Optical Properties of $MoSe_2$ in Heterostructures with MgSe/ZnSe Grown by Molecular Beam Epitaxy

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The best optical properties of transition metal dichalcogenides (TMD) are obtained for monolayers placed between hBN layers. On a small scale, this can be realized using exfoliated materials, but an epitaxial realization of such structure on a large scale is very challenging. Epitaxial TMD can be effectively grown on hBN [1], but due to the high growth temperature of hBN, TMD cannot be covered by hBN without affecting TMD layer. Therefore there is a quest to find materials that can protect TMDs without degrading their properties and possibly form a barrier material for TMDs. This work is concentrated on interactions between $MoSe_2$, ZnSe, and MgSe, and the optical properties of structures containing these materials.

The growth was realized by Molecular Beam Epitaxy on exfoliated hexagonal boron nitride deposited on the silicon (100) wafer covered by 90 nm of silicon dioxide. The $MoSe_2$ monolayer was grown first, to verify its quality, and then it was covered with 10 nm of MgSe and 100 nm of ZnSe. The samples were examined with Atomic Force Microscopy (AFM). Exciton energies were investigated using low-temperature photoluminescence (PL).

The PL signal of the uncovered $MoSe_2$ shows strong, narrow excitonic lines with the full width at half maximum (FWHM) of about 7-8 meV. Such a signal was visible almost everywhere on the hBN surface, which is a sign of a dense arrangement of $MoSe_2$ flakes. However, after the growth of ZnSe, an evident peak from exciton was hardly findable. The possible explanation for that is the similar energy level of the conduction band minimum for $MoSe_2$ and ZnSe (Fig. 1a). To prevent electrons from escaping the $MoSe_2$ layer, the structure has been modified by removing ZnSe in the annealing process and growing the MgSe and ZnSe on $MoSe_2$ (Fig. 1b). During the PL measurements of such a structure, exciton lines were visible in many spots on the sample. The energy of neutral and charged exciton was on average blue-shifted by 6-8 meV, however, this shift varied at different spots on the sample.

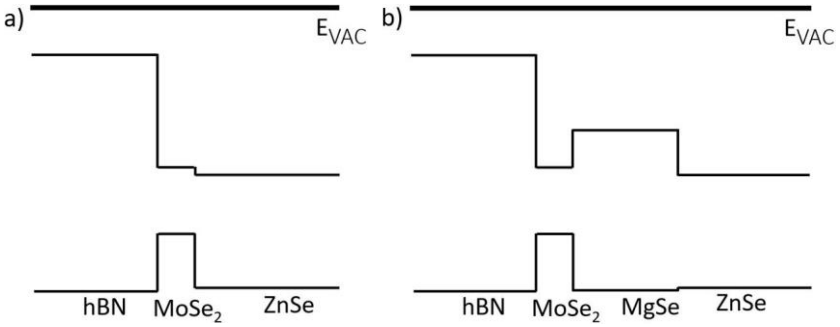

Figure 1: a) Band structure of hBN/$MoSe_2$/ZnSe.
b) Band structure of hBN/$MoSe_2$/MgSe/ZnSe

[1] W. Pacuski, M. Grzeszczyk, K. Nogajewski, A. Bogucki, K. Oreszczuk, J. Kucharek, K.E. Połczyńska, B. Seredyński, A. Rodek, R. Bożek, T. Taniguchi, K. Watanabe, S. Kret, J. Sadowski, T. Kazimierczuk, M. Potemski and P. Kossacki, *Nano Letters* **20**, 3058 (2020).