Understanding the excitonic physics of organic-inorganic 2D perovskites for efficient and low-cost photovoltaics

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Hybrid (organic-inorganic) halide perovskites (HaPs) have recently emerging as a low-cost semiconductors for optoelectronics, notably yielding single-junction solar cells with efficiencies larger than 22%. Two-dimensional (2D) perovskites (2D-HaPs) are a sub-class of HaPs offering a pathway for improving the efficiency and durability of HaP optoelectronic devices, and for developing devices with new functionalities exploiting the unique physics of these materials. However, there still limited knowledge of both the fundamental physics and the growth of both 2D-HaPs crystals and thin films used for integration in devices. In particular, there is no general understanding of the interplay between, on the one hand, the photo-excited states and electronic properties of 2D-HaPs and, on the other hand, their soft and dynamic lattice structure. Here, using optical spectroscopy and magneto-absorption, coupled with structural probes, we report the dependence of the formation, dynamics, and recombination of exciton states on the structural and compositional details of hybrid 2D perovskites [1]. Our work reveals the changes in the exciton properties due to the tuning of the thickness of the 2D perovskites and the size of the organic molecules in the lattice (Fig. 1a). The exciton characteristics are explained by an advanced model which includes quantum and dielectric confinement. Moreover, we demonstrate the existence of unique electronic states located at the edge surfaces of the 2D perovskite layers (Fig. 1b), which promote the dissociation of the strongly bound excitons and possibly result from local distortions of the lattice at the edges [2]. By understanding the details of thin film formation and by controlling the phase purity and orientation of the 2D perovskite crystals in films we fabricated single junction solar cells with >17% power conversion efficiencies with state-of-the-art stability. Finally, we will discuss the hetero-coupling between 2D perovskites and transition metal dichalcogenides, which yield photoluminescence enhancement by more than one order of magnitude as compared to their constituent [3].

REFERENCES

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[3] A. Yang *et al.*, Nano Lett., 19 (2019), 4852.

FIGURES

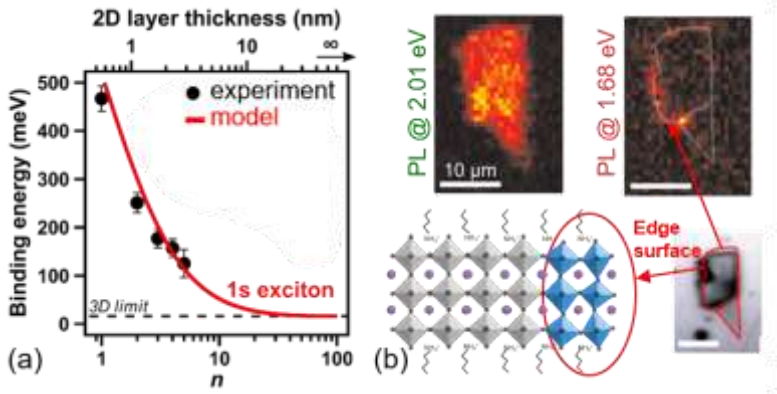

Figure 1: (a) Scaling of the exciton binding energy with the perovskite layer thickness. *n* represents the thickness of the perovskite layers in terms of number of octahedra PbI_6 units in the out-of-plane direction, where the perovskite real thickness is about n times 0.65 nm. (b) Observation of active edge-surface states in certain hybrid 2D perovskite due to local distortions at the edge of the perovskite layers. The top colour pictures are maps of the photoluminescence (PL) detected at two wavelength. The bottom images sketch the location of edge-surfaces in 2D perovskite layers.