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Acoustic Manipulation of Excitons in 2D Semiconductors

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Abstract

The Stark effect is one of the most efficient mechanisms to manipulate many-body states in semiconductor nanostructures. In mono- and few-layer transition metal dichalcogenides, it is usually induced by optical and electric field means. In this contribution [1], we address the tunability of the optical emission energies of excitonic states in $MoSe_2$ monolayers employing the 220 MHz in-plane piezoelectric field carried by surface acoustic waves (SAWs). We transfer the monolayers to high dielectric constant piezoelectric substrates, where the neutral exciton binding energy is significantly reduced. In this way, we are able to dissociate the excitonic complexes (neutral exciton and trions) and quench their photoluminescence emission by more than 90 %. The SAW in-plane piezoelectric field also redshifts the excitonic optical emissions. A model for the acoustically-induced Stark effect yields neutral exciton and trion in-plane polarizabilities of approximately 530 and 630 x 10^{-5} meV/(kV/cm)^2, respectively, which are considerably larger than those reported for monolayers encapsulated in hexagonal boron nitride. Our findings contribute to create alternative routes to manipulate and modulate multi-exciton interactions in two-dimensional semiconductor systems for optoelectronic applications.

References

[1] D. Scolfaro, M. Finamor, L. Trinchão, B. L. T. Rosa, A. Chaves, P. V. Santos, F. Iikawa, O. D. D. Couto Jr., ACS Nano, **15**, 15371 – 15380, (2021).

Figures

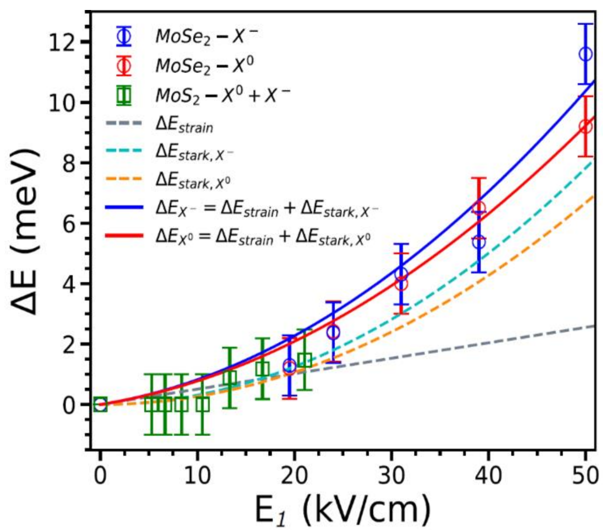

Figure 1: Photoluminescence (PL) redshift of the neutron exciton and trion emission lines in $MoSe_2$ and MoS_2 monolayers as a function of the SAW in-plane piezoelectric field (E_1). Solid lines are fit to the data. Gray dashed line represent the SAW strain contribution to the PL shift.