DREXEL UNIVERSITY
Materials Science and Engineering
College of Engineering

Department of Materials Science and Engineering

PhD Defense

Friday, July 21st, 11 AM EST
Hill Conference Room (Lebow 240)

Creating a Two-Dimensional Heterointerface in Layered Oxide Electrodes for Advanced Electrochemical Energy Storage

Name: Ryan Andris
Advisor: Dr. Ekaterina Pomerantseva

Abstract

Secondary batteries are an important area of research to help create grid-scale energy storage solutions and improvements in smaller devices for use in electric vehicles and laptops. Various transition metal oxides have been studied extensively in these electrochemical systems due to their high theoretical capacity, low toxicity, and high natural abundance. Vanadium oxide is of particular interest due to vanadium's high redox activity in reversible charge storage reactions and its wide range of morphologies and structures. However, metal oxides are limited by their inherent low conductivity that can negatively impact rate performance and long-term stability.

Therefore, this dissertation generates new knowledge needed to synthesize stacked 2D heterostructures combining bilayered δ-$V_2O_5 \cdot nH_2O$ and conductive carbon-based materials using 'bottom-up', 'hybrid', and 'top-down' approaches to enhance bilayered vanadium oxide's electrochemical performance in energy storage systems. The 'bottom-up' approach intercalates small organic molecules into the interlayer region of BVO that are subsequently carbonized using hydrothermal treatment. The 'hybrid strategy integrates small organic molecules into a BVO xerogel using a post sol-gel diffusion process. Again, these molecules are subsequently carbonized using heat treatment processing. Finally, stacked 2D heterostructures are synthesized using 'top-down' cation-driven assembly of exfoliated BVO and graphene oxide nanoflakes. The combined phases with increased electronic conductivity can lead to improved charge storage capability, faster charging, and longer lifetimes. Relationships between the heterostructure synthesis, the final structure, properties, and the electrochemical performance of each material are examined to use this knowledge to create improved electrodes for energy storage devices.