Real-Time X-Ray Texture Study of Langmuir Few-Layer MoS_2 Film During Compression

P. Siffalovic
M. Demydenko, T. Shabelnyk, M. Bodik, D. Kostiuk, Y. Halahovets, M. Jergel, E. Majkova

Institute of Physics, SAS, Dubravska cesta 9, 84511 Bratislava, Slovakia

peter.siffalovic@savba.sk

The liquid exfoliation[1] opened a new avenue for cost-effective and large-scale production of 2D materials. In contrast to the thin film CVD growth technology, the fabrication of thin films from solution-based fractions of 2D nanomaterials requires a careful reconsideration of available deposition technologies. The formation of Langmuir films of mono- or few-layer 2D materials provides high-quality layers in thermodynamic equilibrium which can be further transferred onto arbitrary substrates. Here we present a systematic study of the Langmuir film formation of few-layer MoS_2 on water subphase. A fraction of the few-layer MoS_2 flakes with a controlled size dispersion in ethanol/water solution was spread onto the water subphase. A dedicated laboratory X-ray experimental setup was employed to track in real-time the texture evolution of MoS_2 Langmuir film during continuous compression. The isotherm of surface pressure versus film area along with the texture analysis using 002 diffraction are shown in Fig. 1. A sketch showing different packings of MoS_2 flakes and the respective changes in reciprocal space are depicted in Fig. 2. At the low surface pressure below 3 mN/m, the Langmuir film consists of randomly scattered isolated islands of MoS_2 flakes. The width χ_{002} (FWHM) of the 002 diffraction streak at the constant q_{002} value in reciprocal space is directly proportional to the mean angular spread of the flakes tilt from horizontal (water subphase surface). The surface pressure range from 3 to 4 mN/m can be associated with a liquid-condensed (Lc) phase similar to molecular Langmuir films. Here, the gradually growing surface pressure is accompanied by a minor 0.5° increase of the flakes tilt. Further increase of the surface pressure (equivalent to solid phase) up to a critical value of $\Pi_C \approx 15$ mN/m is manifested by a significant increase of the orientation misalignment by 7°. The compression above Π_C results in an irreversible collapse of the MoS_2 monolayer.

References

[1] V. Nicolosi, Science, 340 (2013) 1226419

Figures

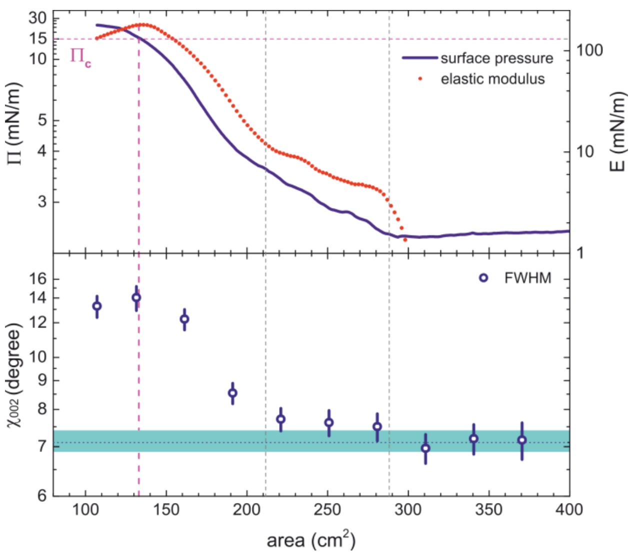

Figure 1: Π-A isotherm and corresponding MoS_2 texture based on 002 diffraction.

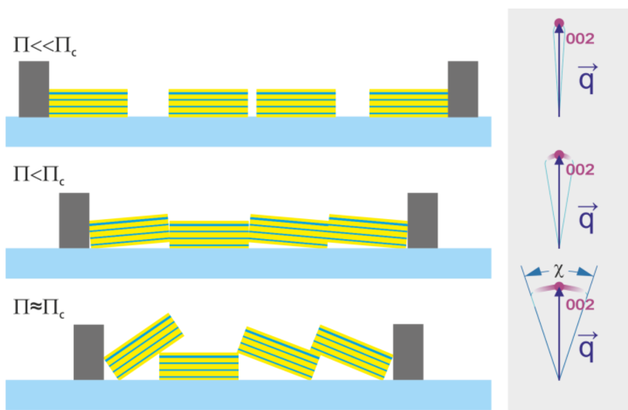

Figure 2: Scheme of different phases and their representation in reciprocal space during compression of MoS_2 Langmuir film.