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Mixed Dimensional Van der Waals Heterostructures for Opto-Electronics.[1]

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The isolation of a growing number of two-dimensional (2D) materials has inspired worldwide efforts to integrate distinct 2D materials into van der Waals (vdW) heterostructures. While a tremendous amount of research activity has occurred in assembling disparate 2D materials into "all-2D" van der Waals heterostructures, this concept is not limited to 2D materials alone. Given that any passivated, dangling bond-free surface will interact with another via vdW forces, the vdW heterostructure concept can be extended to include the integration of 2D materials with non-2D materials that adhere primarily through noncovalent interactions. In the first part of this talk I will present our work on emerging mixed-dimensional (2D + nD, where n is 0, 1 or 3) heterostructure devices performed at Northwestern University. I will present two distinct examples of gate-tunable p-n heterojunctions 1. Single layer n-type MoS_2 (2D) combined with p-type semiconducting single walled carbon nanotubes (1D) and 2. Single layer MoS_2 combined with 0D molecular semiconductor, pentacene. I will present the unique electrical properties, underlying charge transport mechanisms and photocurrent responses in both the above systems using a variety of scanning probe microscopy techniques as well as computational analysis. This work shows that van der Waals interactions are robust across different dimensionalities of materials and can allow fabrication of semiconductor devices with unique geometries and properties unforeseen in bulk semiconductors. Finally, I will briefly discuss our recent work from Caltech on near-unity absorption in atomically-thin photovoltaic devices.

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