Effects of Substrate Crystallinity on MoS_2 Grown by CVD

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Abstract

Two-dimensional materials, represented by graphene, remain their structural stability even in an atomically thin film, in which confined electrons exhibit anomalous behavior compared to that in bulk crystals. Especially, transition metal dichalcogenides (TMDCs) have attracted considerable interest as emerging device materials for nanoelectronics because their electronic properties can be changed considerably by combinations of composed atoms [1]. Recently, chemical vapor deposition (CVD) of TMDC monolayers has been demonstrated directly on dielectric substrate by using solid sources [2]. Chemical reactions among precursor materials lead to TMDCs nucleation on the substrate surface. In this regard, surface diffusion of precursors would have a significant impact on the growth kinetics; however, it still remains unclear how substrate crystallinity and roughness affect the resultant film quality. To address this issue, we demonstrated atmospheric pressure CVD of MoS_2 on c-plane sapphire and polycrystalline alumina substrates by using MoO_3 and sulfur solid sources.

Raman spectroscopy and photoluminescence (PL) measurements (Fig.1) revealed that monolayer MoS_2 was grown on the sapphire substrate, which was confirmed by Raman peak distance (~19 cm^{-1}) between two characteristic modes (E^1_{2g} and A_{1g}) and a strong PL emission peak at ~1.88 eV. The MoS_2 on the alumina substrate showed broad Raman peaks and a relatively large peak distance while strong PL emission was confirmed. The MoS_2 layers were then transferred onto SiO_2/Si substrates to check the uniformity in thickness using the color contrast caused by light interference (Fig.2). While the MoS_2 grown on the sapphire substrate consists of triangular-shaped islands, MoS_2 islands grown on the alumina substrate are irregular in shape and partly have multilayer regions. This explains the Raman and PL results on the alumina substrate: the spectrum is the superposition of peaks from monolayer and multilayer regions in the island. The differences in the resultant islands are probably originated from differences in growth kinetics on each substrate surface. The growth kinetics, including adsorption, dissociation and diffusion processes of the precursors would correlate with surface orientations. The alumina substrate is composed of crystal grains with various orientations, thus providing the MoS_2 islands different from those on sapphire.

References

[1] K. Dolui *et al*., Phys. Rev. B **88** (2013) 075420
[2] Y-H. Lee *et al*., Adv. Mater. **24** (2012) 2320

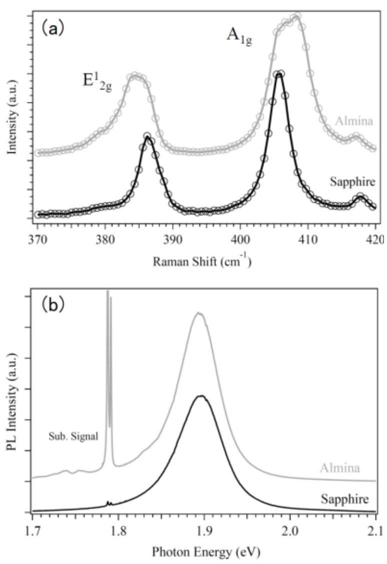

Fig.1 (a) Raman and (b) PL spectra

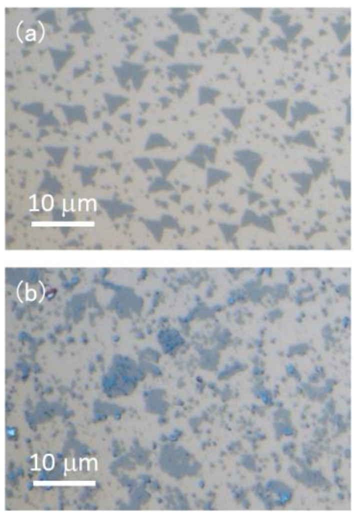

Fig.2 Optical microscope images of MoS_2 grown on (a) sapphire and (b) alumina substrate after transfer onto SiO_2/Si substrate.