An Adventurous Journey of Exploring Atoms in a Nanostructure World of Materials: A Transmission Electron Microscopy Study

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Transmission electron microscopy (TEM) is unique among material characterization methods in that it allows for direct imaging of atomic structure and defects. With the invention and development of aberration correctors over the last 15 years, TEM now possesses the ability to image individual atoms and directly identify structure at sub-Ångstrom length scales.

In Professor Nasim Alem's research group at Penn State, our work focuses on using TEM as a tool to understand material behavior and properties in unique functional materials. We study atomic structure and defects, connecting local structural deformations to changes in electronic, chemical, ferroelectric, and other emergent properties. We also apply spectroscopic tools within the TEM to further understand local variations in chemistry and electronic structure. Where possible, we also apply innovative data processing and machine learning techniques to push the boundaries of information that can be extracted at the atomic scale.

Current projects in the group vary across a range of material types and collaborations. At Penn State, this includes collaborations through the Materials Research Science and Engineering Center (MRSEC) to understand atomic structure in novel high-entropy oxides and ferroelectrics. Externally, projects include a Department of Energy funded project studying hybrid metal halide perovskites and a U.S. Air Force funded work on the wide bandgap semiconductor beta gallium oxide (β-Ga_2O_3). Hybrid inorganic-organic perovskites show promise for use in improving solar cell performance, while β-Ga_2O_3 has been identified as a low-cost successor to silicon carbide and gallium nitride for use in applications requiring high temperatures and high electric fields.