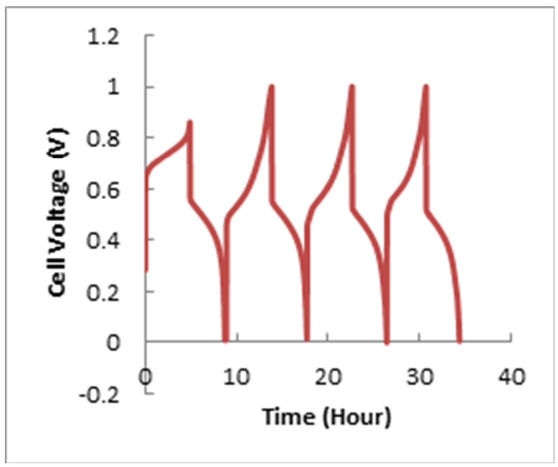

Figure 2: Reversible charge and discharge cycles at 25 cm^2 redox flow cell with 10 mM of two types of quinones being charged and discharged at 50 mA.

We will present results on the electrochemical properties of various quinones in acid media in an electrochemical half-cell and in full redox flow cells.

Acknowledgement
The work presented here was carried out with funding from ARPA-E and the University of Southern California.