Interfacial Charge Transfer Mechanisms Driving High Responsivity in WS_2 QD/MoS_2 Photodetectors

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Abstract

Mixed-dimensional heterostructures that integrate zero-dimensional (0D) quantum dots with two-dimensional (2D) transition-metal dichalcogenides (TMDs) provide a powerful route to modulate light–matter interactions for next-generation optoelectronic devices . In this work, we report a facile hydrothermal synthesis of WS_2 quantum dots (QDs) coupled with mechanically exfoliated MoS_2 flakes to form a robust 0D–2D van der Waals hybrid photodetector. Structural and spectroscopic analyses confirmed highly crystalline, uniformly dispersed WS_2 QDs with tunable emission spanning blue to green, and their successful integration across multilayer MoS_2 channels [1-2]. Device-level characterization revealed ultrahigh responsivity (>8000 A/W at 0.05 nW white light) and detectivity approaching 10^{12} Jones, surpassing pristine MoS_2 phototransistors. Density functional theory and many-body perturbation (GW) calculations further elucidated quasiparticle band alignment and enhanced carrier separation driven by interfacial electric fields, confirming the role of photogating and quantum confinement in prolonging carrier lifetimes. These results establish WS_2 QD/MoS_2 heterostructures as a scalable platform for broadband, low-power photodetection, with implications for imaging, sensing, and flexible optoelectronics.

References

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[2] Yin, W.; Bai, X.; Chen, P.; Zhang, X.; Su, L.; Ji, C.; Gao, H.; Song, H.; Yu, W. W. *ACS Appl. Mater. Interfaces* 2018, 10 (50), 43824−43830.

Figures

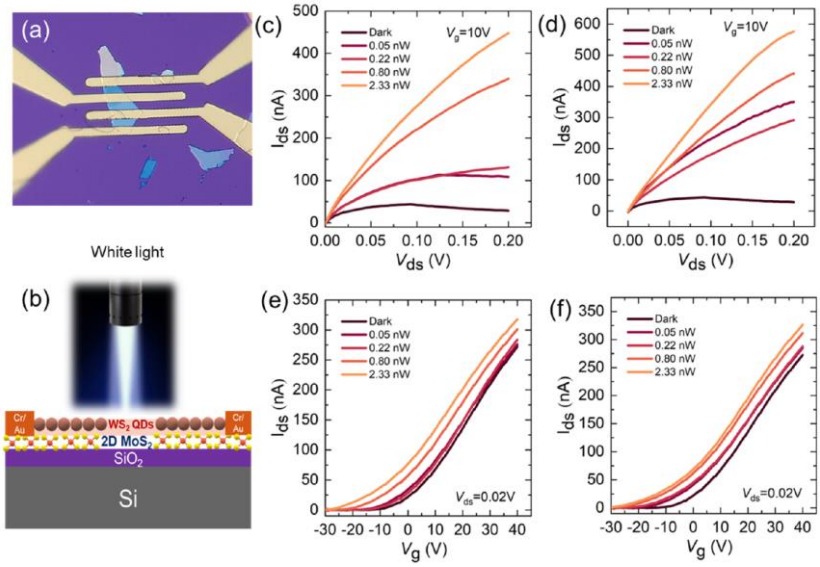

Figure 1: (a) Optical image of the fabricated MoS2 FET on the SiO2/Si substrate. (b) Schematic of a 0D/2D heterostructure device and measurement. Drain−source current (*I*ds) vs drain−source voltage (*V*ds) of (c) the pristine MoS2 device and (d) the WS2 QD/MoS2 hybrid device at zero back-gate voltage (*V*g = 10 V) during the dark condition and the different powers of white light illumination. Back-gate voltage (*V*g)- dependent transfer characteristics (*I*ds−*V*g) of (e) the pristine MoS2 device and (f) the WS2 QD/MoS_2 hybrid device, respectively.