Layer Number Controllability of Transition-metal Dichalcogenides and The Establishment of Hetero-structures by Using Sulfurization of Thin Transition Metal Films

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Abstract

In one our previous publications, it has been demonstrated that through the sulfurization of pre-deposited transition metals, different transition metal dichalcogenides (TMDs) and their hetero-structures can be prepared [1]. Large-area and uniform MoS_2 films can also be obtained by using this approach [2]. In this work, through the control of pre-deposited Mo film thicknesses, we have achieved layer number controllability down to a single-layer MoS_2 by using this growth technique. The Raman spectra of the two samples sulfurized with 0.5 and 1.0 nm Mo are shown in Fig. 1 (a). Two characteristic Raman peaks E^1_{2g} and A_{1g} representing the in-layer and out-of-layer vibration modes of MoS_2 films are observed. The frequency differences Δk of the Raman peak are 20.8 and 24.6 cm^{-1} for two samples sulfurized with 0.5 and 1.0 nm Mo, respectively, which suggest that less MoS_2 layers are obtained for the sample sulfurized with 0.5 nm Mo. The more intense PL intensity of the sample with 0.5 nm Mo shown in Fig. 1 (b) also confirms this point. The high-resolution transmission electron microscopy (HRTEM) images shown in Fig.1 (c), have revealled that 1- and 3-layer MoS_2 are obtained for the two samples, respectively. A sample with sequential 0.5 nm Tungsten (W)/sulfurization/0.5 nm Mo/ sulfurization/ 0.5 nm W/ sulfurization procedures is prepared. The Raman spectrum and the cross-sectional HRTEM image of the sample shown in Fig. 2 have revealed the establishment of 1-layer WS_2/1-layer MoS_2/1-layer WS_2 double hetero-structures. Through this growth technique, good layer number controllability down to a single layer of 2D crystals and TMD hetero-structures can be achieved. The complexity introduced by the 2D crystal hetero-structures in a few atomic layers will bring new device applications to 2D materials.

References

[1] C. R. Wu *et al*, Nano Lett., 16 (2016) 7093.
[2] K. C. Chen *et al*, Jpn. J. Appl. Phys., 55 (2016) 090302.

Figures

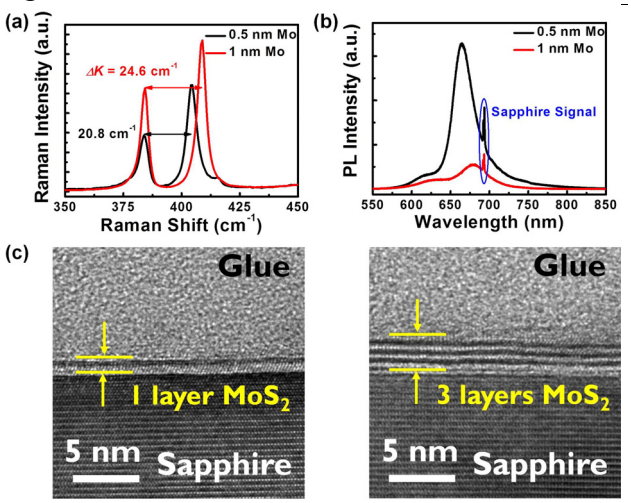

Figure 1: (a) The Raman, (b) the PL spectra and the cross-sectional HRTEM images of the two samples sulfurized with 0.5 and 1.0 nm Mo films.

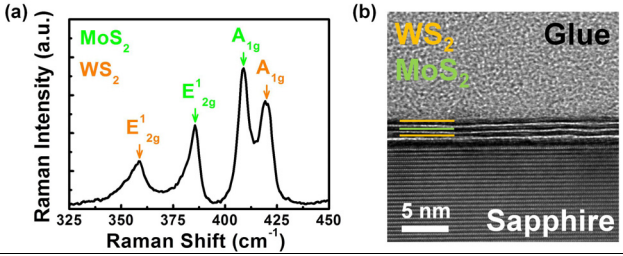

Figure 2: (a) The Raman spectrum and (b) the cross-sectional HRTEM image of the sample with a 1-layer WS_2/1-layer MoS_2/1-layer WS_2 double hetero-structure.