Hyperspectral mapping of optoelectronic properties at length scales that matter in 2D and 3D semiconductors

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My group focuses on investigating and controlling light-matter interactions in solid state materials at length scales relevant to their critical properties and processes. We are particularly interested in understanding the nano- and meso-scale interactions between localized states in materials, and relating these properties with system and device functionality. We do this by correlating spatially-dependent physical properties (e.g. electronic structure) with chemical and/or biological information (e.g. molecular composition, reaction rates and dynamics) and morphological structure.

Most of this talk will center on our recent efforts in probing exciton properties in the 2D semiconductor transition metal dichalcogenides (TMDCs). I will first discuss our efforts aimed at the nano-optical investigation of these materials, where we uncover new optoelectronic regions and spatially-varying features that were hidden in prior optical studies. Complementary to the near-field measurements, we also performed hyperspectral photoluminescence-excitation (PLE) mapping of TMDCs, which enables us to directly probe excited state properties, revealing charge puddling, unexpectedly-large binding energies, “anomalous” high-energy absorption features, and the first experimental determination band-gap renormalization as a function of carrier density in MoS2. Finally, I will shift from discussing materials that are effectively “all surface” to our efforts in 3D carrier lifetime tomographic mapping within real solar cell devices. We successfully use this technique to address one of most longstanding questions in the PV field: how does $CdCl_2$ treatment effect carrier recombination in CdTe devices, specifically in.subsurface bulk, grain boundary and interfacial regions? We reveal how $CdCl_2$ treatment – a universal process for improving efficiency – suppresses non-radiative recombination and enhances carrier lifetimes throughout the film with substantial improvements particularly near grain boundaries *and the critical p-n junction*.