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Full Length Article

Investigation of charge transport and band alignment of MoS_2-ReS_2 heterointerface for high performance and self-driven broadband photodetection

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ABSTRACT

Two dimensional (2D) van der Waals heterostructures are becoming one of the ascendant research areas for semiconducting device application owing to their remarkable optoelectronic properties, which allows more functioning ability beyond its individual constituent. 2D layered materials can be easily integrated and form heterostructure due to the dangling bond free surfaces. However, for novel optoelectronic device applications, the understanding of charge carrier dynamics at the interface of heterostructures is critical and essential. Here, we demonstrate the charge transport behaviour and energy level band alignment at MoS_2-ReS_2 heterointerface. Interlayer coupling and charge transport behaviour are investigated by Raman and photoluminescence spectroscopy. The photoelectron spectroscopy confirms type II band alignment between MoS_2-ReS_2 interface, which is required for efficient separation and transportation of charge carriers. As a proof of concept, a highly sensitive, self-biased broadband photodetector is fabricated with a responsivity of 42.61 A/W at a low bias of 1 V under the illumination of 800 nm, which is 16 fold higher than the reference pristine MoS_2 photodetector. Moreover, fast rise/decay transient photoresponse (20/19 ms) strongly advocate the spatial separation of charge carriers across the interface. Our proposed work establishes the MoS_2 and ReS_2 as promising candidates for next-generation broadband photodetector applications.

1. Introduction

Two dimensional (2D) transition metal dichalcogenides (TMDCs) evolved as propitious materials for the development of optoelectronic and electronic applications because of their exclusive mechanical, optical, and electrical properties [1,2]. Molybdenum disulfide (MoS_2), one of the TMDCs, has emerged as a potential candidate for various electrical, optical and catalytic applications owing to its high absorption coefficient, large and tunable bandgap (1.2–1.8 eV), high carrier mobility, and presence of active edge-sites. Moreover, scalable production and ease of fabrication with high environmental stability have attracted worldwide researchers to utilize MoS_2 for future optoelectronic applications [3–5]. Despite the revolutionize development in performance of MoS_2 photodetector, the employment of single material limits the photodetection capability. As a single material, MoS_2 suffered from low optical absorption, which restricts its use in high performance photodetector applications. Integration of two or more high absorbing materials provides the opportunity to achieve superior light absorption and wide spectral response which leads to substantial enhancement in device performance.[6–8] Thereby, optical absorption of MoS_2 can be enhanced by forming the heterostructure with other high optical absorbing materials. Heterostructure photodetector devices exhibit superior photoresponse, which can access more functioning ability beyond its individual constituents [9,10]. Also, the surface of 2D materials is free from dangling bonds that can be easily integrated without any restriction of lattice misfit [11]. Hence, a large number of heterostructure combinations are possible due to the existence of interlayer coupling in 2D materials [12].

In this regard, the integration of MoS_2 with other 2D TMDCs such as WS_2 [13], WSe_2 [14], $MoTe_2$ [15], $MoSe_2$ [16] etc. has been investigated. Among them, most of the studied TMDCs display isotropic behaviour owing to high lattice symmetry. In contrast to isotropic

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