Heterostructuring in mechanically deformed van der Waals materials

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Heterostructures (HSs) of van der Waals (vdW) crystals are created by stacking atomically thin layers with different compositions and relative angular alignment thus prompting an endless number of combinations. Another key feature of vdW HSs (and of the constituent layers) is their highly sensitive response to strain [1].

Here, we show two exemplary cases, where combined heterostructuring and strain add new functionalities to and improve the optoelectronic characteristics of 2D crystals.

First, we consider HSs formed by strained transition metal dichalcogenide (TMD) monolayers (MLs) and h-BN. Strain is achieved by proton irradiation of TMD bulk flakes, in which protons lead to a local blistering of the crystal just beneath the topmost plane and hence to the formation of highly strained ML micro/nano-domes filled with H_2 [2]. The capping with h-BN promotes an elastic energy transfer from the domes to h-BN that eventually prevents the dome deflation at the liquefaction temperature of H_2 (~33 K). In turn, this preserves the dome strain field and enables the fabrication of spatially controlled quantum emitters [3].

Secondly, InSe/TMD dome HSs are presented. InSe features excellent transport properties but poor emission efficiency in the few layer limit. We exploit the strain-induced transition of the valence band maximum from K to Γ in MS_2 (M=Mo,W) ML domes [4] to enable efficient carrier transfer TMD MLs to the InSe. As a result of these processes a sizable increase in the emission efficiency of InSe is observed.

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