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# CVD grown transition metal dichalcogenide monolayers and their van de Waals heterostructures

2D layered materials, particularly semiconducting transition metal dichalcogenides (TMDs), such as $MoS_2$ and $WSe_2$, have attracted tremendous research works, due not only to their atomically thin thickness, but also to many exciting new phenomena associated with new materials. Recent advances in van der Waal (vdW) heterobilayers (hBLs) formed by vertical stacks of two different monolayer TMDs further show their promise for novel device applications. TMD hBLs also feature their type-II band alignment, which can separate photoexcited electrons and holes into different materials to form interlayer excitons, which can carrier spin and valley pseudospin in different layers as a novel valleytronic platform. Here, I will present our recent endeavors on the material synthesis and fundamental study of 2D TMDs and their vdW hBLs grown by chemical vapor deposition (CVD). Recent progress on synthesizing highly oriented TMDs, h-BN and noble metal dichalcogenides (such as $PtSe_2$ and $PdSe_2$ with strongly layer number dependent properties) will be presented. In the second part, I will focus on CVD-grown $WSe_2/MoSe_2$ and $WS_2/MoS_2$ hBLs with perfect interlayer atomic registry. Such a commensurate stacking is very different from the incommensurate stacking in manually stacked hBLs, where the inevitable interlayer translation, twist and/or lattice mismatch could lead to a periodic variation of local atomic registry, i.e., the so-called Moiré superlattice. The perfect interlayer atomic registry can lead to new coupled spin-valley physics caused by the interlayer quantum inference. The stacking symmetry is found to play a critical role in not only the interlayer spin transfer, but also the helicity of circularly polarized emissions from interlayer excitons. Stacking dependent interlayer hybridizations that forms new-type of excitonic states will be demonstrated. The impact of the presence or absence of Moire potential on the interlayer exciton diffusion in hBLs will be presented. By stacking the CVD-grown highly oriented TMDs, heterobilayers with small twist angles (< 5°) near the perfect R-type (0°) and H-type (60°) stacking can be studied. The impacts of Moire periodicity on the interlayer exciton emissions with be demonstrated and discussed.

## References

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## Figures

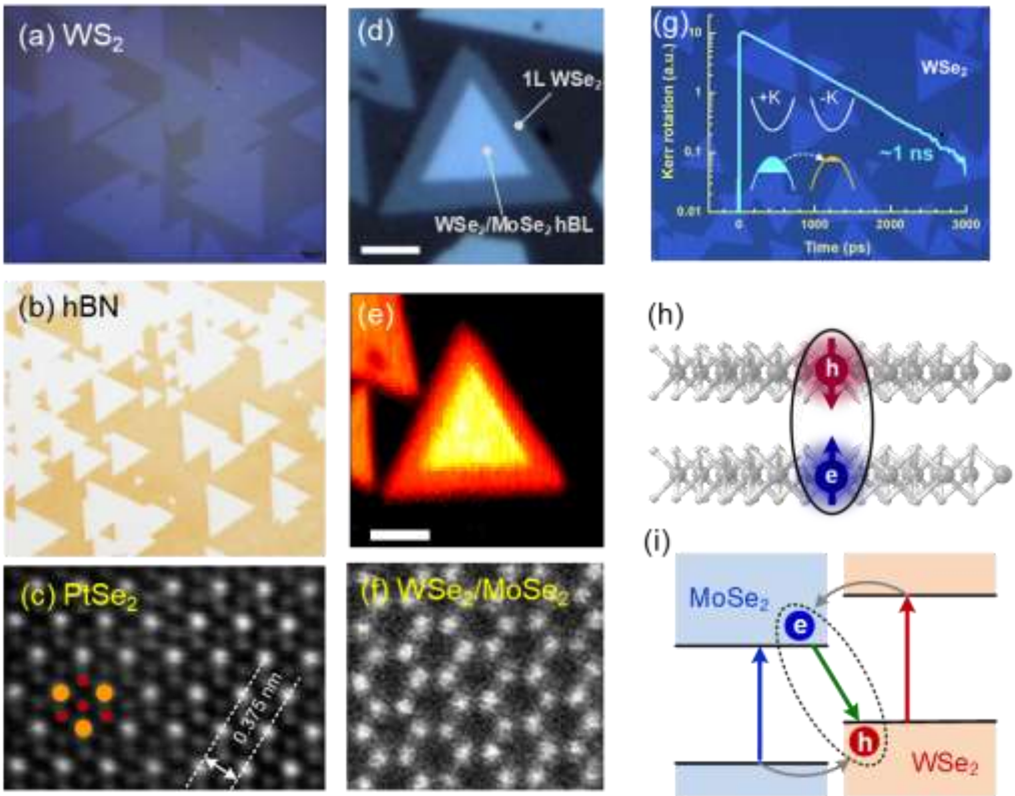


**Figure 1:** CVD grown 2D layered materials, such as transition metal dichalcogenides, hexagonal boron nitride (hBN) and van der Waals heterostructures. **(a)** Highly-oriented $WS_2$ flakes grown on sapphire substrates with two orientations (0° and 60°). **(b)** hBN grown on Cu(111) surface. **(c)** Transmission electron microscope image of CVD-grown $PtSe_2$. **(d)** $WSe_2/MoSe_2$ heterobilayers grown directly by CVD. anogroove system. **(e)** Second harmonic generation imaging of $WSe_2/MoSe_2$ heterobilayers. **(f)** Atomic registry of $WSe_2/MoSe_2$ heterobilayers with H-type stacking. **(g)** Time-resolved Kerr rotation spectroscopy of valley polarized holes in WSe2. **(h,i)** Schematics of interlayer excitons with electrons in $MoSe_2$ and holes on $WSe_2$ layers.