Thiol Functionalization of Tellurium Vacancies in $MoTe_2$ for Type III Heterojunction Phototransistors

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Abstract

Molybdenum ditelluride ($MoTe_2$) nanosheets possess distinctive physico-chemical properties and opto-electric characteristics owing to their adjustable and narrow band gap (E_g ~ 1 eV), facilitating simultaneous electron and hole transport.[1,2] Despite considerable efforts in the development of p-type $MoTe_2$ field-effect transistors (FETs), challenges persist due to tellurium (Te) point vacancies, raising reliability concerns.[3,4] In this study, we tackle this challenge by surface treatment of $MoTe_2$ with 1-butanethiol to mitigate Te vacancies. Comprehensive materials and electrical characterizations provided unambiguous evidence for the efficient chemisorption of butanethiol. The resulting thiol-treated $MoTe_2$ FET demonstrates a 10-fold enhancement in hole current and a positive threshold voltage shift of 25 V, indicative of effective hole carrier doping. Moreover, we extend this molecular engineering strategy to fabricate van der Waals heterostructures, developing a n-SnS_2/thiol-$MoTe_2$ junction FET (thiol-JFET). Remarkably, the thiol-JFET exhibits a significant negative photoresponse with a responsivity of 50 A W^{-1} and a fast response time of 80 ms based on band-to-band tunneling. Additionally, the thiol-JFET showcases gate-tunable tri-modal photodetection, encompassing two photoactive modes (positive and negative photoresponse) and one photo-inactive mode. These findings underscore the promise of molecular engineering approaches in augmenting the performance and functionality of $MoTe_2$-based nanodevices for advanced 2D-based optoelectronics.

References

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Figures

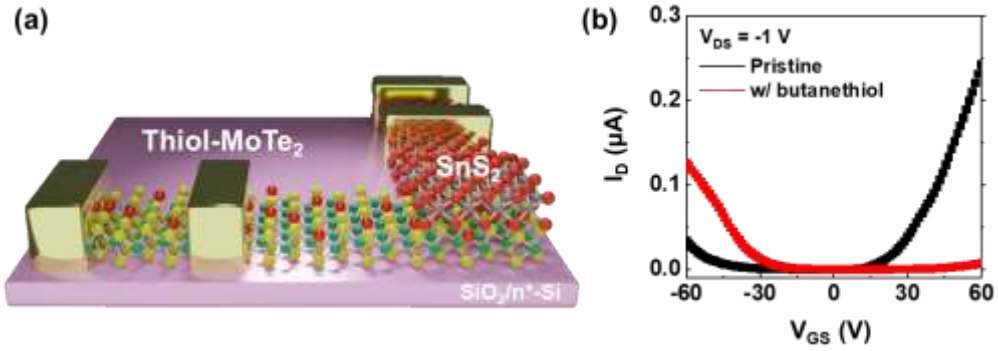

Figure 1: (a) 3D schematic view of SnS_2/thiol-$MoTe_2$ heterojunction FET. (b) Transfer characteristics of the n-type pristine $MoTe_2$ in black and p-type thiol-$MoTe_2$ FET in red.