High resolution structural, chemical and electrical characterization of molybdenum disulfide for next generation field effect transistors

Filippo Giannazzo

CNR-IMM

Transition metal dichalcogenides, such as MoS_2, recently attracted considerable interest for future electronic and optoelectronic applications [1]. Many recent studies indicated that the basic transport properties (doping, contact resistance,..) of these materials critically depend on the presence of nano- or atomic-scale defects [2,3]. Hence, the combination of high resolution structural/chemical and electrical characterization methods is fundamental to understand and, eventually, modify these electrical properties.

In this work, we show that the Schottky barrier of multilayer MoS_2 surface can be tailored at nanoscale using soft O_2 plasma treatments. The morphological, chemical, and electrical modifications of MoS_2 under different plasma conditions were investigated by several microscopic and spectroscopic techniques, including X-ray photoelectron spectroscopy (XPS), atomic force microscopy (AFM), conductive AFM (CAFM), aberration-corrected scanning transmission electron microscopy (STEM), and electron energy loss spectroscopy (EELS) [4]. Nanoscale current-voltage measurements by CAFM showed that the Schottky barrier height map can be conveniently tuned starting from a narrow distribution (0.2-0.3 eV) in the case of pristine MoS_2 to a broader distribution (0.2-0.8 eV) after O_2 plasma treatment, which allows both electrons and holes injection. This lateral inhomogeneity in the electrical properties was associated with variations of the incorporated oxygen concentration in the MoS_2 multilayer surface, as shown by STEM/EELS analyses and confirmed by ab initio density functional theory (DFT) calculations. Back-gated multilayer MoS_2 FETs showing ambipolar (i.e. both p- and n-type) current transport were fabricated by self-aligned deposition of source/drain contacts in the O_2 plasma functionalized areas, and their electrical behavior is discussed in terms of the peculiar current injection mechanisms in the oxygen functionalized MoS_2 surface.

[1] B. Radisavljevic, et al., Nat. Nanotechnol. **6**, 147 (2011).
[2] S. McDonnell, et al., ACS Nano **8**, 2880 (2014).
[3] F. Giannazzo, et al., Phys. Rev. B **92**, 081307(R) (2015).
[4] F. Giannazzo, at al. ACS Appl. Mater. Interfaces **9**, 23164−23174 (2017).