Exciton dynamics in $CH_3NH_3PbI_3$ single crystals

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Although the power conversion efficiency (PCE) of solar cells developed based on methylamonium lead iodide perovskite $CH_3NH_3PbI_3$ ($MAPbI_3$) is approaching a value of over 20% [1], which is comparable to the highest PCEs of inorganic semiconductor thin-film solar cells [2], a further improvement can be proceeded if more insights into the photophysics of $MAPbI_3$ are obtained. Therefore, many studies have been done to explore the fundamental properties of $MAPbI_3$ [3-6]. Despite the strong efforts, there are still many issues remaining unclear. The exciton binding energy of orthorhombic-phase $MAPbI_3$ at low temperatures is approximated to be in a range of 16 to 63 meV [7-9]. However, so far there is no experimental evidence showing clearly the existences of excitons and biexcitons. In thin-film samples, the tetragonal phase maintains even at temperatures below the phase transition, and the ultrafast carrier transfer from the orthorhombic phase to the tetragonal phase is likely to prevent the formation of excitons in the major orthorhombic phase [10]. In order to gain understanding of the basic physics of excitons and biexcitons in $MAPbI_3$, works on single crystals have to be performed.

In this work, we study the temperature-dependent optical properties of $MAPbI_3$ single crystals using time-resolved photoluminescence spectroscopy performed under one- and two-photon excitation. We discuss the excitonic- and biexcitonic-related emission bands, and an estimation of biexcitonic binding energy can be deduced properly.

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Reference

[1] W. S. Yang et al., *Science* **348**, 1234 (2015).

[2] M. A. Green et al., *Prog. Photovoltaics* **23**, 1 (2015).

[3] Y. Yamada et al., J. Am. Chem. Soc. **136**, 11610 (2014)

[4] C. Wehrenfennig et al., *APL Mater.* **2**, 081513 (2014).

[5] H.-H. Fang et al., *Adv. Funct. Mater.* **25**, 2378 (2015).

[6] R. L. Milot et al., *Adv. Funct. Mater.* **25**, 6218 (2015).

[7] Y. Yamada et al., *IEEE J. Photovoltaics* **5**, 401 (2015) and references therein.

[8] Q. Lin et al., *Nat. Photon.* **9**, 106 (2015).

[9] A. Miyata et al., *Nat. Phys.* **11**, 582 (2015).

[10] L. Q. Phuong et al., submitted for publication (2015).