pMoOx-nMoS2 Heterojunction Assembly for Tunable and Efficient Optoelectronic Devices

Ulaganathan, Rajesh; Ghimire, Ganesh; Miakota, Denys Igorevich; Canulescu, Stela

Publication date:
2023

Document Version
Peer reviewed version

$pMoO_x$-$nMoS_2$ Heterojunction Assembly for Tunable and Efficient Optoelectronic Devices

Rajesh Kumar Ulaganathan[1], Ganesh Ghimire[1], Denys I. Miakota[1], and Stela Canulescu*[1]

[1]Department of Photonics Engineering, Technical University of Denmark, DK-4000 Roskilde, Denmark

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 (MoS_2) in specific, have attracted a great deal of research interest and showed emerging physical properties. The top surface of MoS_2 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 MoS_2 via a combination of a two-step approach and an oxide deposition. A continuous MoS_2 layer was fabricated through a laser-assisted chemical vapor deposition process followed by patterned deposition of molybdenum oxide (MoO_x) on top of MoS_2. The MoO_x-MoS_2 heterostructure exhibits enhanced photoluminescence confirming p-type doping due to an efficient electron transfer from MoS_2 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-MoS_2 heterostructure compared to PLD-CVD

grown MoS_2. 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-MoS_2 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.