Abstract

Two-dimensional (2D) materials family has been receiving considerable research attention since the breakthrough discovery of graphene. Transition metal dichalcogenides (TMDs), an emerging class of materials in 2D family, are recognized for their exceptional electrical and optical properties, making them appealing candidates for future nanoscale device applications. For industrial-scale applications, large-area growth of these 2D TMDs is essential and is now possible through growth techniques like chemical vapour deposition (CVD). However, these techniques create a bottleneck in device performance by introducing disorder and interfacial strain within the 2D films. A significant advantage of CVD lies in its capability to create 2D bilayers of various stacking orders, which exhibit distinct physical properties dictated by the presence/absence of inversion symmetry. This thesis focuses on two major aspects: 1) Utilizing spectroscopic tools, benchmarking, and investigating critical factors, such as disorder, strain, and interlayer coupling, on the optical and electrical properties of 2D TMDs; 2) Fabrication and investigation of nanoscale devices through transport measurements utilizing the benefit of differently stacked bilayer growth. The first part of the thesis covers a comprehensive investigation on optical emission characteristics of CVD-grown polycrystalline WSe_2 monolayers (MLs) with mirror twin and tilt grain boundaries. While ML WSe_2 films with mirror twin grain boundaries (MTGBs) show a photoluminescence (PL) enhancement, the flakes with tilt grain boundaries (TGBs) exhibit interesting triangular areas with either enhancement or quenching of PL intensity. This study identifies the critical role of local charge doping from adatoms and lattice strain on PL intensity of ML WSe_2 with MTGBs and TGBs. In the second part of the thesis, we focus on the investigation on the interlayer coupling of twisted bilayer (TBL) WSe_2, which is fabricated by utilizing CVD-grown WSe_2 MLs, using a modified dry transfer method combined with a water delamination process. We show that Raman spectroscopy can probe the variation in interlayer coupling of the TBL system as well as is capable to distinguishing the 2H and 3R stacked polytypes of bilayers. One interesting finding is the observation of the weakest interlayer interaction for bilayer WSe_2 with twist angle of 30°. We also demonstrate the strain evolution with twist angle for TBL-WSe_2. The third and last part of the thesis investigates the sliding ferroelectricity of CVD-grown 3R-stacked bilayer WSe_2 by using graphene as an electrical sensor. The sliding ferroelectricity develops with the sliding of one atomic layer over another in 2D vdW layered materials through interfacial charge transfer. Here we describe a detailed electrical transport of graphene/hBN/3R-WSe_2 device with the bottom gate voltage sweep, which investigates the ferroelectricity of 3R-WSe_2. We find hysteretic transport characteristics indicating ferroelectricity of 3R-WSe_2. One notable observation is the transition of hysteresis to anti-hysteresis behavior of graphene transport with the increase of temperature. We discuss the impact of disorder present in CVD-grown 3R-WSe_2 on the modulation of graphene resistance. Overall, this thesis provides an important insight into the implementation of industrial-scale device applications by highlighting the necessity for considering the influence of disorder, strain, and interlayer interactions in CVD-grown 2D films.

Keywords: WSe_2, Grain boundary, Defects, Strain, Twist angle, Sliding ferroelectricity.