Aerosol-Assisted Chemical Vapor Deposition of MoS_2 and ZnS Thin Films

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Transition metal dichalcogenides (TMDCs) are versatile two-dimensional (2D) materials that have unique optical and electronic properties. Amongst them, molybdenum disulfide (MoS_2) and zinc sulfide (ZnS) have attracted attention due to their semiconductor nature. Remarkably, MoS_2 shows a thickness-dependent bandgap that ranges from 1.2 eV for bulk (indirect bandgap) to 1.9 eV for monolayer (direct bandgap). Furthermore, ZnS exhibits a similar property with a large bandgap from 3.26 eV to 3.7 eV. The band gap of these materials laying from the near-infrared to the visible and ultraviolet range of the electromagnetic spectrum potentially makes them suitable for photodetectors and photovoltaics [1]. Various deposition techniques such as physical vapor deposition (PVD) and chemical vapor deposition (CVD) have been successful growth methods of monolayer MoS_2 [2]. However, these methods have had limited success in the synthesis of crystalline 2D ZnS thin films. Moreover, there are still great challenges on scalable production in terms of large-area uniform growth. Here we demonstrate that the epitaxial growth, by an Aerosol-Assisted Chemical Vapor Deposition (AACVD) method, [3] results in large area coverage (~1 cm^2) of MoS_2 on different substrates (Si, SiO2, glass, hBN, and HOPG). The morphology and thickness of MoS_2 can be tuned by precursor concentration and/or growth temperature allowing for the engineering of different structures such as nanorods, snowflake-like structures, and 2D layers as thin as 40 nm (see Figure 1). The AACVD method is also successful in the synthesis of ZnS thin films of 400 nm thickness. The growth of 2H-MoS_2 and Wurtzite ZnS was confirmed by X-ray diffraction (XRD), Raman, and electron-dispersive X-ray (EDX) spectroscopies. Raman analysis indicates that the grown MoS_2 structures show a substrate-dependent strain. On the other hand, ZnS crystalline growth can only be successfully achieved on smooth surfaces such as glass and exfoliated Indium selenide layers on SiO_2 indicating substrate dependency [3]. The successful growth of 2H-MoS_2 and Wurtzite ZnS offer the prospect for large-area device fabrication that exploit distinctive optical and electronic properties.

References

[1] J. Zhu *et al.*, RSC Adv., **112** (2016) 110604.
[2] Y. Xie *et al.*, Nanotechnology, 28 (2017) 084001.
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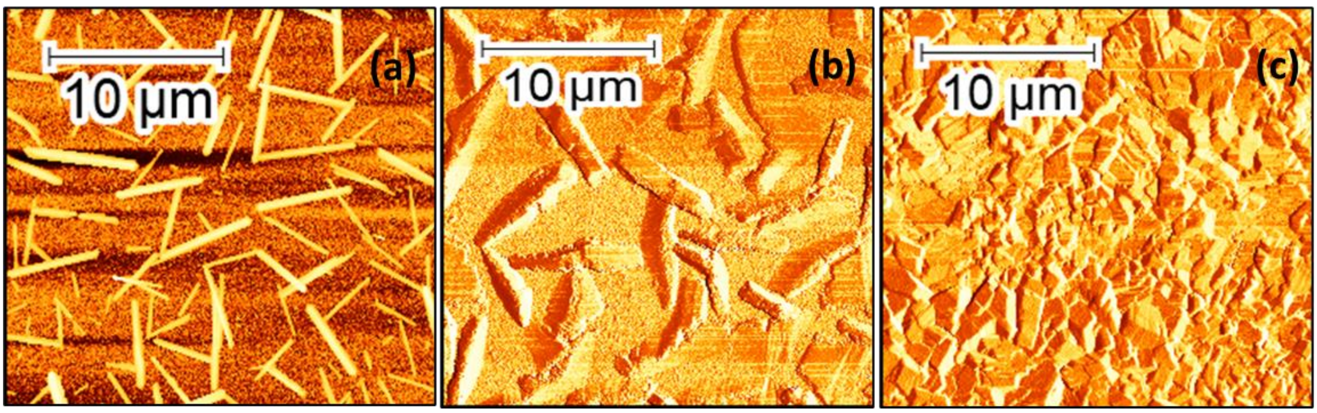

Figure 1: AFM image of MoS_2 nanorods (a), snowflake-like structures (b), and 2D layers (c) on glass substrates.