Van der Waals Heterostructures

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Layered materials consist of extended two-dimensional covalently bond molecular layers that are stacked and held together by mainly weak van der Waals interactions. Despite the weak interlayer interactions, the properties of a single layer materials may be significantly different from the bulk material of the same compound. Famously, for example, semiconducting MoS_2 exhibits an indirect to direct band gap transition as it is thinned to a single layer. This implies that interlayer interactions are non-negligible in describing the materials properties. Moreover, the interlayer interactions may be tuned in van der Waals heterostructures by combining dissimilar layered materials. In this talk, I will present our recent progress in synthesizing monolayer van der Waals materials on a dissimilar van der Waals substrate and the investigations of the material properties of such heterostructures. While early progress in the field of van der Waals heterostructures has been made by mechanical exfoliation and stacking, in our group we utilize epitaxial growth by molecular beam epitaxy, which opens the door to more chemically unstable (often metallic) van der Waals materials that are difficult or impossible to prepare by exfoliation as monolayers. Specifically, we discuss $TiSe_2$ and VSe_2 as examples for layer and interface tunable many body physics systems. We show that an excitonic insulator phase in $TiSe_2$ is dependent on interlayer interaction. For VSe_2 we demonstrate, for the first time, that a van der Waals material that is paramagnetic in the bulk can become ferromagnetic in the monolayer. This is a crucial step in the potential use of van der Waals materials for spintronic applications.