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pMoO_x-nMoS₂ Heterojunction Assembly for Tunable and Efficient Optoelectronic Devices

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Abstract

Creating a p-n junction is an essential topic in material science for most semiconductor devices fabrication, which has excellent prospective in applications for next-generation integrated circuits and numerous optoelectronic devices. Therefore, a facile and straightforward methodology for building a p-n interface is particularly promising. After discovering graphene, layered two-dimensional materials (2D) family, and molybdenum sulfide (MoS₂) in specific, have attracted a great deal of research interest and showed emerging physical properties. The top surface of MoS₂ is free of dangling bonds that can artificially allow forming a heterojunction with other 2D crystals. A unique integration of 2D materials facilitates novel device structures, particularly in optoelectronics such as photodetectors, photovoltaics, light-emitting diodes, and lasers.

In this work, we focus on developing a reliable approach to form a p-n junction on MoS₂ via a combination of a two-step approach and an oxide deposition. A continuous MoS₂ layer was fabricated through a laser-assisted chemical vapor deposition process followed by patterned deposition of molybdenum oxide (MoO_x) on top of MoS₂. The MoO_x-MoS₂ heterostructure exhibits enhanced photoluminescence confirming p-type doping due to an efficient electron transfer from MoS₂ to MoO_x. The p-type doping is also confirmed using X-ray photoelectron spectroscopy (XPS). Moreover, Raman spectroscopy reveals a substantial shift in-plane (A_{1g}) and out-of-plane (E_{2g}) Raman peaks within the MoO_x-MoS₂ heterostructure compared to PLD-CVD

grown MoS₂. Surprisingly, our data indicate both doping and stress/strain induced in the heterostructure region.

Moreover, Fermi level pinning in the interface region of MoO_x-MoS₂ heterostructure will be analyzed under a varying gate and source-drain voltage in fabricated thin-film field-effect transistors with different thicknesses of MoO_x layer deposited. Additionally, the photovoltaic and photodetector performances will be explored. This p-n heterostructure with a large surface area creates a solid optical absorption due to modulated band structure in the p-n junction area by band bending. This allows strong absorption of visible-light photons and numerous photo-generated electron-hole pairs with an efficient transfer of charge carriers. This offers a new path to ease the integration of p-n junctions on a larger area for enhanced optoelectronic device performances in both rigid and flexible substrates.