Interlayer Energy Transfer in WS_2-hBN-MoS_2 Heterostructure

Gayatri[1], Natalia Zawadzka[1], Adam Babiński[1], Maciej R. Molas[1], Arka Karmakar[1]

[1]*Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland*

Heterostructures (HSs) made by the vertical stacking of van der Waals monolayers (1Ls) have shown great potential in next-generation opto/electronic device applications [1]. Interlayer charge transfer (CT) and energy transfer (ET) are the two main photocarrier relaxation pathways in these materials. However, at very small or no interlayer distances, CT is more probable than ET. In the type-II transition metal dichalcogenides (TMDs) HS, ET happens *via* the dipole-dipole coupling (Förster type) when there is an overlap between the emission spectrum of the donor material and the absorption spectrum of the acceptor material [2]. To investigate this further, we studied a HS made by the 1Ls of tungsten disulfide (WS_2) and molybdenum disulfide (MoS_2), with hexagonal boron nitride (hBN) as a charge-blocking interlayer (optical micrograph in Figure a), using temperature-dependent differential reflection contrast (RC), photoluminescence (PL), and photoluminescence excitation (PLE) spectroscopy. We find that at a low temperature (5 K), WS_2 PL enhancement from the HS area (Figure b) is due to an efficient ET from the MoS_2 to WS_2 monolayer, whereas at room temperature (300 K) there is a slight reduction (Figure c). Our preliminary results show great promise for studying the interlayer ET process from a *lower-to-higher* bandgap material.

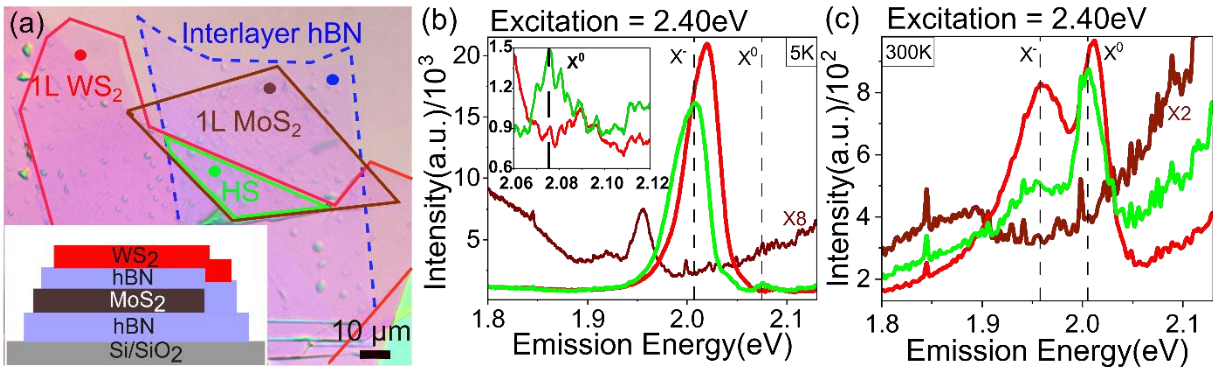

Figure: *(a) Optical image of the sample with a schematic illustration of the cross-sectional view of the HS as an inset. (b-c) PL spectra from the three areas of the sample with an excitation energy of 2.40eV (here, dashed vertical lines indicate the positions of the bound exciton(X^-) and the neutral exciton(X^0) of WS_2 in the HS region; X8 and X2 represent the multiplication factor of the intensity of MoS_2), (b) at 5 K, which clearly shows the enhancement in the intensity of the WS_2 neutral exciton in the HS region compared to the 1L of WS_2 (c) at 300 K, which indicates no enhancement but a slight decrease in the intensity of the WS_2 exciton in the HS. This confirms the energy transfer from MoS_2 to WS_2 at low temperatures, which is absent at room temperature.*

References:

[1] Shi J. Liang *et al.*, *Adv. Mater.* **32**, 27 (2020).

[2] Arka Karmakar *et al.*, *Nano Lett.* **23**, 12 (2023).