Influence of the substrate and environment on the optical properties of the WSe_2 monolayers

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Atomically thin transition-metal dichalcogenides (TMDCs) have recently attracted significant attention due to their remarkable physical properties and potential applications in optoelectronics and spintronics. The most common method of elaboration of TMDCs monolayers (MLs) is exfoliation on SiO_2/Si substrates. Optical properties of TMDCs monolayers are strongly dependent on the interaction with substrate and surrounding gas.

We report on comprehensive photoluminescence (PL), reflective contrast (RC) and Raman scattering studies of WSe_2 MLs mechanically exfoliated on SiO_2/Si substrates with different thickness of SiO_2 layer, performed at room temperature (T=295 K) in ambient and vacuum, We found that thickness of the SiO_2 layer greatly influences the RC spectra [Fig.1]. In the RC spectra of MLs exfoliated on SiO_2/Si substrate with thickness of SiO_2 layer equal to 200 nm and 270 nm, the exciton (X) and trion (T) resonances are well resolved, both in vacuum and ambient. In contrast, in the RC spectra of MLs exfoliated on the 300 nm thick SiO_2 layer, only the X resonance is observed. For all studied samples the X line dominates the PL spectra recorded in ambient. The intensity of PL performed in vacuum is significantly lower. The X line also dominates the emission spectra of the MLs exfoliated on 200 nm and 300 nm thick SiO_2 layers, whereas for the 270 nm thick SiO_2 layer the X and T lines are comparable in intensity. The trion intensity exceeds exciton intensity with the increase of excitation power density.

We attribute all these effects to the different densities of the two dimensional carrier gas, originating from the charge transfer, both from the substrate and from the environment. We discuss the role of neutral and charged defects corresponding to crystal growth conditions and elaboration on monolayers on determination the charge transition levels as well as the resulting positions of the ML Fermi level.

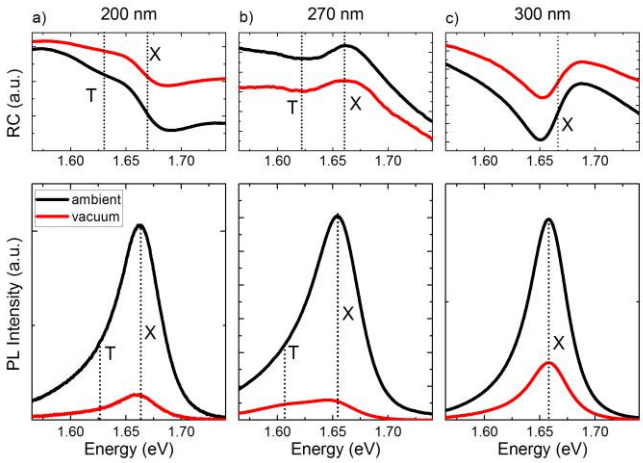

Fig. 1. Comparison of the PL and RC spectra of the WSe_2 MLs exfoliated on the substrates with different SiO_2 thickness, recorded at T=295 K in vacuum and ambient.