High Quality $CsPbI_{3-x}Br_x$ Thin Films Enabled by Synergetic Regulation of Fluorine Polymers and Amino Acid Molecules for Efficient Pure Red Light Emitting Diodes

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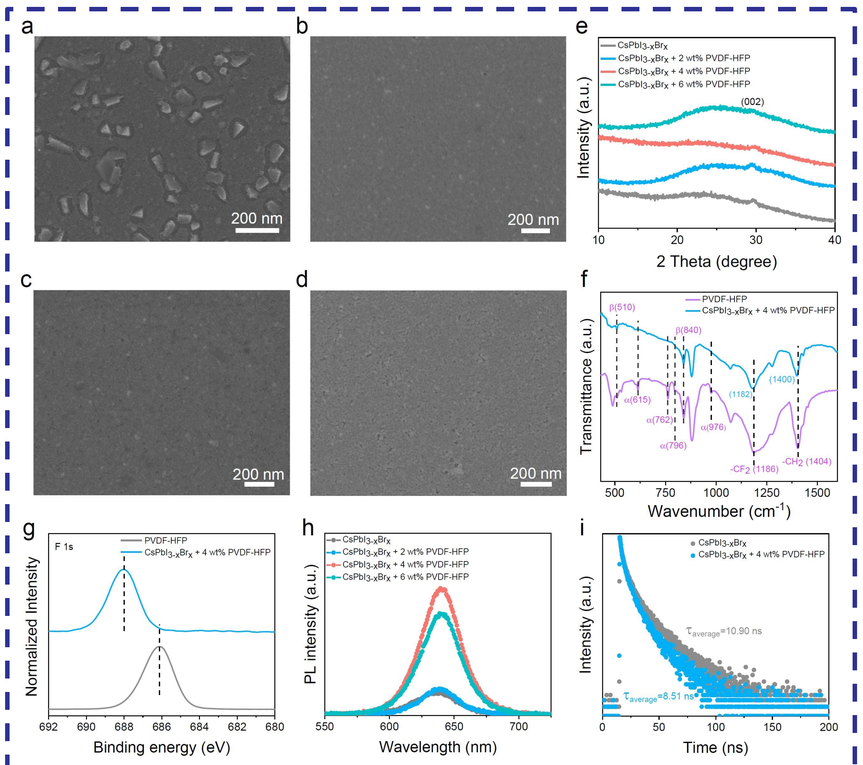
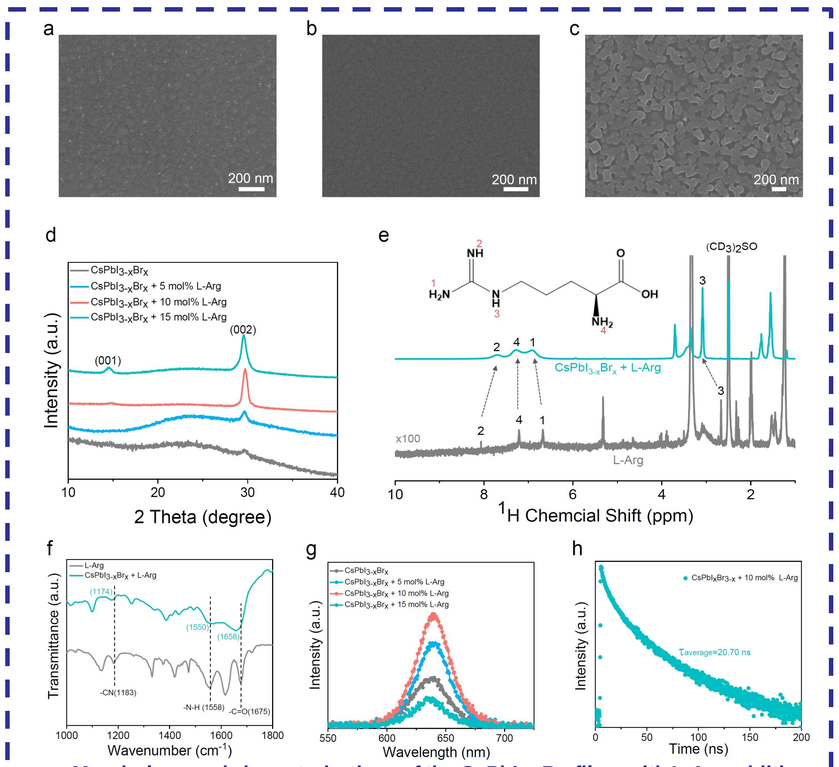
Abstract

All-inorganic $CsPbX_3$ (X = Cl, Br, or I) perovskite thin films are attractive emissive layers for high-performance light-emitting diodes (LEDs) due to their precisely tunable bandgaps, excellent color purities, good stabilities, and solution processabilities. However, the fabrication of high-quality $CsPbI_{3-x}Br_x$ thin films is very challenging because the crystal growth of mixed halide $CsPbI_{3-x}Br_x$ is in low controllability. Herein, a synergetic regulation strategy using fluorine polymer (Poly(vinylidene fluoride-co-hexafluoropropylene)) and a small amino acid molecule (L-Arginine) is developed to fabricate high-quality $CsPbI_{3-x}Br_x$ thin films for efficient pure red perovskite LEDs. In the fabricated $CsPbI_{3-x}Br_x$ thin film, the fluorine polymer plays a crucial role in confining $CsPbI_{3-x}Br_x$ crystal size at the nanoscale and the small amino acid molecule acts as a passivation agent to reduce the trap-state density. Under this synergetic effect, a uniform $CsPbI_{3-x}Br_x$ thin film with a high photoluminescence quantum yield up to 40% can be obtained to fabricate an efficient pure red perovskite LED with a maximum external quantum efficiency of 4.5% and a maximum brightness of 3100 cd m^{-2}. The reported synergistic regulation strategy will open a new avenue to fabricate efficient pure color $CsPbX_3$ perovskite LEDs[1].

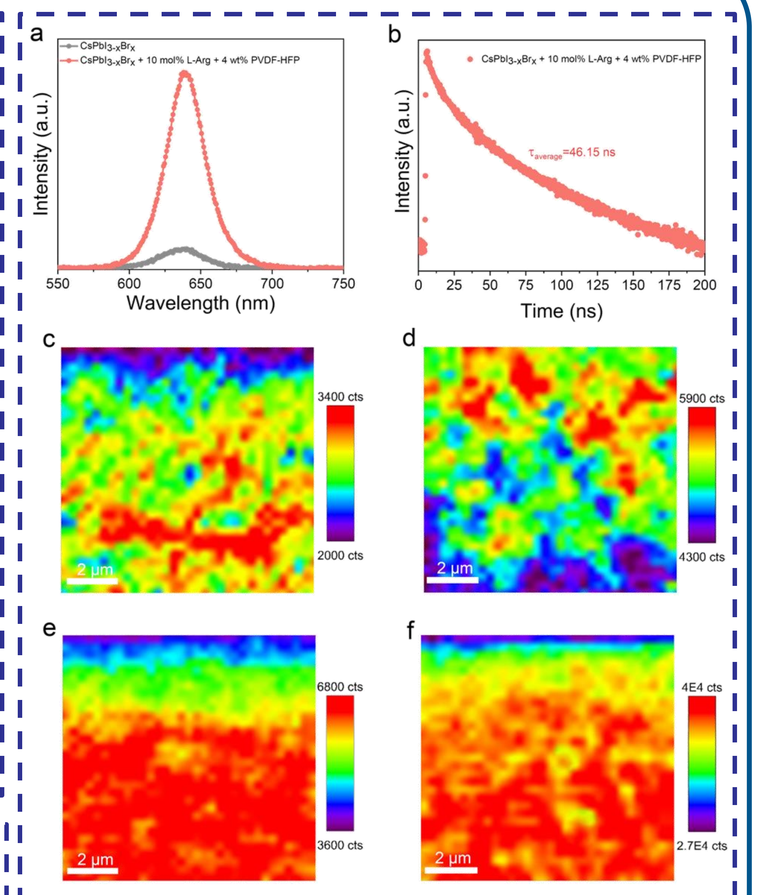
Major Accomplishments



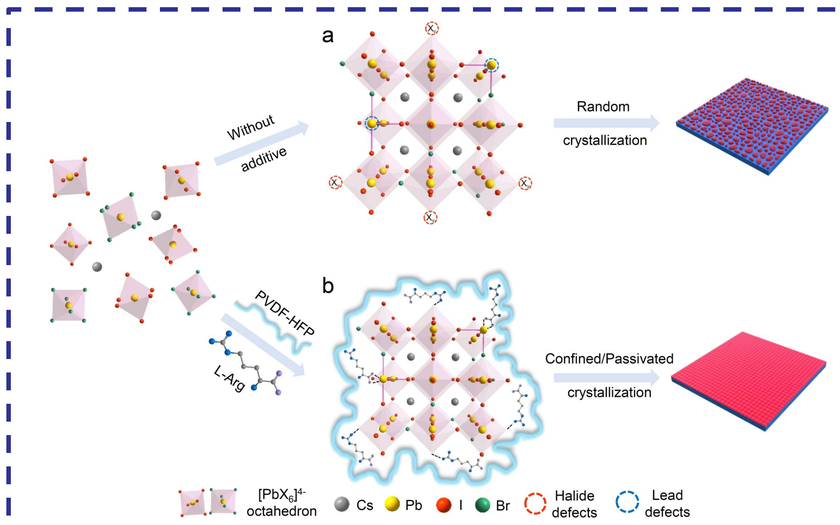
Characterizations of the $CsPbI_{3-x}Br_x$ films regulated by PVDF-HFP additive



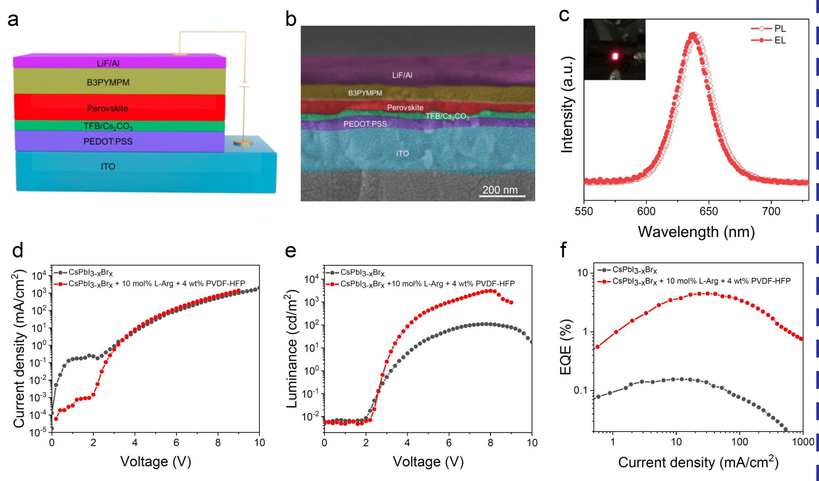
Morphology and characterizations of the $CsPbI_{3-x}Br_x$ films with L-Arg additive



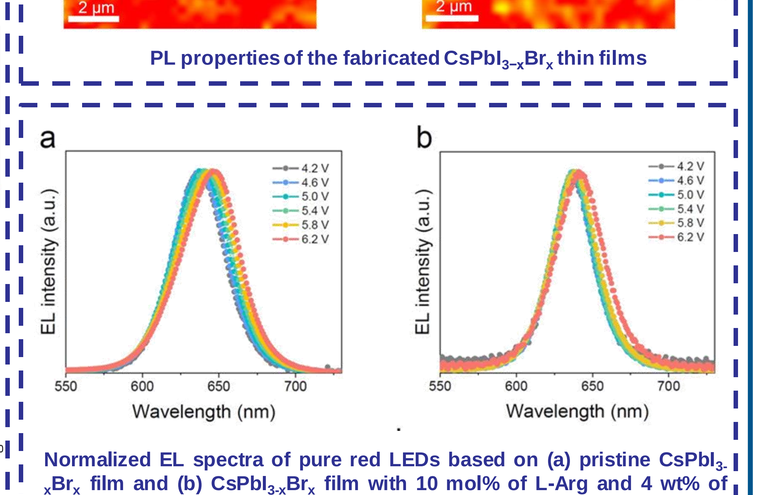
PL properties of the fabricated $CsPbI_{3-x}Br_x$ thin films



Schematic illustration of the crystal growth and surface passivation of $CsPbI_{3-x}Br_x$ polycrystalline thin films regulated by PVDF-HFP and L-Arg



Device characteristics of $CsPbI_{3-x}Br_x$ film-based pure red perovskite LEDs



Normalized EL spectra of pure red LEDs based on (a) pristine $CsPbI_{3-x}Br_x$ film and (b) $CsPbI_{3-x}Br_x$ film with 10 mol% of L-Arg and 4 wt% of PVDF-HFP under different driving voltages

Key Take-Away

We have developed a one-step spin-coating method to prepare high-quality $CsPbI_{3-x}Br_x$ thin film with a high PLQY of ≈40% by adding PVDF-HFP and L-Arg into the perovskite precursor solution. Using the optimized $CsPbI_{3-x}Br_x$ thin film with 10 mol% of L-Arg and 4 wt% of PVDF-HFP as an emitter layer, we fabricated pure red perovskite LED emitting at 637 nm with a high brightness of 3100 cd m^{-2} and high EQE of 4.5%. We unraveled that PVDF-HFP played a crucial role on the formation of $CsPbI_{3-x}Br_x$ nanocrystals and the small L-Arg molecule acted as passivation agent on the surface of nanocrystals to reduce the trap-state density in the fabricated high-quality $CsPbI_{3-x}Br_x$ thin film. Our proposed mixed halide anion strategy in solution-processable $CsPbX_3$ perovskite films with polymer and amino acid synergetic regulation showed a great potential to fabricate efficient pure color perovskite LEDs.

Relevant publications:

[1] Kun-Hua Wang, Li Wang, Hong-Bin Yao, et al. *Adv. Optical Mater.* 2020, 2001684.

[2] Kun-Hua Wang, Yan-De Peng, Hong-Bin Yao, et al. *ACS Photonics*, 2019, 6 , 667–676.

[3] Kun-Hua Wang, Liang Wu, Hong-Bin Yao*, Shu-Hong Yu*, et al. *Angew. Chem. Int. Ed.* 2016, 55, 8328-8332.

[4] Kun-Hua Wang, Hong-Bin Yao*, Shu-Hong Yu* *Langmuir* 2018, 34 (2), 595-602.

[5] Kun-Hua Wang, Hong-Bin Yao*, *Sci. China Chem.* 2018, 61, 1047-1061.

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