DREXEL UNIVERSITY
Materials Science and Engineering
College of Engineering

Department of Materials Science and Engineering

PhD Dissertation Defense

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Understanding the Role of MXenes as Synthetic Precursors for Advanced Energy Storage Materials

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Secondary batteries, such as the Li-ion battery, have been identified as a critical technology for the pursuit of advanced energy storage systems. However, in the wake of environmental and societal concerns related to Li-ion batteries, new materials and energy storage solutions are being pursued to enable operational diversity within the energy storage industry. Bilayered vanadium oxide has been identified as a viable cathode active material for secondary batteries through its high theoretical capacities and compositional tunability. Recent developments in BVO performance have been marked by use of transition metal carbides, or MXenes, as synthetic precursors. Despite this, the conversion from MXene to oxide is still poorly understood, and their capabilities in beyond Li-ion systems have limited demonstration.

In this dissertation, I discuss the use of two-dimensional (2D) transition metal carbides (MXenes) as promising precursors for the synthesis of advanced oxide cathode materials for batteries. The nanoscale 2D morphologies and unique surface chemistries of MXenes enable facile transformation into high-performance oxides. First, I will show how modifying the MXene transition metal chemistry promotes new electrochemical behavior of derived oxides in lithium-ion batteries. Introducing multiple transition metals during MXene synthesis enables the doping of one transition metal into the oxide structure after conversion that unlocks new electrochemical behavior in Li-ion batteries. Second, I will demonstrate how etchant composition used for MXene synthesis causes downstream effects on electrochemical properties of MXene-derived oxides in potassium-ion batteries. The surface chemistry of MXene affects oxide properties after transformation, with proper etching control leading to better capacities and stability during K-ion cycling. Third, I will highlight how MXenes can transform into oxides with novel morphologies that enable high performance in aqueous zinc-ion batteries. Existing oxide compositions can be realized in new MXene-reliant forms that, with proper electrolyte selection, can lead to superior Zn-ion cycling performance. My findings show the versatility of MXene-based synthesis of promising active materials in advanced battery systems.