Metal-halide perovskites - new fascinating playground for exciton physics

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Organic and inorganic metal-halide perovskites have emerged in recent decade as revolutionary semiconductor materials for energy harvesting, light emission and scintillators applications. The unique synergy of soft lattice and opto-electronic properties are often invoked to explain superior characteristic of perovskites materials in applications. At the same time such unique synergy creates fascinating playground for exciton physics which challenges our understanding of this elementary excitation. In this talk I will demonstrate that even after decade of intense investigation the notation "unique" so often used in case of perovskites deserves serious scrutiny.

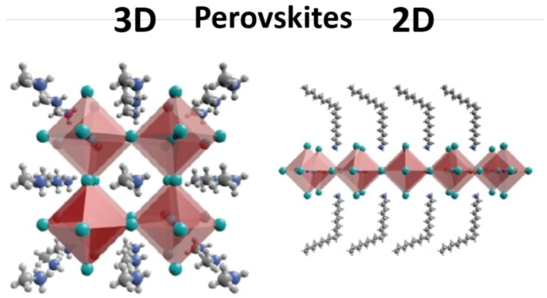

Figure 1: Schem of 3D and 2D perovskite structures composed of halides octahedras surrounded by organic molecules.

The characteristic structure of bulk and low dimensional perovskite materials comprises of corner-sharing octahedra BX_6, composed of metal cation and halide anions together with organic or inorganic A cation, which fills the voids between the octahedra. The soft, ionic lattice mixes crystalline, liquid and glassy behaviour forming complex background for electronic excitation where polaronic effects cannot be neglected. This results in not obvious photo-response and opens new path for semiconductors engineering.

Here I will discuss certain aspects of excitonic physics in bulk perovskites [1] and their derivatives [2] (such as 2D perovskites and double perovskites) which makes these materials so particular. First, I will demonstrate how the seemingly trivial problem of exciton binding energy in bulk semiconductor became a challenge in case of metal-halide perovskites. Secondly, I will highlight controversy related to exciton fine structure in perovskite compounds and if the soft lattice can suppress relaxation of excitons to dark state making 2D perovskites great light emitters. I will also show how soft nature of perovskite can be exploited to tune the fundamental properties of semiconductor such as bandgap, carriers effective mass and electron phonon-coupling in 2D perovskites. Finally I will show how the extreme case of exciton-phono coupling leading to exciton self-trapping leads to bright photoluminescence emission in indirect bandgap semiconductor - $Cs_2AgBiBr_6$ Double Perovskite.

[1] M.Baranowski, P. Płochocka *Adv. Energy Mater.*, 1903659 (2020).

[2] A. Surrente, M. Barnaowski, P. Płochocka, *Appl. Phys. Lett.* **118**, 170501 (2021).