MBE grown heterostructures of ZnSe, CdSe, $MoSe_2$, and hBN

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The best optical properties of exfoliated transition metal dichalcogenides (TMDs) are obtained for monolayer materials encapsulated in hBN, so mechanically stacked in heterostructure hBN/TMD/hBN [1]. Part of this heterostructure can be reproduced using epitaxial methods, and indeed TMD grown on hBN exhibits much better optical properties [2] than TMD grown on other substrates. Still, the top hBN layer is missing in such a procedure. To finish heterostructure using large-scale epitaxial methods, the growth of hBN on TMD would be an ideal option. This however seems to be not accessible nowadays, because the very high growth temperature of hBN (over 1200C) makes it impossible to grow it on TMDs without destroying the previously deposited material. Consequently, other cap materials should be considered as candidates for protection of epitaxial TMDs.

In this work, we experimentally verify the possibility of covering TMDs with II-VI compounds based on selenides: ZnSe and CdSe. Materials are chosen due to chemical similarity to TMDs based on selenium, e.g $MoSe_2$, therefore there should be no risk of substitution of Se in TMD by other elements. Moreover, ZnSe is chosen due to its wide band gap and its transparency in the $MoSe_2$ emission spectrum. We expect that for TMDs, ZnSe will be just an isolator, similar to hBN. On the contrary, CdSe emission spectrum is close to the one of $MoSe_2$, so one can expect interactions in a formed heterostructure. Importantly, both ZnSe and CdSe can be grown at low temperatures (typically 300C) compared to temperatures used during the preparation of $MoSe_2$ (300-800C).

Heterostructures ZnSe/$MoSe_2$ and CdSe/$MoSe_2$ were grown using Molecular Beam Epitaxy (MBE) on exfoliated hBN deposited on SiO_2/Si substrates. Atomic force microscopy (AFM) and optical microscopy reveal the rich morphology of grown structures indicating the polycrystalline nature of II-VI material grown on $MoSe_2$. The results of low-temperature photoluminescence show that both ZnSe and CdSe strongly affect the optical spectra of $MoSe_2$. Moreover, the photoluminescence of CdSe is much stronger than the photoluminescence of MBE $MoSe_2$. Therefore research on $MoSe_2$ with II-VI layer present on top seems to be difficult. Still, we checked that the good optical properties of $MoSe_2$ grown on hBN can be restored by desorption of II-VI material from the surface of the heterostructure.

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