Temperature Dependence of Effective Masses in Three-dimensional Methylammonium Lead Trihalides

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Perovskite methylammonium lead trihalides ($CH_3NH_3PbX_3$ with X=Cl, Br, I) have gained particular research interest as promising hybrid compounds with excellent sunlight-to-energy conversion abilities [1]. They constitute a particular semiconducting materials system, in some aspects very different from the well-known family of epitaxial semiconductors. The soft, ionic lattice which mixes crystalline, liquid and glassy behaviour is often invoked to explain the superior characteristic of perovskite materials in applications. At the same time particular mechanical properties of perovskites create a complex background for electronic excitation where polaronic effects cannot be neglected and often challenge our understanding of fundamental parameters describing any semiconductors, for example, carrier mobility or effective mass μ [2,3].

For instance, theoretical prediction points that the soft, ionic lattice together with the unusual temperature dependence of the bandgap characteristic for these materials can lead to a significant rise of the carriers' effective mass with temperature [4,5]. Unfortunately, the temperature-induced rise of the carrier's effective mass in $CH_3NH_3PbX_3$ has never been confirmed experimentally so far. Understanding temperature dependence of reduced effective mass μ is particularly relevant in the context of solar cell applications as it affects carrier mobility.

Here we address the problem of temperature evolution of carrier effective mass by means of magneto-optical studies as μ can be directly extracted from the quantization of the free carrier states into Landau levels. We investigate three crystals methylammonium lead iodide ($MAPbI_3$), bromide ($MAPbBr_3$) and their mixed bromide-chloride analogue ($MAPbBr_{1.5}Cl_{1.5}$) under various temperatures. Using an extreme pulsed magnetic field up to 90 T we observe well-resolved Landau levels in each of the crystals even at temperatures exceeding 100 K. The temperature evolution of the Landau levels clearly points to the rise of the carrier effective mass as a function of temperature corroborating theoretical predictions. Importantly the observed rise of carriers' effective mass cannot be simply attributed only to the bandgap opening with temperature highlighting the importance of polaronic effects for metal-halide perovskites semiconductors.

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