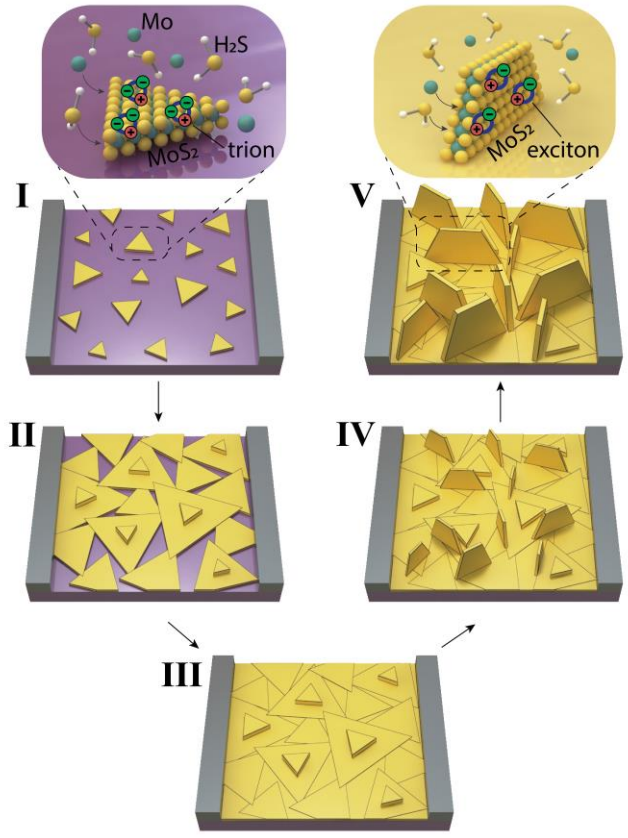
Production and characterization of MoS_2/WS_2 thin films

Artem B. Loginov, Valentina A. Eremina, Petr A. Obraztsov, Alexander N. Obraztsov
University of Eastern Finland, Joensuu 80101, Finland
alexander.obraztsov@uef.fi

Transition metal dichalcogenides (TMDs) are attracting much attention due to a number of their unique properties. A crucial step toward the application of TMDs is understanding their growth mechanisms and elaboration efficient methodologies for their synthesis. In this work we investigate peculiarities of TMD films at different stages of their formation by chemical vapor deposition with gaseous H2S and thermally evaporated transition metal as precursors. The morphology, Raman spectra, photoluminescent properties, and electrical conductivity of the TMD films obtained at various precursors concentrations and deposition duration are studied in the work. We also analyzing influence of deposition time and substrate temperature on the growth of the films and discussing the driving mechanisms. Four growth stages are identified in the TMD film formation process resulting by a mesoporous structure: (i) islands formation in the form of isolated two-dimensional crystallites, (ii) a partial superposition of crystallites during their gradual growth in the substrate surface plane, (iii) a continuous planar film formation, (iv) nucleation and further sprouting growth of the lamellar crystallites, oriented perpendicular to the substrate surface, (v) thickening of these crystallites followed by their growth in lateral dimensions.

The morphological features of the films at these stages were revealed using scanning electron microscopy. According to the results of Raman and PL spectroscopy, it was found that the average number of layers in the film crystallites varies nonmonotonically. Until the film becomes continuous, the crystallites consist of 2-3 layers, then the number of layers grows to 4-5. However, after formation of the vertically oriented crystallites, their thickness again decreases to 2–3 layers in case of MoS2 film and to 3-5 layers for WS2, which is reflected in position of the Raman lines. The PL spectra also change qualitatively during film deposition. At initial stages, the PL spectrum is dominated by the lines associated with recombination of A- and B0-excitons; however, during formation of the vertical structures, a new peak associated with the recombination of the A0-exciton appears, against which the initial exciton peaks cease to be distinguishable after a certain deposition time. However, with deposition time increasing vertically oriented crystallites became thicker (up to 5-9) layers and PL intensity significantly decreased followed by the redshift of A0-exciton peak. Measurements of the film conductivity during film deposition also corresponds to proposed growth model.



The TMD film growth stages:
(I) formation of isolated islands;
(II) crystal islands percolation stage;
(III) formation of a continuous film;
(IV) nucleation and initial growth of vertically oriented crystallites;
(V) – Thickening and later growth of vertically oriented crystallites.