

## **Suppressing Interfacial Nonradiative Recombination with Acetate Interlayer for High-Performance Pure Blue Perovskite LEDs**

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## Experimental Section

**Materials.** PEDOT:PSS (A1 4083), PbBr<sub>2</sub> (99.9%), CsCl (99.9%), PEABr (99.5%), BABr (99.5%), TPBi (99.9%) were obtained from Xi'an Yuri Solar Co., Ltd. Dimethyl sulfoxide was purchased from ACROS. CH<sub>3</sub>COOLi and CH<sub>3</sub>COONa were attained from Meryer. LiF (99.98%) was pursued by Sigma-Aldrich. Aluminum was procured from ZhongNuo Advanced Material Technology Co. Ltd. All chemicals were used as received without further purification.

**Quasi-2D perovskite precursor preparation.** 0.22 mmol CsCl, 0.2 mmol PbBr<sub>2</sub>, 0.12 mmol PEABr, 0.08 mmol BABr were dissolved in 1mL DMSO under continuous stirring for 3 hours at 26°C and then filtered with a 0.22 μm polytetrafluoroethylene filter before spin coating.

**Device fabrications.** We fabricated PeLEDs devices with a structure of ITO/HTL/perovskite/TPBi/LiF/Al. Hole-only devices were constructed with a device structure of ITO/PEDOT:PSS/perovskite/MoO<sub>3</sub>/Ag. The ITO glass was ultrasonically cleaned in detergent, distilled water, ethanol, acetone, isopropanol, and ethanol solution for 15 min. Then the PEDOT:PSS film was prepared by spin-coating PEDOT:PSS (4083) aqueous solution on ITO substrates at 5000 rpm 40 s, and then annealed at 150 °C for 20 min. And the PEDOT:PSS films were modified by spin-coating the H<sub>2</sub>O, CH<sub>3</sub>COOLi, CH<sub>3</sub>COONa solutions at 5000 rpm for 40 s followed by annealing at 150° for 20 min in air. After cooling down, the samples were transferred into a nitrogen-filled glove box and the perovskite precursor was spin-coated at 3000 rpm for 120 s, accompanying by annealing at 70° for 5 min. Finally, TPBi (50 nm), LiF (5 nm), and Al (100 nm) were evaporated by the vacuum evaporator chamber under a pressure of 4×10<sup>-4</sup> Pa. The device area was 0.08 cm<sup>2</sup> and all devices were tested in atmospheric environments after encapsulation.

**Characterizations of perovskite film and device.** The absorption spectra of the samples were measured by SHIMADZU UV-1800. The steady-state photoluminescence spectra and time-resolved PL (TRPL) were measured using an FLS 980 spectrofluorometer (Edinburgh Instruments Ltd). The excitation source is 365 nm from an Xe lamp for PL and the time-resolved luminescence decay was measured using time-correlated single-photon counting with a 375 nm laser. X-ray diffraction (XRD) patterns of the prepared samples were recorded on Bruker D8 advance X-ray diffractometer with graphite monochromatized Cu Kα (λ=1.5405 Å) radiation with a step of 0.02° at a scanning speed of 4° min<sup>-1</sup> in 2θ ranging from 3° to 40°. PLQY was measured by a self-build equipment with a PLQY fiber integrating sphere and Ocean Optics QE65 Pro spectrometer which was bought from Shenzhen Spectrum Research Connected Technology Co.,Ltd. The Fourier transform infrared (FTIR) spectra were recorded with a Thermo Fisher iS50 FTIR. For all the FTIR samples, perovskite solution mixed with an additive powder was prepared before drying. The current density-luminance-voltage (J-V-L), EL spectra, EQE and operating lifetime of the PeLEDs were all performed with a commercialized system (Shenzhen Spectrum Research Connected Technology Co., Ltd) equipped with Keithley 2400, a fiber integrating sphere and Ocean Optics QE65 Pro spectrometer.

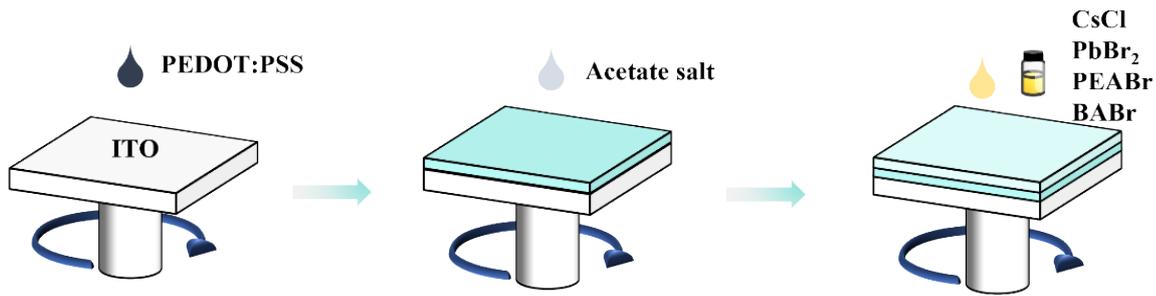


Figure S1. Schematic illustration of the prepared procedure of the perovskite film.

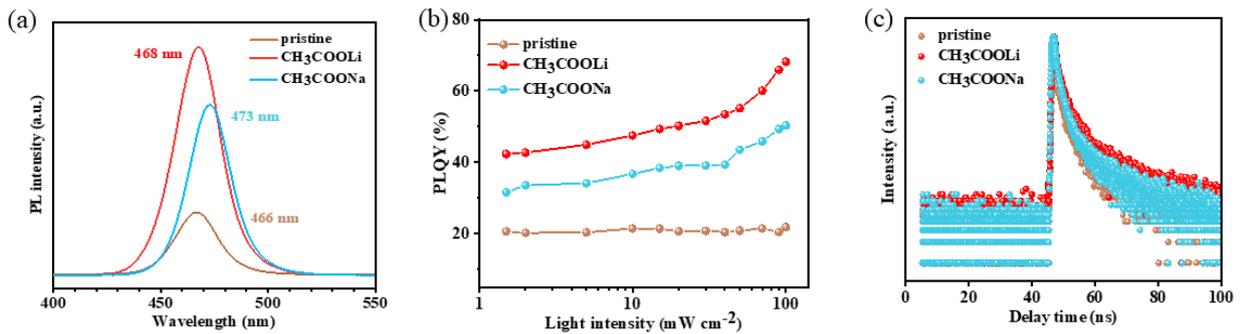


Figure S2. (a) The PL spectra of perovskite films excited from Front sides. (b) the light intensity-dependent PLQY. (c) TRPL curves.

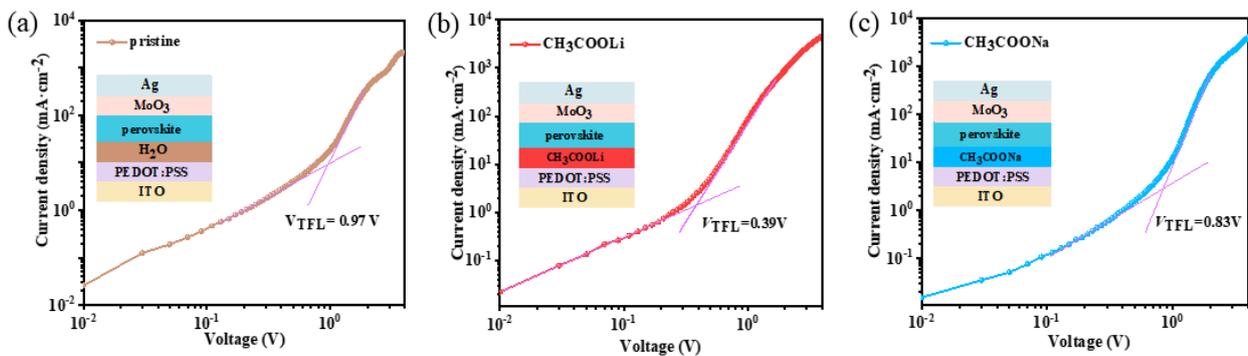


Figure S3. The SCLC curves for the hole-only devices.

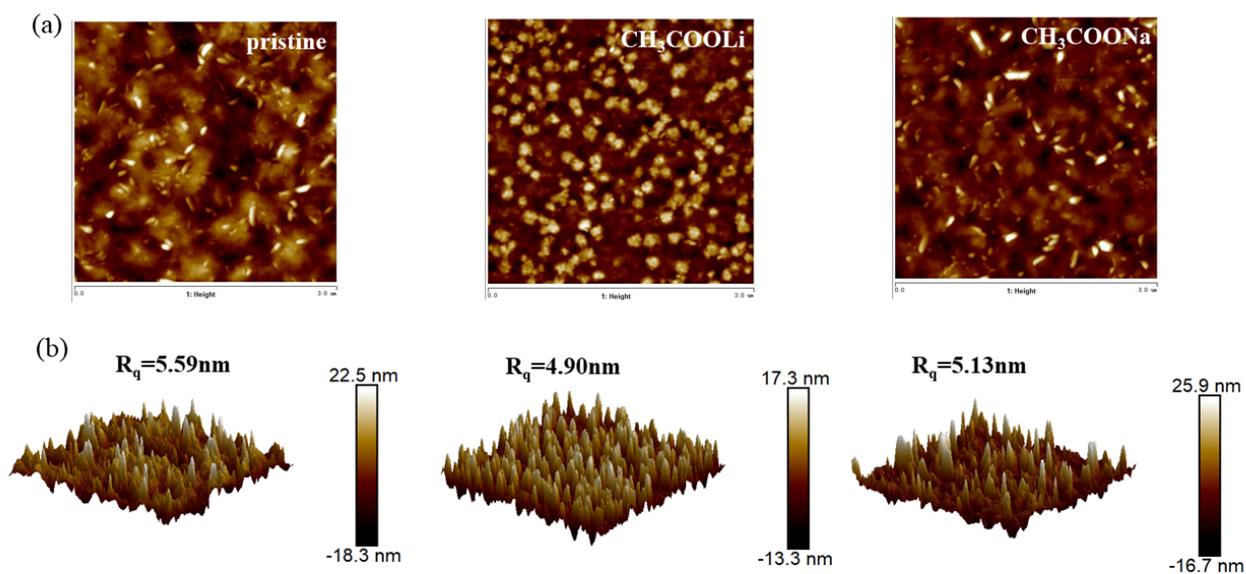


Figure S4. (a) 2D AFM images of height sensor (the dimensions are all 3  $\mu\text{m}$ ). (b) 3D AFM images.

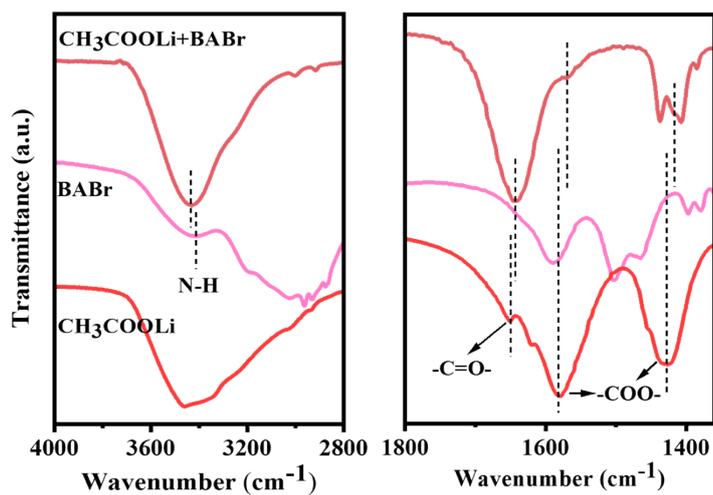


Figure S5. The FTIR spectra of the pure CH<sub>3</sub>COOLi, BABr, CH<sub>3</sub>COOLi with BABr, respectively.

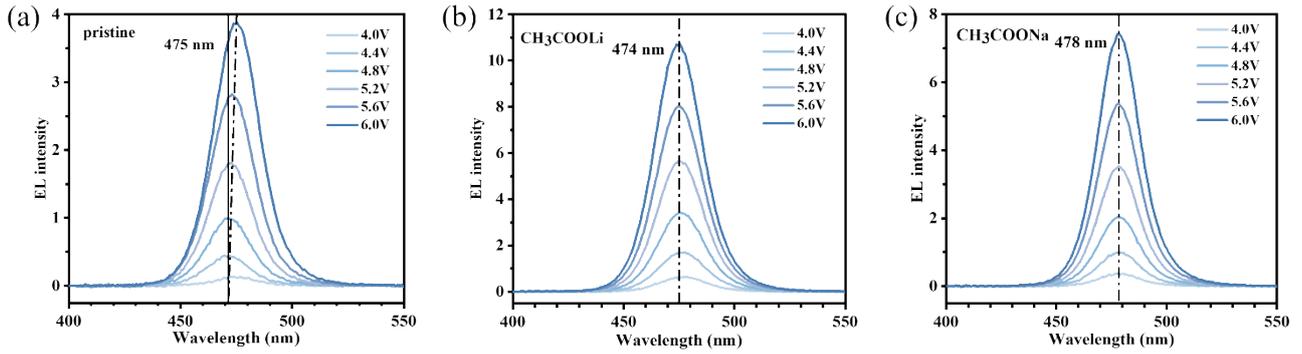


Figure S6. EL spectra of blue PeLED with (a) pristine, (b) CH<sub>3</sub>COOLi and (c) CH<sub>3</sub>COONa under applied voltages.

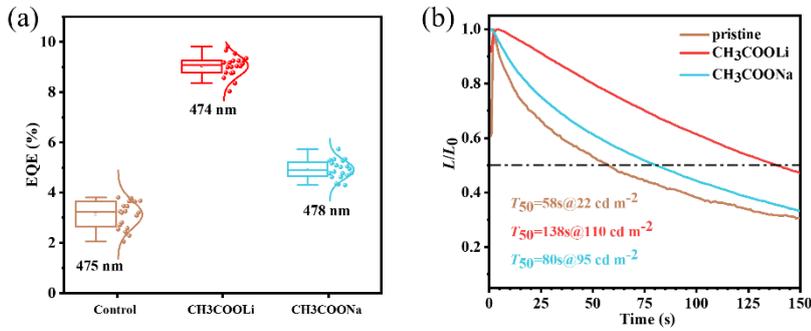


Figure S7. The devices are tested in atmospheric environments after encapsulation. (a) Histogram of the maximum EQEs measured for 20 devices. (b) Operational stability measurement of the PeLED with driving voltage fixed at 4.0V.

Table S1. Fitting results of the TRPL decay curves of the perovskite films.

Perovskite	$\tau_1$ (ns)	$A_1$ (%)	$\tau_2$ (ns)	$A_2$ (%)	$\tau_3$ (ns)	$A_3$ (%)	$\tau_{ave}$ (ns)	$\chi^2$
pristine	1.129	16.75	3.431	45.00	14.699	38.25	2.34	1.09
CH <sub>3</sub> COOLi	1.410	22.87	4.321	42.45	20.784	34.68	9.35	1.08
CH <sub>3</sub> COONa	1.258	18.43	3.581	44.87	15.903	36.70	5.05	1.15

The average PL lifetime  $\tau_{avg}$  is calculated according to the equation:

$$\tau_{avg} = \frac{A_1\tau_1^2 + A_2\tau_2^2 + A_3\tau_3^2}{A_1\tau_1 + A_2\tau_2 + A_3\tau_3}$$

Where  $\tau_1$ ,  $\tau_2$ ,  $\tau_3$  represent time constants for fast ( $\tau_1$ ) and slow decay components ( $\tau_2$  and  $\tau_3$ ), and  $A_1$ ,  $A_2$ ,  $A_3$  are the amplitudes, respectively.

Table S2. Recombination rate and trap state density ( $N_{trap}$ ) of the perovskite films.

Perovskite	PLQY (%)	$\tau_{ave}$ (ns)	$k_r$ (s <sup>-1</sup> )	$k_{nr}$ (s <sup>-1</sup> )	$k_r: k_{nr}$	$N_{trap}$ (cm <sup>-3</sup> )
pristine	21.84	2.34	$9.33 \times 10^7$	$3.34 \times 10^8$	0.28	$4.38 \times 10^{17}$
CH <sub>3</sub> COOLi	68.24	9.35	$7.30 \times 10^7$	$3.40 \times 10^7$	2.15	$1.75 \times 10^{17}$
CH <sub>3</sub> COONa	50.37	5.05	$9.97 \times 10^7$	$9.77 \times 10^7$	1.02	$3.74 \times 10^{17}$

Table S3. The calculated results and relevant parameters of trap state density ( $N_{trap}$ ).

Perovskite	$\epsilon_0$ (F cm <sup>-1</sup> )	$\epsilon_r$	q (C)	L (nm)	$V_{TFL}$ (V)	$N_{trap}$ (cm <sup>-3</sup> )
pristine	$8.854 \times 10^{-14}$	20	$1.602 \times 10^{-19}$	70	0.97	$4.38 \times 10^{17}$
CH <sub>3</sub> COOLi	$8.854 \times 10^{-14}$	20	$1.602 \times 10^{-19}$	70	0.39	$1.75 \times 10^{17}$
CH <sub>3</sub> COONa	$8.854 \times 10^{-14}$	20	$1.602 \times 10^{-19}$	70	0.83	$3.74 \times 10^{17}$

The trap state density ( $N_t$ ) is calculated using the formula:

$$N_t = 2V_{TFL} \cdot \epsilon_r \epsilon_0 / qL^2$$

Where  $\epsilon_0$  and  $\epsilon_r$  represent vacuum permittivity and relative dielectric constant,  $q$  is the single cavity charge, and  $L$  is the thickness of the perovskite film.

Table S4. Summary of device characteristics of PeLEDs.

Devices	EL peak (nm)	EQE <sub>max</sub> (%)	EQE @ 500 (% @ cd m <sup>-2</sup> )	EQE @ 1000 (% @ cd m <sup>-2</sup> )	EQE @ 1500 (% @ cd m <sup>-2</sup> )	L <sub>max</sub> (cd m <sup>-2</sup> )
pristine	475	3.35	2.65@461	1.09@894	-	894
CH <sub>3</sub> COOLi	474	9.90	9.22@470	6.64@967	4.18@1437	1932
CH <sub>3</sub> COONa	478	5.86	5.57@473	4.49@948	3.32@1510	2250

Table S5. Summary of key EL parameters for pure-blue PeLEDs.

Perovskite composition	Type	EL (nm)	EQE (%)	Luminance (cd m <sup>-2</sup> )	Year	Refs
p-F-PEA <sub>2</sub> (Cs/FA) <sub>n</sub> Pb <sub>n-1</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	472	11.10	1516	2024	1
(PEA/BA) <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	472	6.20	726	2024	2
PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	472	4.22	705.9	2024	3
(p-F-PEA/PA) <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	472	15.1	267.5	2025	4
PEA-CsFAPbBr <sub>2</sub> Cl <sub>1</sub>	Q-2D	472	4.26	426.39	2025	5
p-F-PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	473	7.20	493	2023	6
(PEA/BA) <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	473	5.95	528	2024	7
PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	473	6.70	900	2022	8
PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	474	13.20	-	2024	9
PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> Br <sub>3n+1</sub>	Q-2D	474	2.47	40	2025	10
PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	475	14.82	1937	2023	11
o-F-PEA <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	475	7.55	2239	2025	12
(PEA/BA) <sub>2</sub> Cs <sub>n-1</sub> Pb <sub>n</sub> (Br/Cl) <sub>3n+1</sub>	Q-2D	474	9.90	1932	This work	

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