

Supplementary Information

Color-stable blue light-emitting diodes with defect management by sulfonate

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Experimental Details:

Materials. PEABr (>99.5%), BDABr₂ (>99.5%), PbBr₂ (>99.5%), CsBr (>99.5%), PEDOT: PSS (Clevios PVP Al 4083), and TPBi (>99%) were purchased from Xi'an Polymer Light Technology Corp. Triphenylphosphine oxide (TPPO) (99%), RbBr (>99.5%) were purchased from Alfa Aesar. LiBr (99%), Taurine (99%) was purchased from Aladdin. PSS-Na was purchased from Sigma Aldrich. Dimethyl sulfoxide (DMSO) (99.7+%, Extra Dry) were purchased from ACROS. Chlorobenzene (CB) (99.9+%) were purchased from J&K. m-PEDOT: PSS solution is mix of normal PEDOT: PSS (Clevios PVP Al 4083) aqueous solution and 40 mg ml⁻¹ PSS-Na aqueous solution by a volume ratio of 1:1.

Preparation of Perovskite Precursor Solutions. 0.09 mmol CsBr, 0.15 mmol PbBr₂, 0.06 mmol PEABr, 0.06 mmol BDABr₂, 1.24 mg RbBr were dissolved in 1 mL DMSO under continuous stirring overnight and then filtered with a 0.22 μm polytetrafluoroethylene filter before spin coating (The ratio of BDABr₂/PEABr ratio have been optimized).

Device fabrication. The patterned ITO-coated glass substrates were washed with deionized water, ethanol, acetone, isopropanol and ethanol for 20 min, then dried with a nitrogen blow gun. Before use, the ITO was cleaned with ultraviolet ozone for 15 min. m-PEDOT: PSS were spin-coated onto the substrates at 9000 rpm for 50 s followed by annealing on a hot plate at 120 °C for 20 min in ambient air. After cooling, the substrate was then transferred into a N₂-filled glovebox (O₂ <0.1 ppm, H₂O <0.1 ppm). The perovskite films were deposited in glovebox by spin-coating the precursor solution at 4000 rpm for 120s and annealed at 100 °C for 10 min. Chlorobenzene with TPPO (7.5 mg ml⁻¹) was added 40 s after the start of each spin coating process as anti-solvent. Finally, TPBi (40 nm), LiF (1 nm), and Al (110 nm) were deposited under a pressure of 5 × 10⁻⁴ Torr. The active area of the devices was 8 mm². All devices were tested in atmospheric environments.

Perovskite film and device characterization. UV-vis absorption spectra were collected with the spectrophotometer of SHIMADZU UV-1800. The steady-state photoluminescence spectra and time-resolved PL (TRPL) were measured using a FLS 980 spectrofluorometer (Edinburgh Instruments Ltd). The excitation source is 365 nm from a Xe lamp for PL and the time-resolved luminescence decay were measured using time-correlated single-photon counting with a 375 nm laser. X-ray diffraction analysis was carried 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⁻¹ in 2θ ranging from 3° to 40°. X-ray Photoelectron Spectroscopy were carried out by ESCALAB 250Xi (Thermo Fisher). The Fourier Transform Infrared were measured by the Thermo Fisher is50. Scanning electron microscopy (SEM) were performed on a FEI Nova NanoSEM200 microscope. AFM was conducted on Dimension iCon (Bruker). The current density-luminance-voltage (J-V-L), EL spectra, EQE and operating lifetime of the PeLED were recorded simultaneously by using a commercialized system (Shenzhen Spectrum Research Connected Technology Co., Ltd) equipped with Keithley 2400, a fiber integrating sphere and Ocean Optics QE65 Pro spectrometer.

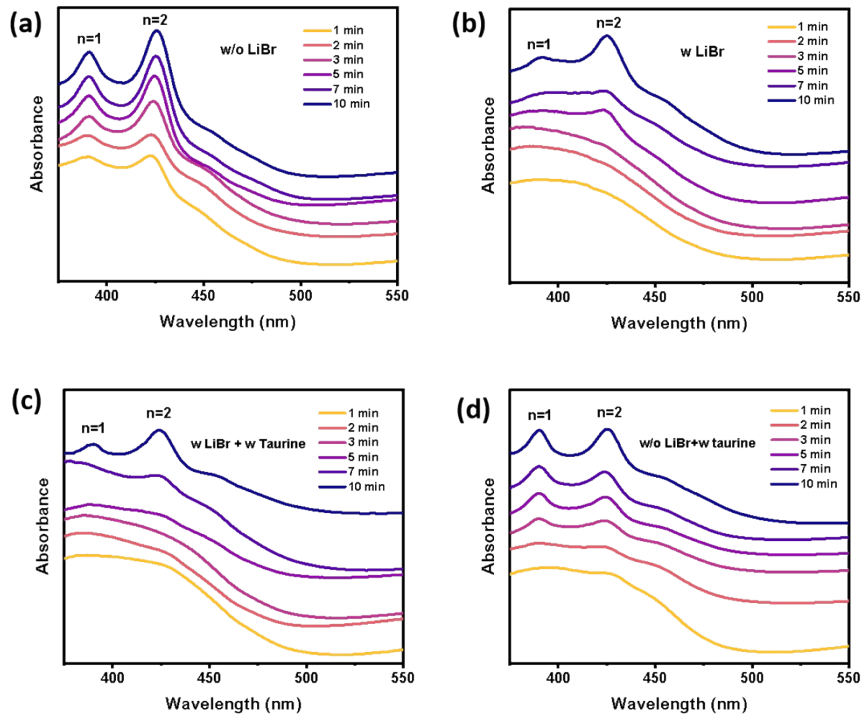


Figure S1. *In-situ* UV-vis absorption for samples a) w/o LiBr b) with LiBr c) with LiBr and with Taurine. d) w/o LiBr and with Taurine

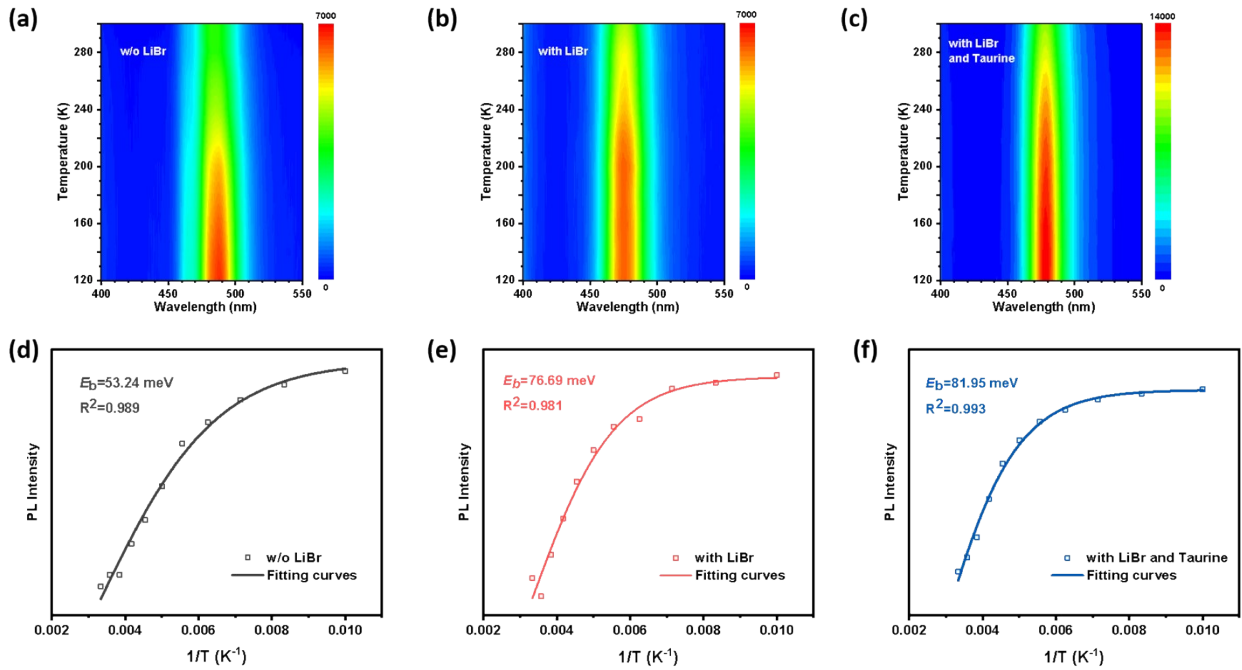


Figure S2. PL spectra of perovskite films from 120 to 300 K. a) w/o LiBr. b) with LiBr. c) with LiBr and Taurine. Relevant integration of the temperature-dependent PL

intensity of perovskite films and fitting curves for E_b . d) w/o LiBr. e) with LiBr. f) with LiBr and Taurine.

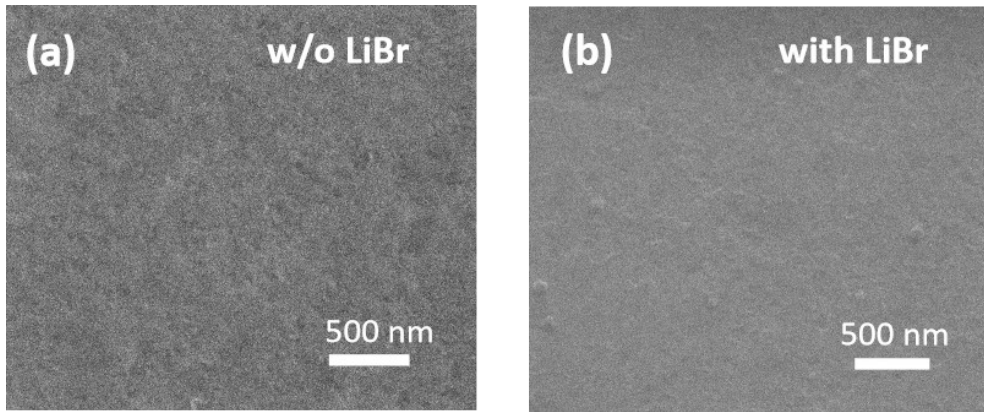


Figure S3. SEM images of perovskite films without LiBr and with LiBr.

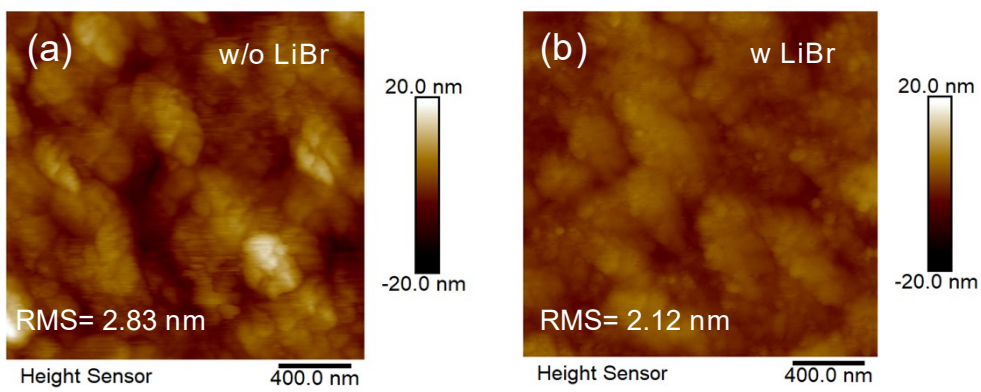


Figure S4. AFM images of perovskite films without LiBr and with LiBr.

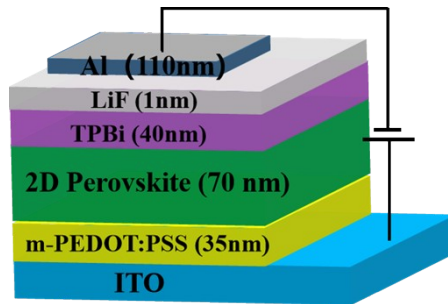


Figure S5. Device structure of the PeLEDs.

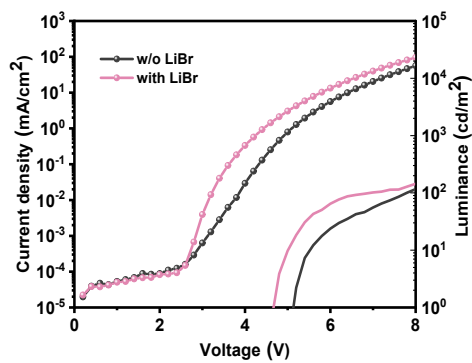


Figure S6. J-V-L curves of PeLEDs with and without LiBr.

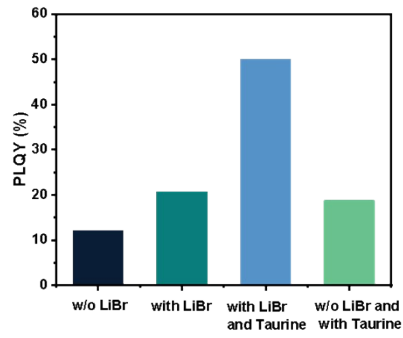


Figure S7. PLQY of different thin perovskite films.

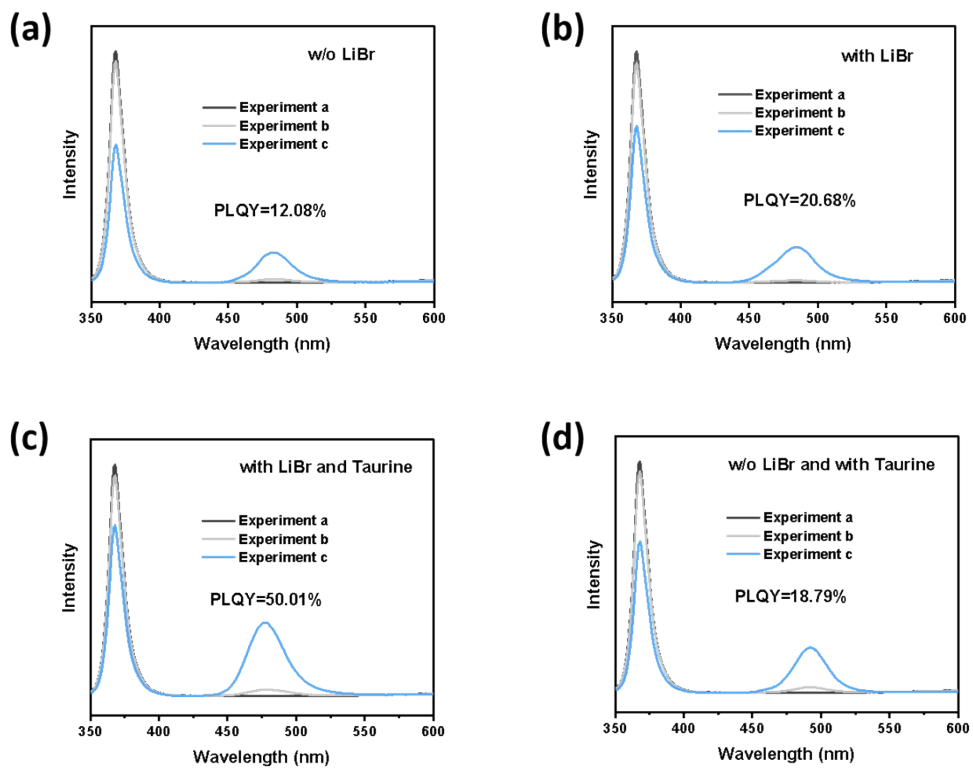


Figure S8. PLQY measurement of different thin perovskite films. a) w/o LiBr. b) with LiBr. c) with LiBr and Taurine. d) w/o LiBr and with Taurine

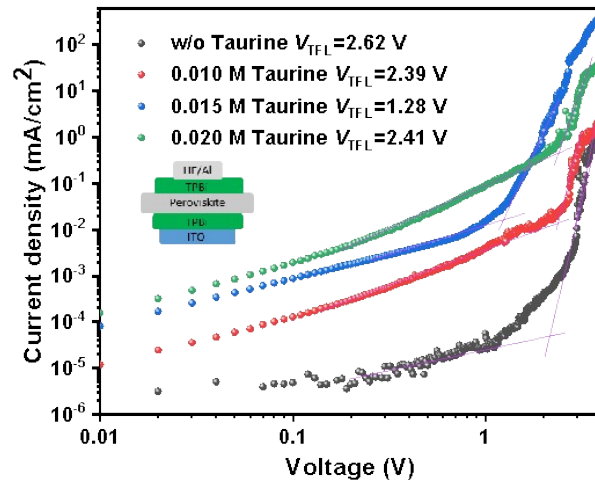


Figure S9. Current density-voltage characteristics of electron-only devices based on ITO/TPBi/pero//TPBi/LiF/Al structure.

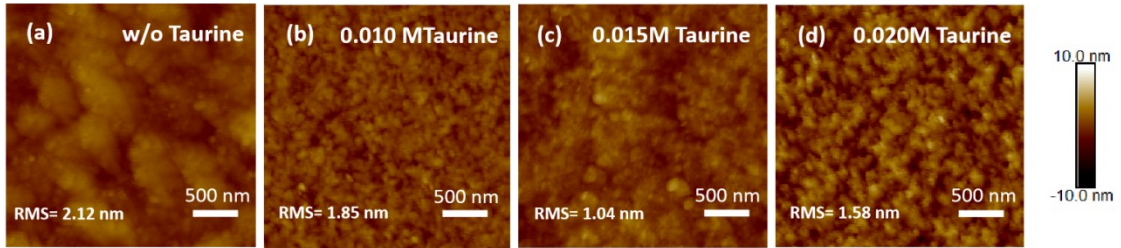


Figure S10. AFM images of perovskites films.

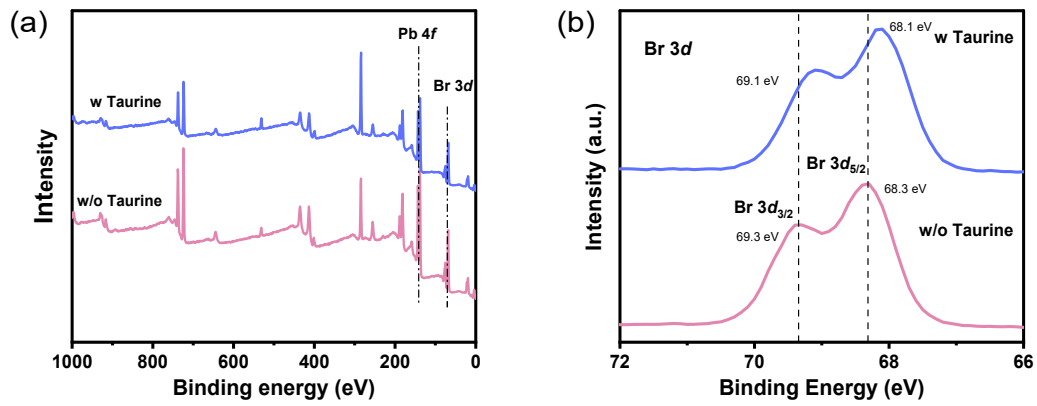


Figure S11. a) The XPS survey spectra of perovskite films with and without taurine treatment. High-resolution spectra of b) Br 3d.

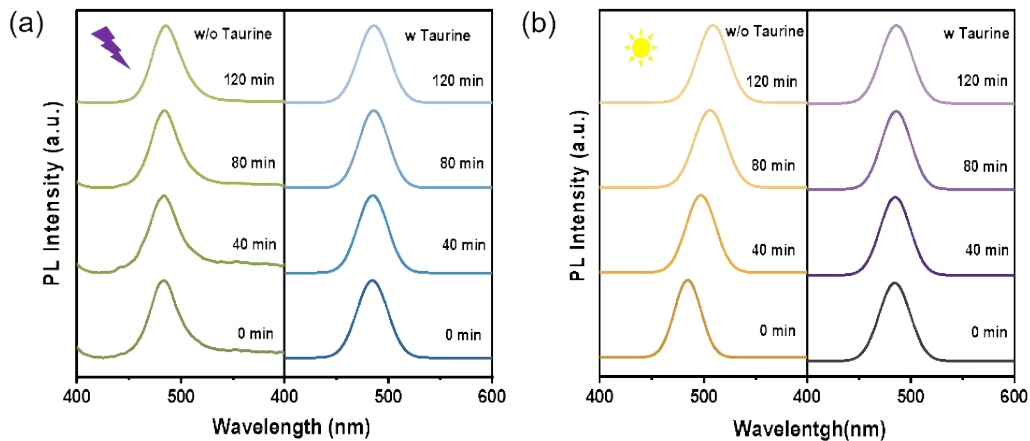


Figure S12. a) Stability measurements of perovskite films with and without taurine treatment under UV illumination (365 nm, 10 mW cm⁻²) and b) heating process (100 °C).

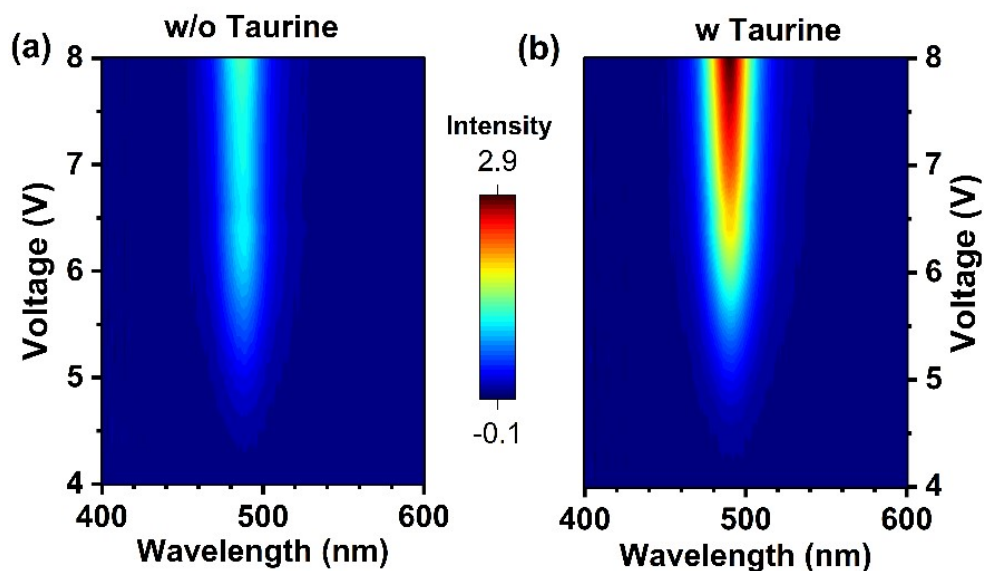


Figure S13. EL spectra of LEDs under different voltage bias.

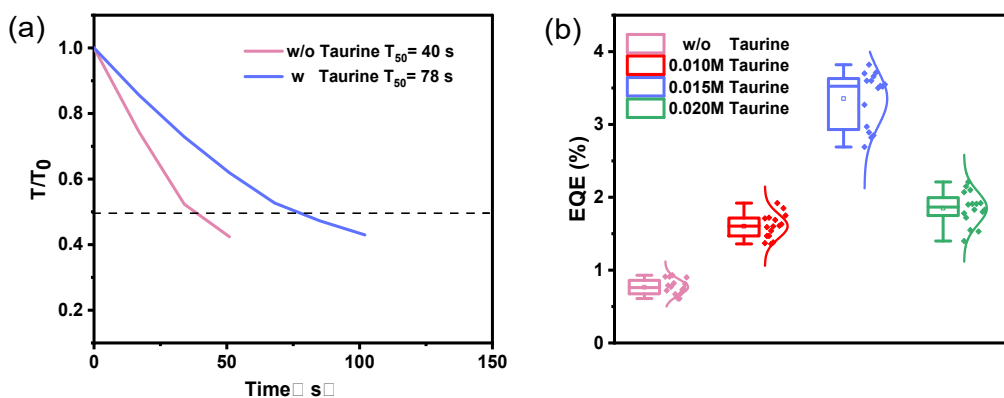


Figure S14. a) The half time of PeLEDs at initial luminance at 30 cd m⁻². b) Statistical graph of PeLEDs.

Table S1. PL lifetime characteristics of different amount taurine modified perovskite films.

x[%]	τ_1 [ns]	A ₁ [%]	τ_2 [ns]	A ₂ [%]	τ_3 [ns]	A ₃ [%]	τ_{avg} [ns]	χ^2
Control	0.75	24.35	2.90	34.44	13.06	41.21	11.17	1.099
w LiBr	0.83	26.91	3.21	33.9	15.12	39.90	12.95	1.097
0.010 M Taurine (with LiBr)	0.80	21.77	3.42	33.75	15.10	44.88	13.13	0.975
0.015 M Taurine (with LiBr)	1.05	20.40	3.85	33.12	17.95	46.48	15.75	1.177
0.020 M Taurine (with LiBr)	1.03	22.32	3.65	34.59	16.28	43.09	13.99	1.005

Table S2. Different concentrations perovskites films of trap densities. EOD is short for electron-only device and hole-only device.

	Taurine conc. (M)	V_{TFL} (V)	n_t ($\times 10^{18} \text{ cm}^{-3}$)
	EOD	0	1.46
	0.010	1.17	0.91
	0.015	1.00	0.77
	0.020	1.10	0.85
	Taurine conc. (M)	V_{TFL} (V)	n_t ($\times 10^{18} \text{ cm}^{-3}$)
	HOD	0	2.62
	0.010	2.39	1.85
	0.015	1.28	0.99
	0.020	2.41	1.86

Table S3. Performance parameters of blue PeLEDs.

Devices	V_{on} (V)	L_{max} (cd m^{-2})	EQE_{max} (%)	EL (nm)	FWHM (nm)
Control	5.2	116	0.28	490	30
w LiBr	4.6	144	0.96	487	28
0.010 M Taurine (with LiBr)	4.0	291	1.86	486	26
0.015 M Taurine (with LiBr)	3.8	442	3.82	487	25
0.020 M Taurine (with LiBr)	4.0	597	1.66	487	25