<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Different carrier recombination processes in CsPbBr3 quantum dots and microcrystals (main article accepted version)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Author(s)</strong></td>
<td>Qian, Cheng; Yin, Tingting; Yan, Jiaxu; Shen, Ze Xiang</td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td>2017</td>
</tr>
<tr>
<td><strong>URL</strong></td>
<td><a href="http://hdl.handle.net/10220/43532">http://hdl.handle.net/10220/43532</a></td>
</tr>
<tr>
<td><strong>Rights</strong></td>
<td>© 2017 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.</td>
</tr>
</tbody>
</table>
Different carrier recombination processes in CsPbBr$_3$ quantum dots and microcrystals

Cheng Qian$^{1,2,3}$, Tingting Yin$^{2,3}$, Jiaxu Yan$^2$, and Ze Xiang Shen$^{1,2,3}$

$^1$Energy Research Institute (ERI@N), Interdisciplinary Graduate School, Nanyang Technological University, Singapore 639798, Singapore
$^2$Division of Physics and Applied Physics, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371, Singapore
$^3$Centre for Disruptive Photonic Technologies, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371, Singapore

E-mail: CQIAN003@e.ntu.edu.sg

Abstract—Good understanding of carrier generation and recombination is crucial for applications in LEDs, lasers, single photon sources and so on. In this work, we studied and compared charge generation and recombination processes of CsPbBr$_3$ QDs and microcrystals (MCs) in order to obtain clearer pictures for their photoluminescence. Power dependent photoluminescence experiments show that excitation species and recombination process are quite different in CsPbBr$_3$ QDs and MCs, where the MCs contain non-radiative dark states resulting a superlinear power dependence of the PL intensity at low excitation power while the QDs materials show linear dependence. At high excitation power, trions are generated in the QDs samples.

Keywords—Perovskites, Quantum dots, Photoluminescence, Carriers recombination, bound excitons, trions

BACKGROUD AND MOTIVATION

Colloidal CsPbBr$_3$ quantum dots (QDs) have emerged as the versatile materials for the promising applications including LEDs,$^1$ lasing gain materials,$^2$ low-cost nonlinear absorbers,$^3$ single photon sources,$^4$ and so on. Nevertheless, good understanding of charge generation and recombination in CsPbBr$_3$ QDs still remains lagging.

In this work, we studied and compared charge generation and recombination process of CsPbBr$_3$ QDs and microcrystals (MCs) in order to obtain a clearer picture of differences between them. X-ray diffraction (XRD) patterns and temperature-dependent Raman scattering indicate all samples crystalized in orthorhombic phase at ambient temperature. Power dependent photoluminescence experiments show that non-radiative trap states play important roles for emission process in MCs. Besides, trions formation is easier in CsPbBr$_3$ QDs, probably because of quantum confinement effect. Our results shed light on the mechanisms of optical behaviors in CsPbBr$_3$.

HIGHLIGHTS OF THIS WORK

In CsPbBr$_3$ MCs, we observed exciton emission peak (X band) and bound exciton emission peak (B band) at 78K. Both exciton and bound exciton emission behave superlinearly at low excitation power density and linearly at higher power. Such power dependence can be explained as due to the presence of a non-radiative carrier recombination pathway via a trap state. (Fig. 1)

No trap states emission peak or bound exciton emission peak were observed in CsPbBr$_3$ QDs. Instead, we observed trion emission peak under higher excitation intensity. Exciton emission increases linearly at first and become sublinear after appearance of trion emission while the trion emission peak show superlinear dependence. (Fig. 2).

![Figure 1. Photoluminescence (PL) of CsPbBr$_3$ Microcrystals (MCs). Left panel: Photoluminescence (PL) spectrum and integral PL intensity of X emission band and B emission band at different excitation intensity at 78 K. Right panel: Schematic of carrier recombination process in CsPbBr$_3$ MCs.](image)

![Figure 2. Photoluminescence (PL) of CsPbBr$_3$ quantum dots (QDs). Left panel: Photoluminescence (PL) spectrum and integral PL intensity of X emission band and T emission band at different excitation intensity at 78K. Right panel: Schematic of carrier recombination process in CsPbBr$_3$ QDs.](image)
REFERENCES


