CVD growth of Transition Metal Dichalcogenides

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Abstract

Transition metal dichalcogenides (TMDs) have attracted extensive attention in their two-dimensional (2D) monolayer form due to the unique properties that leads to a variety of next generation electrical and optoelectronic device applications. Among them, MoS_2 is the first and most investigated member of TMDs family because of its abundance in nature and quite simple process of syntheses. Exfoliation is not scalable for large-scale device fabrication resulting from the absence of controllable thickness, size and uniformity of the 2D film. Chemical vapor deposition (CVD) seems to be the most promising method to synthesize high-quality monolayer in a large-scale. Here we report CVD growth of monolayer MoS_2, $MoSe_2$ and WSe_2 on sapphire substrate.

The growth of MoS_2 on sapphire based on the gas-phase reaction between MoO_3 and sulfur evaporated from solid sources results in characteristic single-crystal domains in the shape of well-defined equilateral triangles that merge into a continuous monolayer film [1]. The monolayer film is composed of coalescing single islands with limited numbers of lattice orientation due to an epitaxial growth mechanism. Even though MoS_2 and sapphire interact only via the relatively weak van der Waals interaction, commensurability of the sapphire lattice with MoS_2 allows the van der Waals interaction to control the lattice orientation of MoS_2 in a similar way as the lattice matching requirement in covalent semiconducting materials. The use of H_2S as a gas-phase sulfur precursor results in more control over growth morphologies: highly-oriented vertically-aligned multilayers or horizontally-aligned monolayer domains in the shape of well-defined equilateral triangles [2].

Whereas, there are numerous reports on MoS_2, the synthesis and characterization of the monolayer selenide TMDs family such as $MoSe_2$ and WSe_2 remains less explored. However, studies show that selenide counterparts may be superior to sulfides in many aspects. Large-area flakes of $MoSe_2$ and WSe_2 have also been successfully grown using solid-state precursors [3].

Raman, photoluminescence and X-ray photoelectron spectroscopy a well as electrical transport measurements confirm that the quality of the CVD-grown TMDs is comparable with exfoliated counterparts [1-3].

References

[1] D. Dumcenco, D. Ovchinnikov, K. Marinov, P. Lazić, M. Gibertini, N. Marzari, O. L. Sanchez, Y.-C. Kung, D. Krasnozhon, M.-W. Chen, S. Bertolazzi, P. Gillet, A. Fontcuberta i Morral, A. Radenovic, and A. Kis, ACS Nano, 9 (2015) 4611

[2] D. Dumcenco, D. Ovchinnikov, O. L. Sanchez, P. Gillet, D. Alexander, S. Lazar, A. Radenovic, and A. Kis, 2D Materials, 2 (2105) 044005

[3] D. Dumcenco, D. Ovchinnikov, K. Marinov, and A. Kis, IEEE, Solid-State Device Research Conference (ESSDERC), (2016) 284
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