Atomic layer deposition of MoS_2 and the influence of subsequent annealing on the optical and structural properties

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MoS_2 belongs to the 2D transition metal dichalcogenide material family. It is an indirect band gap semiconductor for bulk to bilayer thickness, while monolayers are characterised by a direct band gap having an energy of ~ 1.9 eV. The 'Scotch-tape-method' is a simple but a not well controllable exfoliation technique to produce small flakes of different layer thickness. Homogeneous wafer scale deposition is possible using chemical vapor deposition (CVD). Atomic layer deposition (ALD) is a CVD based process usually using pulsed precursor supply at low pressure and low temperature.

In this study, growth of MoS_2 layers on SiO_2/Si substrates is performed by ALD. Raman spectroscopy is used to determine the number of layers by analyzing the frequency difference of the E^1_{2g} and A_{1g} modes. It will be shown that the number of layers can be controlled by the number of ALD cycles (Fig. 1a). The influence of ALD growth parameters on the structural properties will be discussed.

As-grown MoS_2 layers by ALD suffer from poor photoluminescence (PL) properties [1]. To obtain typical PL activity with A and B excitonic emission (Fig. 1b), a subsequent annealing step at higher temperature is required. The influence of different annealing temperatures and atmospheres on the structural, optical and morphological properties is investigated and compared to exfoliated MoS_2. MoS_2 grown directly on free-standing graphene layers dispersed on transmission electron microscopy (TEM) grids enables plan view high resolution TEM measurements for insights in the crystalline quality and the grain size.

References

[1] L. K. Tan, B. Liu, J. H. Teng, S. Guo, H. Y. Low and K. P. Loh, Nanoscale **6** (2014), 10584

Figures

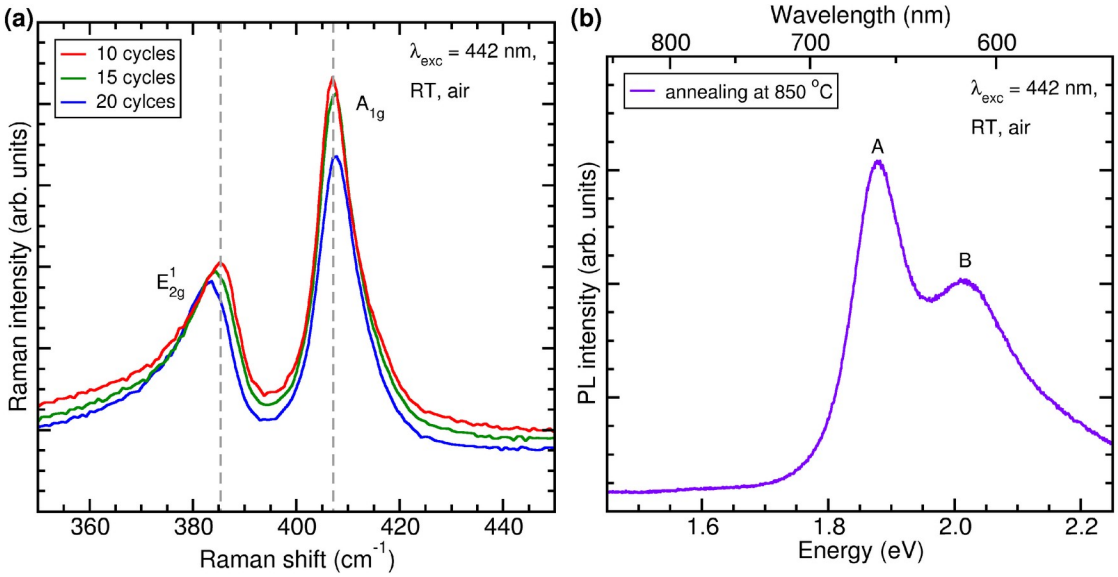

Figure 1: a) Raman spectra of MoS_2 layers: reduction of number of ALD cylces leads to a decrease of the frequency difference of E^1_{2g} and A_{1g} modes. b) PL spectrum of MoS_2 monolayer after annealing showing typical A (1.88 eV) and B (2.01 eV) exciton related emission.