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Photonics of 2D semiconductors

Two-dimensional (2D) van der Waals semiconductors and their heterostructures are an attractive building block for novel photonic devices due to their strongly excitonic character and electrical tunability. For the practical implementation of photonic devices, it is crucial to understand the dynamics of charge [1] and exciton transfer [2] at the van der Waals hetero-interfaces. The first part of this talk will focus on the fundamental optical properties of monolayer transition metal dichalcogenides and persistent extrinsic effects associated with defects and interfacial traps even in high quality materials. The second part will discuss various approaches to realizing electrical generation of excitons and electroluminescence using van der Waal heterostructures [3]. Our group achieved record-low current density threshold for excitonic electroluminescence with MIS-type heterostructures [4]. I will discuss how low-current unipolar injection using hexagonal boron nitride is key to achieving ultralow threshold and high quantum efficiencies. Our photocurrent spectroscopy results also reveal that interlayer charge transfer dynamics is electrically tunable and competes with thermalization, allowing hot carrier energy harvesting. I will also discuss our recent discovery of a novel monolayer MoS_2 growth mechanism based on vapor-liquid-solid conversion [5]. We show that alkali metal plays a key role in reducing the melting point of the precursors and triggering the vapor-liquid-solid mode, yielding expitaxial growth of monolayer nanoribbons.

References

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[2] D. Kozawa *et al.* "Efficient interlayer energy transfer via 2D dipole coupling in $MoSe_2/WS_2$ heterostructures" Nano Lett. 16, 4087 (2016).
[3] J. Wang et al. "Electroluminescent Devices Based on 2D Semiconducting Transition Metal Dichalcogenides" Adv. Mater. 1802687 (2018) DOI: 10.1002/adma.201802687
[4] S. Wang *et al.* "Efficient carrier-to-exciton conversion in field emission tunnel diodes based on MIS-type van der Waals heterostack" *Nano Lett.* 17, 5156 (2017).
[5] S. Li, *et al.* "Vapor-liquid-solid growth of monolayer MoS_2 nanoribbons" *Nat. Mater.* 17, 535 (2018).

Figures

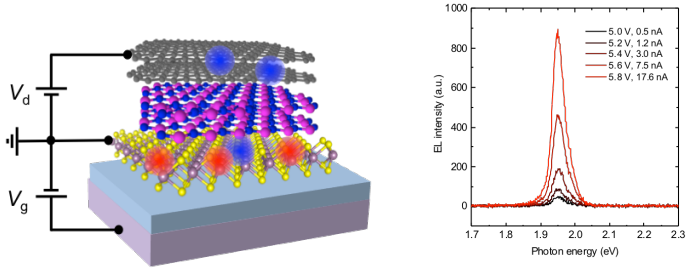

Figure 1: Schematic of MIS-type van der Waals heterostructure (left) and its electroluminescence spectra (right).