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van der Waals Heterostructures Grown by MBE

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In this work, we demonstrate the high-quality MBE heterostructure growth of various layered 2D materials by van der Waals epitaxy (VDWE). The coupling of different types of van der Waals materials including transition metal dichalcogenide thin films (e.g., WSe_2, WTe_2, $HfSe_2$), insulating hexagonal boron nitride (h-BN), and topological insulators (e.g., Bi_2Se_3) allows for the fabrication of novel electronic devices that take advantage of unique quantum confinement and spin-based characteristics. The relaxed lattice-matching criteria of van der Waals epitaxy has allowed for high-quality heterostructure growth with atomically abrupt interfaces, allowing us to couple these materials based primarily on their band alignment and electronic properties. We will discuss the impact of sample preparation, surface reactivity, and lattice mismatch of various substrates (sapphire, graphene, TMDs, Bi_2Se_3) on the growth mode and quality of the films and will discuss our studies of substrate temperature and flux rates on the resultant growth and grain size. Structural and chemical characterization was conducted via reflection high energy electron diffraction (RHEED, X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning tunneling microscopy/spectroscopy (STM/S), atomic force microscopy (AFM), X-ray photoelectron spectroscopy (XPS), and Raman spectroscopy. Experimentally determined band alignments have been determined and compared with first-principles calculations allowing the design of novel low-power logic and magnetic memory devices. Initial results from the electrical characterization of these grown thin films and some simple devices will also be presented. These VDWE grown layered 2D materials show significant potential for fabricating novel heterostructures with tunable band alignments and magnetic properties for a variety of nanoelectronic and optoelectronic applications.