Photo- versus electroluminescence of the WSe_2 monolayer: a comparative study

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Photoluminescence (PL) and electroluminescence (EL) are essentially similar types of spontaneous emission of light from an excited state of a material. The key difference comes from the way of carriers excitation. While the PL emission emerges after excitation of the material using a laser light, the EL appears as a result of an electric current passed through the material. Comparison of these two experiments in monolayers (MLs) of semiconducting transition metal dichalcogenides (S-TMDs), *e.g.* WSe_2 ML, may develop our knowledge about them for their potential applications in optoelectronic devices.

In this work, we investigate the optical response of a light-emitting tunnelling structure based on a WSe_2 ML as an active emission material. The stacking sequence for the sample is: the central WSe_2 ML is encapsulated between two thin hexagonal BN (hBN) flakes being tunnelling barriers, which are embedded between two graphene layers serving as electrodes. The Figure shows the results of the PL and EL measurements at low temperature (T=4.2 K). The obtained PL spectrum composed of a series of emission lines with the highest energy peak related to the neutral exciton (X) is in agreement with the analogous PL spectra of the WSe_2 ML close to the neutrality point, reported in the literature [1]. In contrast, shapes EL spectra exhibit the completely different from the PL response, as well as from each other, while the sign of the applied voltage is reversed. The first difference, *i.e.* between the PL and EL, can be understood in terms of different types of excitation, it means photon versus tunnelling current. Furthermore, the applied voltage needed to observe the EL signal is much larger than the electronic band gap of the ML (~1.9 eV) [2] suggesting additional parasitic processes, which substantially reduce the tunnelling current, and hence the intensity of the EL. The EL disparity reveals different thicknesses of to hBN barriers, leading the unintentional doping the WSe_2 ML due to various numbers of tunnelling electrons and holes. We identify that under positive and negative applied voltages the WSe_2 ML is correspondingly doped with holes (p-type) and electrons (n-type).

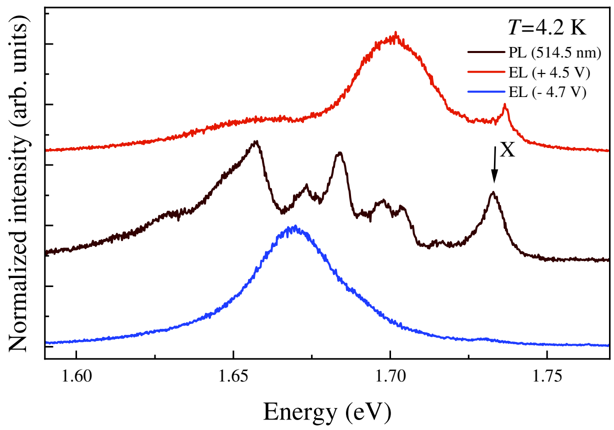

Figure: PL and EL spectra of WSe_2 ML. The spectra are normalized to the maximum intensity and shifted vertically for clarity.

Our results of comparative investigations give us important information of the potential applications of S-TMD MLs in optoelectronic devices.

[1] E. Liu, *et al.*, *PRL* **124**, 196802 (2020).
[2] M. R. Molas, *et al.*, *PRL* **123**, 136801 (2019).