Influence of substrate transfer process on the band structure and the optoelectronic properties of chemical vapor deposited MoS_2 monolayers

M. Frégnaux[1], H. Kim[1], D. Rouchon[1], N. Chevalier[1],
V. Derycke[2], J. Bleuse[3], M. Chhowalla[4] and O. Renault[1]

[1] Univ. Grenoble Alpes, F-38000 Grenoble, France
CEA, LETI, MINATEC Campus, F-38054 Grenoble, France.
[2] CEA, IRAMIS, F-91191 Gif-sur-Yvette, France.
[3] Univ. Grenoble Alpes, F-38000 Grenoble, France
CEA, INAC, F-38054 Grenoble, France.
[4] Materials Science and Engineering, Rutgers University,
607 Taylor Road, Piscataway, New Jersey, 088854, USA
mathieu.fregnaux@cea.fr

Abstract:

Two-dimensional transition metal dichalcogenides (2D TMDs), such as molybdenum disulfide (MoS_2), are very promising materials for optoelectronic application purpose. Having an ultrathin layered structure and a remarkable direct band gap of 1.9 eV in the monolayer (1L) regime, few micrometer MoS_2 domains can be obtained by chemical vapor deposition (CVD). However, integration of these nanosheets into electronic devices may require a substrate transfer process step.
In this paper, we present a combined characterization protocol developed in our group to compare the structural, optical and electronic properties of both as-deposited and substrate transferred MoS_2 1L. Such preliminary study is primordial for subsequent application tests on devices.
The use of X-ray PhotoElectron Emission Microscope (XPEEM) [1] allows us to identify large MoS_2 microdomains (few ten microns) and to control their good stoichiometry. The effective presence of MoS_2 1L and their good crystallinity is verified by atomic force microscopy and Raman spectrometry, respectively.
In addition, XPEEM can be used in the momentum microscopy mode (k-PEEM) to perform parallel angular imaging in a one shot experiment. [2] It provides energy-filtered valence band mapping of a single domain in the reciprocal space, within $\pm$ 2 $Å^{-1}$ and at an energy resolution better than 100 meV. The band structure of MoS_2 1L is then directly generated by projection along the high symmetry directions of the first Brillouin zone. These results are discussed in regards to micro-photoluminescence measurements at low and room temperature.
Finally, this combined photoemission and photoluminescence protocol provides complementary and fundamental information about the influence of substrate transfer process on the optoelectronic properties of these alternative semi-conductors.

This work was performed on the Nanocharacterization Platform (PFNC) of CEA Grenoble.

References

[1] H. Kim, O. Renault et al., Appl. Phys. Lett., **105** (2014) 011605.
[2] C. Mathieu et al., Phys. Rev. B., **83** (2011) 235436.