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Title: Magneto-optical and microscopic properties of organo lead halide perovskites

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Abstract

The hybrid organo-lead halide perovskites are an emerging class of materials, proposed for use as light absorbers in a new generation of photovoltaic solar cells. The chemical formula for these materials is APbX_3 , where A is an organic cation and X represents halide anions (most commonly Br^- , Cl^- or I^- , or alloyed combination of these). The hybrid perovskites combine excellent absorption properties with large diffusion lengths and long lifetime of the carriers, resulting in photon conversion efficiencies as high as 22%. Another advantage is the inexpensiveness of the fabrication process. Therefore, with the rapid development of this class of materials, the perovskite photovoltaics has perspectives to outperform the well-established silicon technology.

Here, we use optical methods to investigate the basic electronic properties and morphology in the thin films of several representatives of the hybrid perovskites. We study the compounds based on Methylammonium and Formamidinium organic cations; the iodides and wide band-gap bromides, showing how the chemical composition influences the investigated parameters.

Using magneto-transmission, we directly determine the values of exciton binding energy and reduced mass. We find that the exciton binding energies at $T = 2$ K, varying from 14 to 25 meV, are smaller or comparable to the average thermal energy at room temperature (≈ 25 meV). Moreover, these values fall further at $T = 160$ K, to 10–24 meV. Based on that we conclude that the carriers photocreated in a perovskite material can be considered to be thermally ionized at room temperature. The measured reduced masses are in the range of 0.09–0.13 of the electron rest mass. We also show that both exciton binding energy and reduced mass depend linearly on the band gap energy. Therefore, the values of these parameters can be easily estimated for the synthesis of new perovskite compounds.

Using spatially resolved photoluminescence, we probe the morphology of perovskite films with micrometer resolution, which enables us to observe single crystalline grains. The resulting maps show that all investigated thin films are composed from the dark and bright crystalline grains. We demonstrate that the low temperature phase transition from tetragonal to orthorhombic phase is incomplete in all studied materials, as the remains of the tetragonal phase are found even at $T = 4$ K. By investigating structurally damaged and photo annealed regions, where the occurrence of the tetragonal phase at low temperatures is enhanced, we attribute its presence to the depleted halide content.

Keywords: hybrid perovskites, photovoltaics, exciton binding energy, effective mass, phase transition
