“Nanoscale imaging of electrochemical energy conversion and storage systems”

Energy needs and environmental trends demand a large-scale transition to clean, renewable energy. Nanostructured materials are poised to play an important role in this transition. However, nanomaterials are chemically and structurally heterogeneous in size, shape, and surface structural features. My research group focuses on understanding the correlation between nanoparticle chemistry/structure and functional properties. The first part of my talk will focus on elucidating charge storage mechanisms in nanoscale materials, which underlies the performance of electrochemical technologies such as batteries and smart windows. I will discuss our high-throughput electro-optical imaging method that measures the battery-like and capacitive-like (i.e., pseudocapacitive) charge storage contributions in single metal oxide nanoparticles. I will present our recent single particle-level measurements that show (1) individual particles exhibit different charge storage mechanisms and (2) particle size-dependent pseudocapacitive charge storage properties. The second part of my talk will focus on solar energy conversion using ultrathin semiconductors such as monolayer-thick (ML) two-dimensional (2D) materials such as MoS2 and WS2. ML semiconductors represent the ultimate miniaturization limit for lightweight and flexible power generation applications. However, the underlying solar energy conversion processes in 2D materials is not entirely understood. We developed a correlated laser reflection and scanning photocurrent microscopy approach to study how layer thickness and surface structural features (edges versus basal planes) influence solar energy conversion efficiency. I will highlight our photocurrent microscopy study that revealed how layer stacking order in heterojunction photoelectrodes influences charge separation, transport, and recombination pathways.