High-Efficiency Blue Perovskite Light-Emitting Diodes

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ABSTRACT

Perovskite light-emitting diodes (PeLEDs) have emerged as attractive optoelectronic devices for displays. However, "Blue Gaps" exit for PeLEDs. In this presentation, we will introduce our recent work on high-efficiency blue PeLEDs through suppressing low-order phase, passivating traps and defects, and facilitating efficient energy transfer between perovskites.

1 Introduction

Perovskite light-emitting diodes (PeLEDs) have emerged as attractive optoelectronic devices for displays, benefit from the promising properties of perovskites including high photoluminescence quantum yields (PLQYs), tunable light emission, high color purity, and low cost [1-3]. In particular, the quasi-2D perovskites are rising as efficient luminescent materials for highly performed blue PeLEDs due to the cascade energy landscape for efficient exciton transfer and the subsequent radiative recombination, which will promote the development of high-efficiency cadmium-free blue quantum dot/perovskite LEDs. However, comparing with the external quantum efficiency (EQE) of green and red PeLEDs, the performance of blue PeLED is still far behind and "Blue Gaps" exists.

2 Results and Discussion

Typical quasi-2D perovskites show a wide distribution of low-order phases, especially the low-n phase quasi-2D perovskites which would result in low emission efficiency owing to the inefficient internal energy transfer. Meanwhile, the defects and traps generated during the perovskite crystallization increase nonradiative recombination, further aggravating the EQE. Here, we demonstrated a unique quasi-2D perovskite with low-order phase suppression and defect passivation for efficient energy transfer and light emission by incorporating a 2D perovskite and an excess ammonium salt into the quasi-2D perovskite solution.

From the theorical calculations as shown in Fig. 1, we can find that, the n=2 phase becomes unstable after mixing the PA ligand and PEA ligand, while the n=3 phase will become stable. Therefore, we can predict that the low-order phase of n=2 will be suppressed after mixing these two ligands. We did absorption experiments to confirm our predication. From Fig.2, we can find that, with the increase of the 2D perovskite with PEA ligand, the absorption peak of n=2 phase become smaller and smaller, and finally nearly only the n=3 phase exists. From the transient absorption, we also can find that the signal of n=2 phase nearly disappeared after introducing the 2D perovskite with PEA ligand. All these data confirms that the low-order n=2 phase has been suppressed successfully. On the other hand, the excess PEABr induced with the 2D perovskite, can passivate the perovskite ion vacancies effectively, so as to decrease the trap states and improve the PL performance. By optimizing the new class of quasi-2D perovskite, as shown in Fig.3, we achieved blue PeLEDs with EQE of 7.51%, which demonstrated a 117% enhancement compared with the control sample of 3.46%. The work contributes to promoting efficient and stable blue PeLEDs.

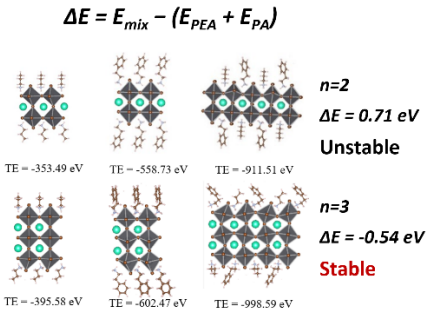

Fig.1 Total energies of quasi-2D perovskites through first-principles calculations

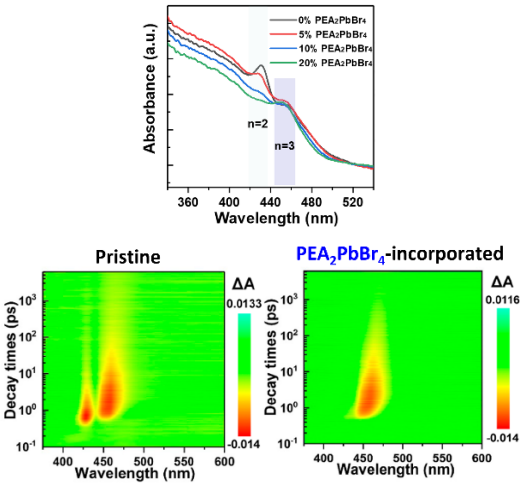

Fig.2 Absorption properties of quasi-2D perovskites

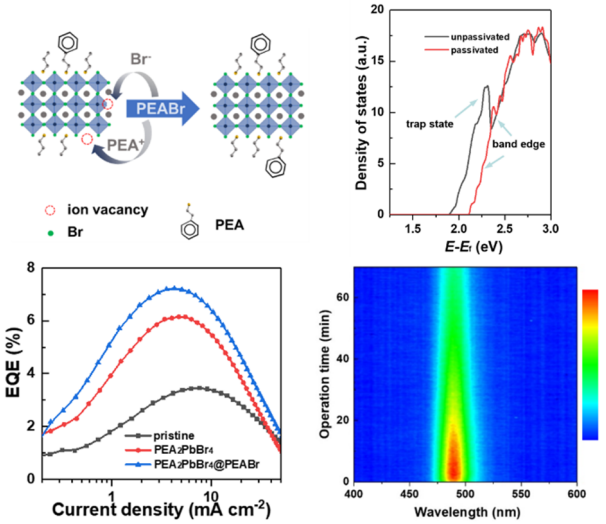

Fig.3 Enhancing EQE of blue PeLED through defect passivation

Besides, it is noted that the quasi-2D perovskite layers are separated from each other by spacer cations. Typical spacer cations, such as PEA^+, BA^+ can only interact with the perovskite layers at one side and leave a van der Waals gap with other quasi-2D perovskite layers. It is thus a concern that the van der Waals gap will induce a loose space between quasi-2D perovskite layers and subsequently inefficient energy transfer in the perovskite film causing poor PeLED efficiency. In addition, the presence of weak van der Waals gaps also deteriorates the stability of quasi-2D perovskite structure due to easy degradation of perovskite structure upon exposure to different operation conditions, such as continuous heat and light soaking during PeLED operation.

In this work, a bifunctional ligand of 4-(2-aminoethyl) benzoic acid (ABA) cation was strategically introduced into the perovskite to diminish the weak van der Waals gap between individual perovskite layers for promoting coupled quasi-2D perovskite layers (Fig. 4). One end of the group is bonded with one perovskite by hydrogen bond, and another end bonded with an adjacent perovskite as ligand, so in theory, the introduced ABA group will diminish the van der Waals gap between individual perovskites. In particular, the strengthened interaction between coupled quasi-2D perovskite layers favors an efficient energy transfer in the perovskite films. From the transient absorption data we can find that, the time of carrier transfer from low-order phase to high-order phase decreases from 1.31ps to 0.67ps after introducing the bifunctional group, demonstrating more efficient carrier transfer in the modified quasi-2D perovskites. In addition, the introduced ABA can also simultaneously passivate the perovskite defects by reducing metallic Pb for less nonradiative recombination loss. The trap density decreases to less than half of the original one. Benefiting from the advanced properties of ABA incorporated perovskites, highly efficient blue PeLEDs with external quantum efficiency of 10.11% and a very long operational stability of 81.3 min, among the best performing blue quasi-2D PeLEDs, were achieved.

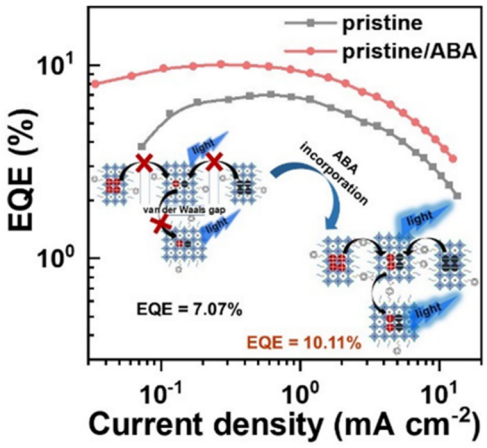

Fig. 4 Enhancing EQE of blue PeLED through diminishing the weak van der Waals gap

3 Conclusions

In this work, we boosted the EQE of blue PeLED from 3.46% to 10.11% through suppressing low-order phase, passivating traps and defects, and facilitating efficient energy transfer between perovskites.

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