Controlling wafer-scale epitaxial growth of transition metal dichalcogenides using MOCVD

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Abstract

Our research is focused on the development of an epitaxial growth technology for layered dichalcogenides MX_2 (M=Mo, W and X= S, Se), based on metal organic chemical vapor deposition (MOCVD). This process uses metal hexacarbonyl and hydride chalcogen precursors to deposit monolayers on 2" sapphire wafers in a cold-wall reactor. A multi-step precursor modulation growth method is used to independently control nucleation density and the lateral growth rate of monolayer domains on the sapphire substrate [1]. Using this approach, uniform, coalesced monolayer TMD films were obtained at growth rates on the order of ~1 monolayer/30 min. In-plane X-ray diffraction demonstrates that the films are epitaxially oriented with respect to the sapphire [2]. Controlling the growth temperature and chalcogen flux was crucial in establishing an epitaxial relation. For example, dark-field transmission electron microscopy (DF-TEM) of transferred WS_2 monolayers show ~95% single orientation coverage with minimal bilayer and inversion domains (Figure 1). These single-crystal transferred films also show narrow exciton linewidths (~31 meV) and negligible defect-related emission at 80 K (Figure 1). The key features observed during the growth of MoS_2, WS_2, $MoSe_2$ and WSe_2 will be compared and discussed. The authors acknowledge financial support of the U.S. National Science under NSF cooperative agreement DMR-1539916 and EFRI 2-DARE Grant EFRI-1433378.

References

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Figures

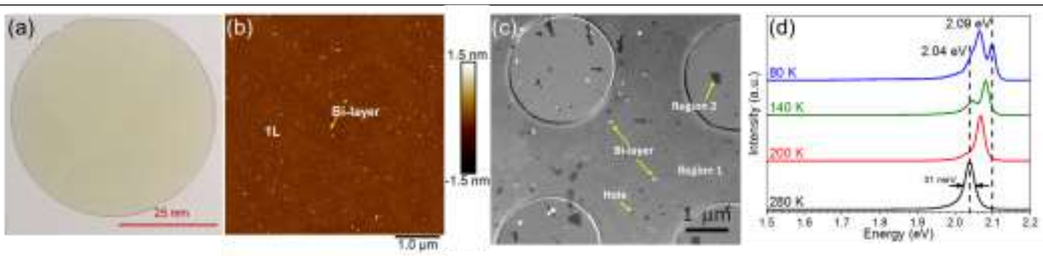

Figure 1: (a) Photograph of 2" WS_2 film on c-sapphire, (b) AFM micrograph of WS_2 film with < 1% bilayer, (c) Composite dark-field TEM map of the film corresponding to (b) and (d) Temperature-dependent photoluminescence (PL) of WS_2 monolayer