NINETEENTH2025 – Abstract: Electrical and Optoelectronic Properties of $WS_2/PdSe_2$ Heterostructures

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In the last decades, two-dimensional (2D) materials have been widely studied. 2D materials exhibit promising features like absence of dangling bonds, strong light-matter interaction and bandgap tunability, which make them ideal candidates for electronic and optoelectronic applications. In this context, the development of van der Waals (vdW) heterostructures has been a significant turning point in materials science and nanotechnology, leading to the realization of devices with superior performance. Tungsten disulfide (WS_2) presents low carrier mobility, which ranges from 0.01 to 5 $cm^2\ V^{-1}\ s^{-1}$ passing from ambient conditions to high vacuum, while palladium diselenide ($PdSe_2$) presents high electron and hole mobilities, up to 297 and 244 $cm^2\ V^{-1}\ s^{-1}$, respectively, in ambient conditions and 749 and 97 $cm^2\ V^{-1}\ s^{-1}$, in high vacuum. [1,2]

Firstly, prepatterned Si/SiO_2 substrates with Cr/Au electrodes were prepared through a lithography process and subsequent thermal evaporation for the deposition of metals. High-quality flakes were mechanically exfoliated by bulk crystals of WS_2 and $PdSe_2$.[3] The transfer of a WS_2 flake on a prepatterned substrate was followed by the alignment and transfer of the $PdSe_2$ flake. $PdSe_2$-based field-effect transistors (FETs) exhibit ambipolar conduction with limier on/off ratio, whereas devices based on $WS_2/PdSe_2$ heterojunctions exhibit n-type conduction with high carrier mobility up to approximately 100 $cm^2\ V^{-1}\ s^{-1}$ and on to off current ratios on the order of 10^7-10^8.

Adsorbates play a crucial role on the electrical properties of the $WS_2/PdSe_2$ heterostructures; its role is deeply investigated and explained. Specifically, electrical measurements were first conducted in ambient pressure and then in high vacuum, at a pressure of around 1 x 10^{-4} mbar; moreover, the reversibility of the pressure-dependent process was analyzed by repeating and comparing the set of measurements in ambient conditions again. Additionally, the photoconductivity of the $WS_2/PdSe_2$ heterostructure is deeply investigated, evidencing the evolution as a function of pressure from 1000 to 10^{-4} mbar, and from 10^{-4} to 1000 mbar. The air-vacuum-air analysis, in dark and light conditions, shows the reversibility of the process of capture and release of adsorbates.

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