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(Dis)order in the court: Probing Imperfections in Quantum Materials with Monochromated EELS

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Two-dimensional (2D) compound semiconductors and dielectrics exhibit a range of levels of disorder dependent on their stoichiometry, which can be engineered based on growth conditions, substrate interactions, or atom-by-atom modifications with charged projectiles. There is an entire framework of studies that builds upon research dedicated towards the associated properties with heterogeneities in films, but fail to make one-to-one correlations with the atomic arrangement of the lattice and the optical/infrared emissions. In this talk, we first use aberration-corrected scanning transmission electron microscopy (STEM) to visualize the atomic sites, then machine learning to map out the positions and relative displacement of the atoms in the vicinity of defects. Next, core-loss electron energy loss spectroscopy (EELS) is used to determine the global and local composition, as well as localized carbon and oxygen impurities to unveil their role in stabilizing strain-driven polymorph. Last, monochromated EELS inside an aberration-corrected STEM is used, which greatly reduces the energy distribution of the electron source to maximize the energy resolution without sacrificing too much spatial resolution. Accordingly, we map the high-frequency vibrational modes and exciton complexes in transition metal dichalcogenides (TMDs) and barrier layers in Josephson junctions using off-axis EELS to correlate the impact single-atom modifications have on the vibrational and optical spectrum. Ultimately, we address applications ranging from quantum sensors to thermoelectric junction devices.

Topical Area

Emerging research and multimodal techniques

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