Direct growth of 2D materials heterostructures based on pulsed laser deposition of solid oxide precursors

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Abstract

The rapid increase in 2D materials research led by graphene pursues their wide range of physical properties and chemical stability [1]. Single layer 2D semiconductors, such as MoS2, WS2, MoSe2, and WSe2 (TMDs) exhibit visible-near infrared direct bandgap of 1-2 eV and strong light-matter coupling. Moreover, 2D TMDs with various bandgaps can be used as building blocks in vertical van der Waals heterostructures (vdWHs), which show even higher promise for various applications in devices [2]. However, physical stacking of 2D TMDs layers in vdWHs is not feasible for large-scale applications, but it is particularly challenging to grow atomically thin MoS2/WS2 heterostructures directly. Inspired by work of Xu et.al. [3] on MoS2 two-step synthesis, here we report on controllable synthesis of vertically stacked MoS2/WS2 vdWHs made by high-temperature sulfurization of oxygen-deficient MoOx and WOx. We applied two-step growth of MoS_2 and WS_2 based on pulsed laser deposition (PLD) of oxide precursors to obtain two-dimensional MoS_2/WS_2 heterostructure. A two-step growth consists of: (1) oxide bilayer films deposition by with a background gas; (2) sulfurization in a tube furnace at high-temperature in a sulphur-rich environment. The oxides grown by a non-equilibrium PLD process exhibit high oxygen vacancy concentration in both MoO_x and WO_x films, and facilitate MoS_2 and WS_2 lateral crystal growth. These results may serve as a potential step to integrate dissimilar 2D TMDs layers. Next, we investigate the possibility to use direct PLD of quasi-continuous $MoSe_2$ and WSe_2 thin films combined with two-step grown MoS_2 and/or WS_2 layers to merge sulfides and selenides in a vdWHs. Thus, our study suggests a way towards fabrication of vdWHs without using individual layer transfer. The potential results of this study are formation of high quality crystals with a good Photoluminescence (PL) and strong Raman signals from individual layers. The synthesis of heterostructures was examined by Raman spectroscopy, Raman mapping, PL, AFM, SEM, optical microscopy, and STEM.

References

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Figures

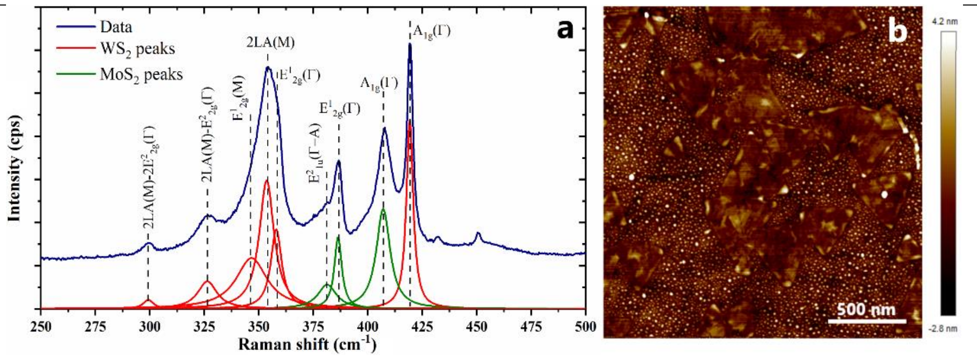

Figure 1: a) Raman spectra of MoS2-WS2 heterostructure and b) AFM image of the constituent layers