Molecular beam epitaxy of $MoSe_2$ on sapphire: structure and electrical properties

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Van der Waals assembly using the molecular beam epitaxy (MBE) technique is an appealing method for the fabrication of two-dimensional transition metal diselenides (TMDs) down to one monolayer. Indeed, one can grow high purity layers and it is uniformly scalable [1]. In this approach, fully relaxed epilayers can be obtained on substrates with chemically (quasi) inert surfaces owing to the low density of dangling bonds.

In this poster, we report on the MBE growth, structural and electrical properties of layered $MoSe_2$ on insulating sapphire. The TMDs epilayers were fabricated by a two-step growth process which consists of depositing TMDs layers at temperatures ranging from 350°C to 600°C followed by a post-deposition annealing around 700°C. We point out that the growth rate and the substrate temperature of the first step play a key role in the growth dynamics of the TMDs on sapphire. The post-deposition annealing allows to improve the crystalline quality and to smooth the layers. Figure 1 displays the grazing incidence x-ray diffraction spectrum of one monolayer $MoSe_2$ on sapphire. The reflections coming from $MoSe_2$ are clearly visible along two directions of sapphire. The phi-scan RHEED is found to be isotropic when rotating the samples. This means that the TMD layer is polycrystalline and composed of multi-domains without any preferential in-plane orientation. Additional results from the layer characterization have been also obtained by Raman spectroscopy, indicating unambiguously the fingerprint of TMDs monolayers over a centimetre-sized surface. Electrical measurements were carried out on the layered $MoSe_2$ using a 4-probe geometry with contacts made of a stack of Mo/Pd deposited *in-situ* in the MBE chamber. The temperature dependence of the resistivity indicates an insulating character, which can be well fitted in the framework of the variable range hopping model. Moreover, the MoSe2 layers exhibit a negative magnetoresistance: the resistivity decreases when applying a magnetic field. This behaviour, also reported recently in micro-flakes of TMDs [2], points to an intrinsic property of the magneto-transport mechanism in TMDs, which occurs at very short scale [3].

References
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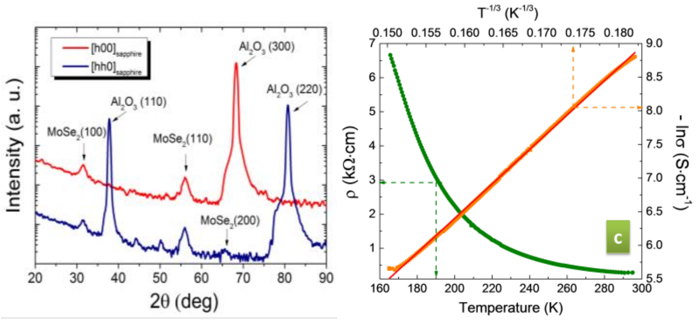

(a) (b)

Figure 1: (a) XRD of one monolayer MoSe2 on sapphire and (b) resistivity versus temperature.