Tunability of the Photoluminescence and Coupled Charge Transfer Dynamics in Monolayer MoS_2 Decorated with WS_2 Quantum Dots

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Atomically thin transition metal dichalcogenides (TMDs) are semiconductor films with excellent electrical and optical properties, which are promising candidates for a wide range of optoelectronic applications. Herein, we systematically study the tunability of the photoluminescence (PL) of the monolayer MoS_2 (1L-MoS_2) decorated with WS_2 quantum dots (WS_2 QD). The room temperature PL spectrum of pristine 1L-MoS_2 is quenched with its decoration with WS_2 QDs (see Figure 1). From the Kelvin probe force microscopy analysis, we have established a decrease in the work function of 1L-MoS_2 with the decoration of WS_2 QDs. Using the four-energy level model, a detailed quantitative analysis involving coupled charge transfer was employed to explain the redshift and the systematic decrease in the intensity of the PL peak in 1L-MoS_2/WS_2 QD heterostructure. The modulation of the PL spectrum in the heterostructure is attributed to the increase in the formation of negative trions through the charge transfer from WS_2 QD to the 1L-MoS_2 and thus making the 1L-MoS_2 heavily n-type doped, with change in carrier density, $\Delta n_e \sim 1.5\times10^{13}$ cm^{-2}, as shown in Figure 2. This study establishes the contribution of defects and concentration dependent rate kinetics in the coupled charge transfer dynamics in 1L-MoS_2, and it lays out a convenient strategy to manipulate the optoelectronic properties of 1L-MoS_2 for various applications.

Figures

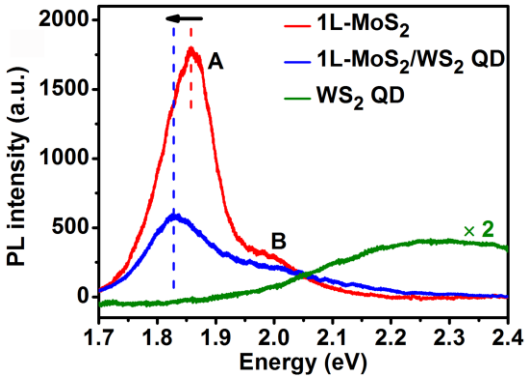

Figure 1: Comparative PL spectra of pristine 1L-MoS_2, WS_2 QDs and 1L-MoS_2/WS_2 QD HS (with 24 mg/L concentration of WS_2 QD) measured with 488 nm excitation using a micro-Raman system.

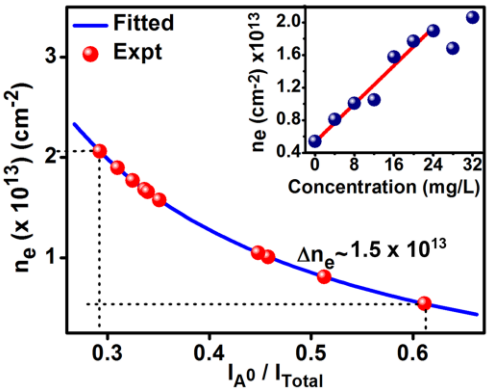

Figure 2: Calculation of electron density (n_e) in the heterostructure based on the law of mass action; the inset shows n_e as a function of the concentration of WS_2 QDs.