Spin-to-charge conversion in a single $MoSe_2$ layer grown by van der Waals epitaxy on SiO_2/Si

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Two-dimensional materials based on transition metal dichalcogenides (TMDs) have gained increasing attention because of their fascinating electronic and optical properties [1]. Crystal symmetries and spin-orbit coupling have also lead to a new field of research called valleytronics [2]. The growth of layered TMDs down to one monolayer over large lateral dimensions is necessary to develop new devices and to explore novel physical properties. Standard mechanical exfoliation produces flakes of size limited to ≈10 µm. In this work, we have used molecular beam epitaxy to grow large-scale (cm^2) $MoSe_2$ atomically thin films with high uniformity and purity on SiO_2/Si. The growth is followed by a post-deposition annealing to improve the crystal quality as shown by the RHEED pattern in Fig. 1a. We investigated the crystal structure of a single layer using Raman spectroscopy, grazing incidence x-ray diffraction and scanning transmission electron microscopy (STEM) as shown in Fig. 1b. In parallel, the electronic structure was probed by temperature dependent photoluminescence. The large area allowed us to perform reliable magneto-transport measurements varying the carrier concentration applying a back gate voltage or illuminating the sample with a He-Ne laser. Finally, a 10 nm-thick Ag spacer was grown *in-situ* on top of a single $MoSe_2$ layer followed by the deposition of a 15 nm-thick CoFeB film by *in-situ* sputtering to perform spin pumping measurements into an X-band cavity. The spin diffusion length in Ag is long enough so that the spin current generated at the ferromagnetic resonance of CoFeB can reach the $MoSe_2$ layer with negligible spin depolarization. Temperature, RF-power and angular dependent measurements were performed to study the spin-to-charge conversion phenomena in this material by valley Hall effect and/or inverse spin Hall effect.

References

[1] Two-dimensional Transition-Metal Dichalcogenides, A. V. Kolobov and J. Tominaga, Springer Series in Materials Science (2016).
[2] J. R. Schaibley et al., Nature Rev. Mater. 1, 16055 (2016).

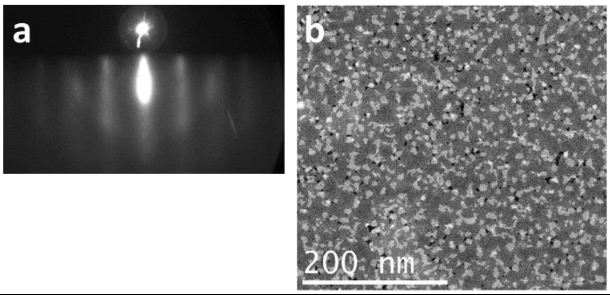

Figure 1: a isotropic RHEED pattern recorded after the growth and annealing of a single $MoSe_2$ layer. **b** STEM image of 1.2 ML of $MoSe_2/SiO_2$/Si. The brightest areas correspond to the second layer.