$MoSe_2$ as an epitaxial quantum well with asymmetric MgSe and hBN barriers

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The best optical properties of transition metal dichalcogenides (TMD) are obtained for monolayers placed between hBN layers [1]. On a small scale, this can be realized using mechanical transfer, but epitaxial realization of such structure on a large scale would be very challenging: epitaxial TMD can be effectively grown on hBN [2], but due to the high growth temperature of hBN, TMD cannot be epitaxialy 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 TMD quantum well. We propose barriers made of II-VI semiconductors, which can be grown on 2D materials at very low temperatures [3], and since we decided to cover $MoSe_2$, we choose wide gap selendies: ZnSe and MgSe.

The growth is realized by Molecular Beam Epitaxy on exfoliated hexagonal boron nitride deposited on the SiO_2/Si wafer. First, The $MoSe_2$ monolayer is grown on a large wafer, and optical quality is verified. Then the wafer is cleaved into smaller pieces, which are covered either directly by 100 nm of ZnSe or first by 10 nm of MgSe and then by 100 nm of ZnSe.

The low-temperature photoluminescence (PL) signal of the uncovered $MoSe_2$ shows strong, narrow excitonic lines with the linewidth of about 7-8 meV. Such a signal is visible almost everywhere on the hBN surface, which is a sign of successful growth of homogenous $MoSe_2$ [2]. However, after the growth of ZnSe on $MoSe_2$, a exciton peak is hardly findable. The possible explanation for that is the higher level of the conduction band for $MoSe_2$ than for ZnSe (Fig. 1a). To prevent electrons from escaping the $MoSe_2$ layer, we introduced high energy gap barrier, MgSe, before ZnSe (Fig. 1b). Indeed, PL measurements of such a structure reveal exciton lines on large areas of the sample, with similar linewidth to uncovered sample, but with the energy of neutral and charged exciton blue-shifted by 6-8 meV. Observation of strong and narrow lines is an indication that in contrary to ZnSe, MgSe is a good barrier material for both electrons and holes in $MoSe_2$, as depicted in Fig. 1.

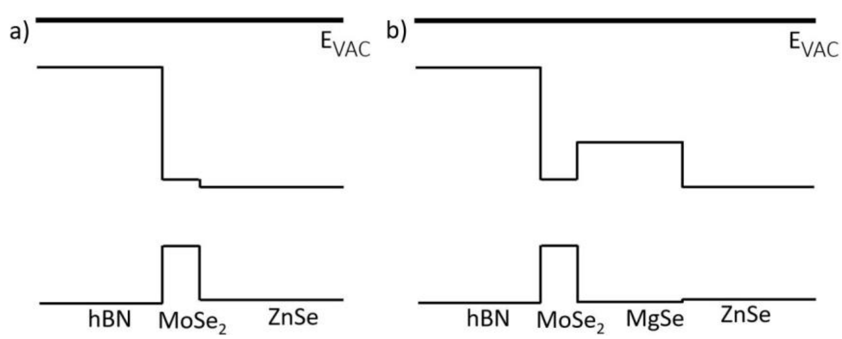

Fig. 1. Band structure: a) type II hBN/$MoSe_2$/ZnSe and b) type I hBN/$MoSe_2$/MgSe/ZnSe

References

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