Exploiting intrinsic defectiveness in MoS_2-based field-effect transistors for sensing applications: from polycyclic aromatic hydrocarbons to heavy metal ions

Fernando J. Urbanos, Sara Gullace, Paolo Samorì
Université de Strasbourg, CNR ISIS UMR 7006, 8 allée Gaspard Monge, Strasbourg, F-67000, France
jimenezurbanos@unistra.fr

The increasing population and industrial development are responsible for the environmental pollution characterized by a severe contamination of air, water and soil. Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous environmental pollutants which results from the incomplete combustion of organic materials (e.g., coal, oil, petrol, and wood). PAHs' intrinsic properties such as thermostability have made them highly persistent in the environment. Their various health effects have caused the increased concern of the scientific comunity and governmental organizations.
Low-dimensional materials are ideal scaffolds to be used as active components in chemical sensing because they combine a high surface-to-volume ratio with physical and chemical properties that are highy susceptible to environmental changes. The non-covalent recognition events occurring between the low-dimensional nanostructure and the analyte of choice when interfaced, can be used as transduction mechanisms, yielding extraordinary performance in chemical sensing. Among low-dimensional materials, 2D transition metal dichalcogenides (TMDCs) are ideal materials to be integrated in sensors with an electrical readout. By pursuing this strategy, MoS_2-based field-effect transistors (FETs) have been recently proved to be an excellent candidate for heavy metal ion sensing [1].
In this work, we present premilinary results on PAH MoS_2-based sensors, relying on the high affinity between those molecules and intrinsic point defects in TMDCs. X-ray photoelectron spectroscopy (XPS) and low-temperature photoluminescence (PL) showed a significant reduction of the defectiveness of MoS_2 when exposed to different PAHs solutions. Transfer characteristics in the MoS_2 FETs provided unambiguous confirmation that naphthalene acts as a p-dopant for MoS_2. Interestingly, we observed a strict correlation of this doping with low-temperature PL and Raman measurements. The neutral exciton in MoS_2 became more prominent after exposure to PAH solutions. PL signal increased after naphthalene exposure, indicating a p-type doping of the MoS_2 [2]. Along the same line, shifts in the MoS_2 A_{1g} Raman peak were observed after exposure to the solutions, in good agreement with the observed p-doping in the transfer characteristics.

References

[1] Fernando J. Urbanos, Sara Gullace, Paolo Samorì, Nanoscale, 2021, 13, 19682-19689
[2] Dong Min Sim et al. ACS Nano, 2015, 9, 12, 12115–12123

Figures

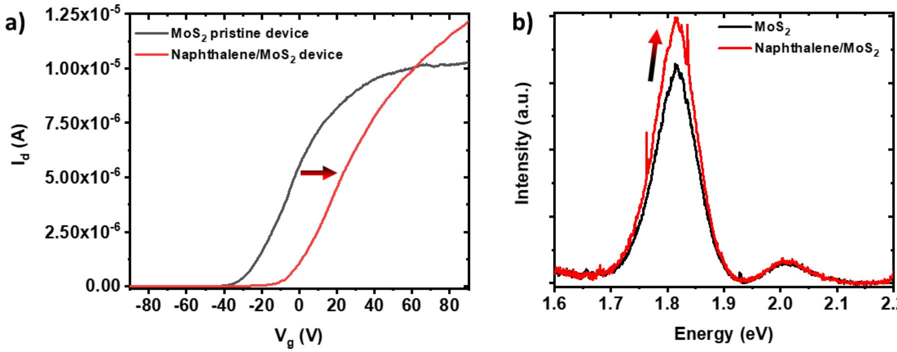

Figure 1: **a)** Transfer characteristic of both pristine (in black) and naphthalene exposed (in red) devices. Threshold voltage shifted towards positive values indicating a p-type doping. **b)** PL characterization of the pristine and functionalized MoS_2 in black and red, respectively. The increase observed in the PL after naphthalene exposure indicates a p-type doping, in good agreement with the electrical characterization.