Giant enhancement of light emission from InSe in selectively strained InSe/MS_2 (M=Mo,W) heterostructures

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Abstract

The possibility to create heterostructures (HSs) of van der Waals crystals by stacking atomically thin layers with different compositions has led to the discovery of many fascinating effects, such as the observation of moiré excitons and highly-correlated electronic states [1]. In addition, strain has been demonstrated to be a most powerful tool to modify controllably the electronic properties of 2D materials and HSs [2].
Here, we report an exemplary case, where the interplay between heterostructuring and strain improves notably the optoelectronic characteristics of atomically thin flakes of InSe. The latter features excellent transport properties [3], but poor emission efficiency in the few layer limit, thus inhibiting the development of InSe-based fast photodetectors. We show that the emission yield of InSe can be boosted by coupling InSe to strained transition metal dichalcogenide (TMD) monolayers (MLs). Strain is achieved by proton irradiation of TMD bulk MS_2 (M=Mo,W) flakes, in which protons lead to a local blistering of the crystal just beneath the topmost lattice plane and hence to the formation of highly strained ML micro/nano-domes filled with H_2 [4]. InSe is subsequently coupled to strained MS_2 ML domes by HS fabrication. In turn, the strain-induced reshuffling of the valence bands in the MS_2 domes [5] enables the direct transfer of holes from the Γ point of MS_2 to that of InSe, while electrons undergo a defect-assisted tunnelling from the conduction band of the strained MS_2 ML to that of InSe. As a result of these charge transfer processes, an increase by up to two orders of magnitude in the exciton emission efficiency of InSe is eventually observed and theoretically framed.

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