Optical/Electronic Heterogeneity of WSe$_2$ at the Nanoscale
Kyoung-Duck Park, Omar Khatib, Vasily Kavtsov, Ronald Urbricht, Department of Physics, Department of Chemistry, and JILA, University of Colorado at Boulder, Genevieve Clark, Xiaodong Xu, Department of Physics, Department of Materials Science and Engineering, University of Washington at Seattle, Markus Raschke, Department of Physics, Department of Chemistry, and JILA, University of Colorado at Boulder — Many classes of two-dimensional (2D) materials have emerged as a potential platform for novel electronic and optical devices. However, the physical properties are strongly influenced by nanoscale heterogeneities in the form of nucleation sites, defects, strains, and edges. Here we demonstrate nano-optical imaging of the associated influence on structure and electronic properties with sub-20 nm spatial resolution from combined tip-enhanced Raman scattering (TERS) and photoluminescence (TEPL) spectroscopy and imaging. In monolayer WSe$_2$ micro-crystals grown by physical vapor deposition (PVD), we observe significant variations in TERS and TEPL near crystal edges and atomic-scale grain boundaries (GBs), consistent with variations in strain and/or exciton diffusion. Specifically, theoretical exciton diffusion lengths (25 nm) at GBs and heterogeneous nanoscale (30-80 nm) PL emission including a spectral blue-shift at edges are experimentally probed. Further, we are able to engineer the local bandgap of WSe$_2$ crystals by dynamic AFM-control in reversible (24 meV) and irreversible (48 meV) fashions, enabling systematic in-situ studies of the coupling of mechanical degrees of freedom to the nanoscale electronic properties in layered 2D materials.

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