Project # 2: Electrocatalytic Energy Conversion at the Interfaces of Hybrid Carbon-Bismuth Nanoparticle Assemblies

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**ABSTRACT**

*Project Context.* Significant strides are being made to enhance the efficiency of energy generation using sustainable and abundant sources such as the wind and sun. Over the last 25 years, solar panel efficiency has increased from about 14% for crystalline Si cells to about 44% for multijunction cells [1], while worldwide electricity generation from wind has increased by two orders of magnitude [2]. A lingering problem that limits the economic viability of these technologies is the need to store vast amounts of energy whenever supply exceeds demand so as to balance the energy needs when the sun is not shining or the air is stagnant. Liquid chemical energy storage using redox flow batteries has been proposed as a method to meet this need [3]. However, all-vanadium and iron/chrome redox systems have been limited by low chemical energy conversion rates due to the inefficiency of available carbon felt and carbon fiber catalysts. More active yet sustainable catalysts are being sought and research efforts in this area are well-aligned with the grand challenge identified by the NAE to make solar energy economical. Recently, alternative electrocatalysts using earth-abundant materials such as highly dispersed carbon nanoparticles alone [4] or in hybrid assemblies with bismuth (Bi) nanoparticles have shown promising results in bench-scale experiments [5]. The key objective of this project is to investigate, for the first time, the operational efficiency of redox flow batteries with well-defined electrodes that have been constructed using these novel catalyst systems. Electrochemical conversion occurs at the interfaces of these highly networked structures.
**Project Description.** Integration of electrocatalytic carbon nanoparticle assemblies into working redox flow batteries will be conducted in the first year. Electrostatic assembly is a specialty of our research group [6] and will be used to create the necessary electrodes. Figure 1(a) shows a high magnification image of the surface of such a nanoparticle structure; while Figure 1(b) provides the associate lab scale performance as a function of the number of nano-particle layers deposited; and while Figure 1(c) shows the vanadium solution that will be employed by the students. Students will incorporate the structures shown in Figure 1(a) into functioning batteries.

**Facilities to be Used.** Research will be conducted at the AC’s state-of-the-art electrochemical laboratory located in ERC 671. Instrumental techniques include cyclic voltametry with impedance characterization of operating redox flow batteries. Spectroscopies and microscopies to characterize electrode structure are also available on-site.

**Research Content Training.** Students will be trained by both the AC, SAC and AC’s research assistant on the operation of all required instrumental methods. A field-trip is planned to Mound Technical Solutions in Miamisburg, Ohio. This local company provides outstanding analytical instruments in the area of energy generation and storage to government, academia, and industry.

![Electron microscopy image of the surface of a 50-layer carbon nanoparticle electrode.](image1a.png)

![Cyclic voltogram as a function of the number of nanoparticle layers (0 to 100) at a sweep rate of 10 mV/sec.](image1b.png)

![Vanadium solution.](image1c.png)

**Figure 1.** (a) Electron microscopy image of the surface of a 50-layer carbon nanoparticle electrode. (b) Cyclic voltogram as a function of the number of nanoparticle layers (0 to 100) at a sweep rate of 10 mV/sec. (c) Vanadium

**References**


