05: Growth by van der Waals epitaxy and characterization of two-dimensional transition metal diselenides

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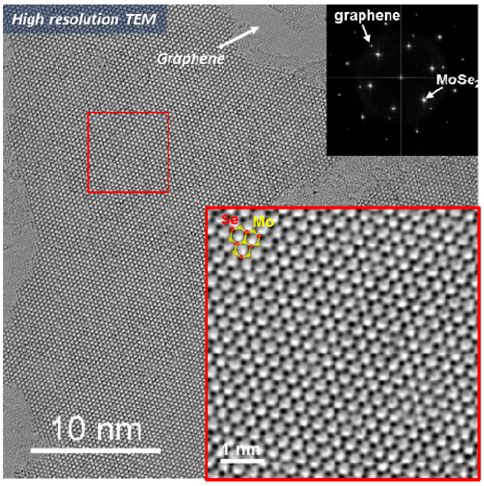
Layer-structured transition metal dichalcogenides (TMDs) have drawn much attention recently since they are being considered as a new class of semiconducting two-dimensional (2D) materials with thickness-tunable band-gap modulation. In the single-layer configuration, the TMDs offer a unique platform to explore not only the carrier transport in an ultrathin channel but also the control of 2D excitonic systems and the spin-valley physics. Molecular beam epitaxy (MBE) is of particular interest to grow such materials because one can obtain high purity layers with a precise control of the thickness and a flexible choice of metals. Most importantly, MBE allows for the growth of TMDs over large areas (cm^2) which is the blocking point for the use of such materials at the industrial level nowadays.



In our lab, we have developed the van der Waals epitaxy of TMDs by co-depositing in ultrahigh vacuum the transition metal (Mo, W, Sn, Pt…) and the selenium. The example of a single $MoSe_2$ layer grown on CVD graphene is shown in the figure. In the van der Waals epitaxy process, the interaction between the substrate and the epilayer is so weak (of van der Waals type) that the TMDs grow directly with their bulk characteristics even at the single layer level. By this, we can grow high quality single-crystalline layers over large areas.

In this training course, we propose the attendees to grow $MoSe_2$ multilayers by van der Waals epitaxy on a SiO_2/Si substrate. Preliminary chemical surface cleaning will be performed prior to the introduction of the substrate into the MBE chamber. Six metallic pads will then be grown *in-situ* on top of the $MoSe_2$ layers in order to contact them in a double Hall cross geometry. The TMD film will first be characterized by Raman spectroscopy to verify the crystalline quality. Then, the electrical properties of the same film will be measured by using a back gate voltage to deduce the sheet conductivity, doping type and level as well as the field effect mobility.

Reference:

"Millimeter-scale layered MoSe2 grown on sapphire and evidence for negative magnetoresistance", M. T. Dau, C. Vergnaud, A. Marty, F. Rortais, C. Beigné, H. Boukari, E. Bellet-Amalric, V. Guigoz, O. Renault, C. Alvarez, H. Okuno, P. Pochet, M. Jamet, Appl. Phys. Lett. 110, 011909 (2017).