Strain-tuning of the optoelectronic and spin properties of 2D crystals

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Within the variegated family of two-dimensional crystals, semiconducting transition-metal dichalcogenides (TMDs) show alluring optoelectronic and spin properties in the monolayer (ML) limit, featuring a direct bandgap which results in an efficient visible/near-infrared light emission, and a strong spin-orbit coupling. Furthermore, these materials display exceptional flexibility and robustness and can be subjected to remarkable strains.
Here, we present a novel technique to induce controllable strain-fields in TMDs and study their effects. By hydrogen irradiation treatments, we induce the formation of hydrogen-filled nano- or micro- bubbles with single-layer-thickness, acting as efficient light emitters (Fig. 1(a-b)) [1]. These stable and robust nano- and micro-bubbles host complex strain fields, that cause dramatic changes in the TMD electronic properties. Photoluminescence steady-state and time-resolved studies highlight the occurrence of a strain-induced direct-to-indirect bandgap crossover (Fig. 1(c)) [2]. Magneto-optical experiments and ab-initio calculations allow us to achieve information on the spin and valley properties of k-space direct and indirect excitons. Indeed, a dramatic reduction of the exciton gyromagnetic (g-)factor is observed under high strains (Fig. 1(d)) and explained in terms of intriguing hybridisation mechanisms between the two exciton species. Our results reveal the potential of strain in tuning not only the emission energy of excitons in TMDs, but also their g-factor.

References

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Figures

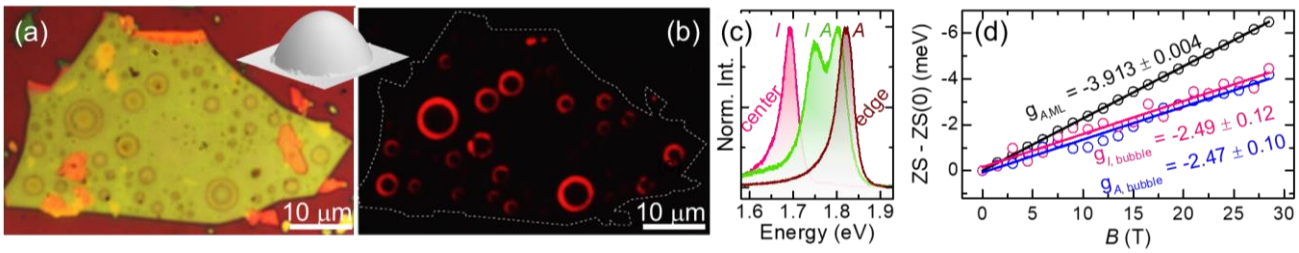

Figure 1: (a-b) Optical image of a WS_2 flake with micro-bubbles (a) and image of the luminescence measured from the same area (b) [2]. Inset: Atomic-force microscopy image of a bubble. (c) Typical spectra acquired while going from the edge of a bubble to its centre. At the edge the total strain ε_{tot} is ~2% and the direct *A* exciton dominates, while at the centre ε_{tot} ~4% and the indirect *I* exciton dominates. (d) Zeeman splitting (ZS) for increasing the magnetic field (up to 28.5 T) for an unstrained WS_2 ML (*A* exciton) and two WS_2 bubbles whose spectrum was dominated by *A* and *I* excitons.