Mixed-dimensionality heterostructures (2D/1D) for gas sensing applications

Haifa Taoum[1]
Ileana Florea[12], Costel-Sorin Cojocaru[1]
[1]*LPICM, École Polytechnique-CNRS, IP Paris, Route de Saclay, 91128 Palaiseau Cedex, France*
[2]*Université Côte d'Azur, CRHEA, CNRS, 06903, Sophia-Antipolis, France*
haifa.taoum@polytechnique.edu

In today's world of technological innovation, semiconductors play a crucial role. To satisfy the escalating demand for enhanced functionalities, new concepts of mixed dimensionality heterostructure have emerged. By combining two-dimensional (2D) nanomaterials with one-dimensional (1D) nanomaterials, the resulting hybrid Van der Waals heterostructures will have improved performances due to synergistic effects.
Transition Metal Chalcogenides (TMDs) and Single-Walled Carbon Nanotubes (SWCNTs) promise enhanced performances in multiple eras, notably in gas sensing. Their unique properties like ultra-high surface-to-volume ratio, and thermal, electrical, and mechanical stability make them suitable for such activity. [1] [2] The purpose is to create a gas sensor that has low dimensions with superior performance in terms of sensitivity, selectivity, and stability. Gas sensors that are based on high-quality WS_2@SWCNTs and MoS_2@SWCNTs heterostructures were fabricated using a bottom-up dry approach, employing a sequential growth method that combines Chemical Vapor Deposition and Molecular Beam Epitaxy techniques. The as-grown materials exhibit high crystalline structures and high purity at the interfaces, as demonstrated by various characterization techniques such as Raman spectroscopy, SEM, TEM, and Photoemission Analysis techniques, which are usually challenging to achieve. Additionally, a difference in electronic properties was observed. Since the electronic properties of WS_2 and MoS_2 are intrinsically different, an opposite type of doping was expected where the WS_2@SWCNTs have proven an n-type semiconductor and MoS_2@SWCNTs a p-type semiconductor. This achievement opens the door to further scientific exploration and advancement. To assess their performance, various tests including humidity sensing, temperature, and blue light excitation have been conducted. These tests reveal interesting stability under high temperatures and elevated relative humidity conditions with a good response recovery.
Further measurements will be performed to evaluate the selectivity, sensibility, and ability to perform monitoring functioning of TMDs@SWCNTs nanosensors in the presence of different byproduct gas molecules.

References

[1] Dresselhaus, G., et al., World Scientific, (1998).
[2] Han, S.A., et al., Nano Convergence, 1(2015), 17.