Strain in Flatlands

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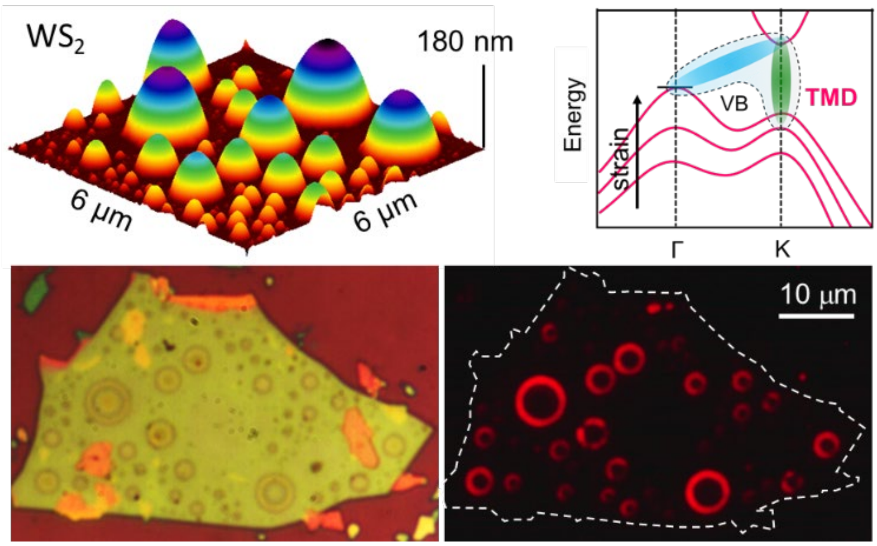
Two-dimensional (2D) crystals have led to a change of paradigm in Solid State Physics. The discovery of graphene, the forerunner of 2D crystals, dates back to 20 years ago. Since then, hundreds of 2D crystals have been isolated from the so-called van der Waals materials. Despite their atomic thickness, 2D materials feature an outstanding mechanical robustness and resilience, so that mechanical deformations represent one of the most viable and effective tools to engineer their properties.

Here, we show how strain can be exploited in 2D materials to fine-tune their optoelectronic properties and to engender novel effects. We focus on transition metal dichalcogenides (TMDs) monolayers (MLs), where we developed an original method to engender localised strains. The presented approach is based on low-energy (10 eV) hydrogen-ion irradiation of bulk flakes that leads to the formation of micro/nano-domes made of a single ML directly lifted from the underlying bulk lattice and filled with highly pressurised H_2 (tens to hundreds of atm) [1]. The domes can be made spatially controlled by combining proton irradiation with electron beam lithography. They host complex strain fields that reach record values of about 10% [2] and can be exploited to address the elastic properties of van der Waals materials [3].

The high strain fields hosted by the domes cause dramatic changes in the ML electronic properties. Optical spectroscopy studies reveal intriguing phenomena, comprising a strain-induced direct-to-indirect bandgap crossover [4] and exciton hybridisation effects as derived by Zeeman splitting measurements up to 30 T [5]. Importantly, the strain values attained on specific regions of the domes promote an especially favourable electronic configuration, whereby defect levels admix with extended state levels leading to intense and narrow emission lines featuring quantum behaviour [6].

Our results demonstrate the great potential of strain to create exciting new avenues in Flatlands.



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