Supplementary Information

Phase stabilization via A-site ion anchoring for ultra-stable perovskite light emitting diodes

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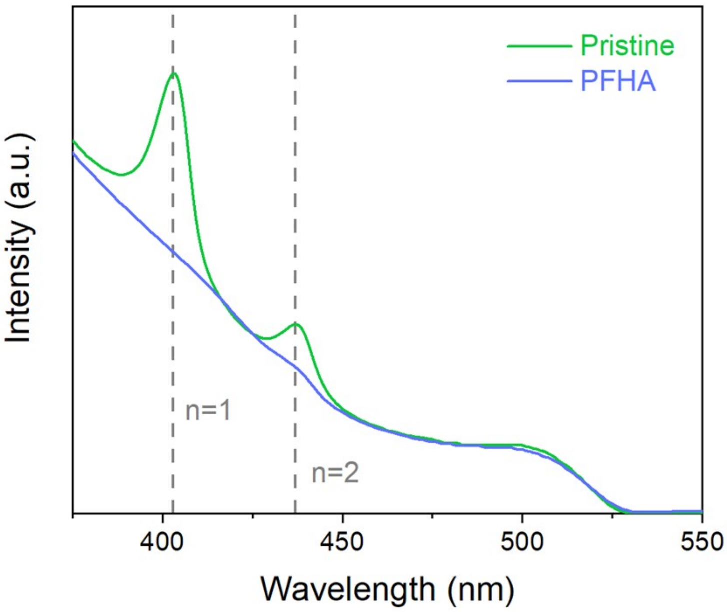

Fig. S1 | UV-Vis absorption spectra of pristine and PFHA perovskites.

Herein, n represents the number of layers alongside the thickness direction of the 2D phases.

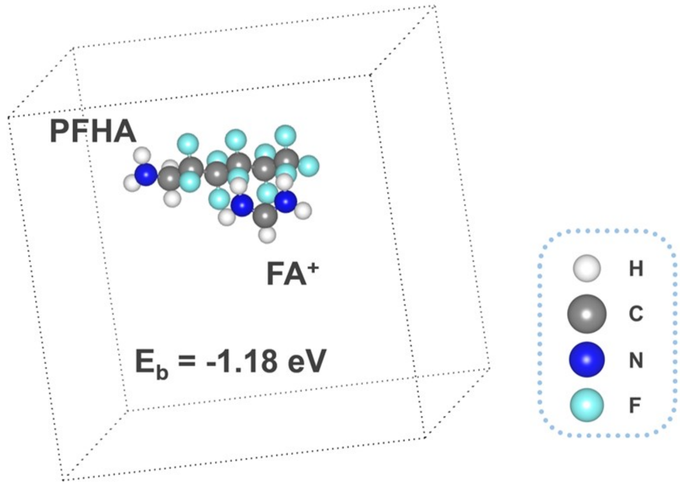

Fig. S2 | Representative configuration of PFHA coordination with FA^{+}. The calculated binding energy is -1.18 eV.

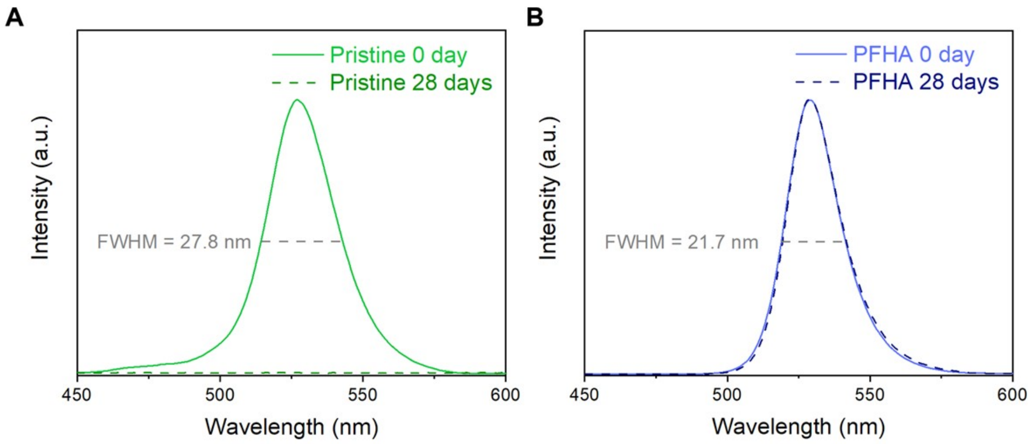

Fig. S3 | PL spectra of (A) pristine and (B) PFHA perovskite films upon 28 days ambient storage.

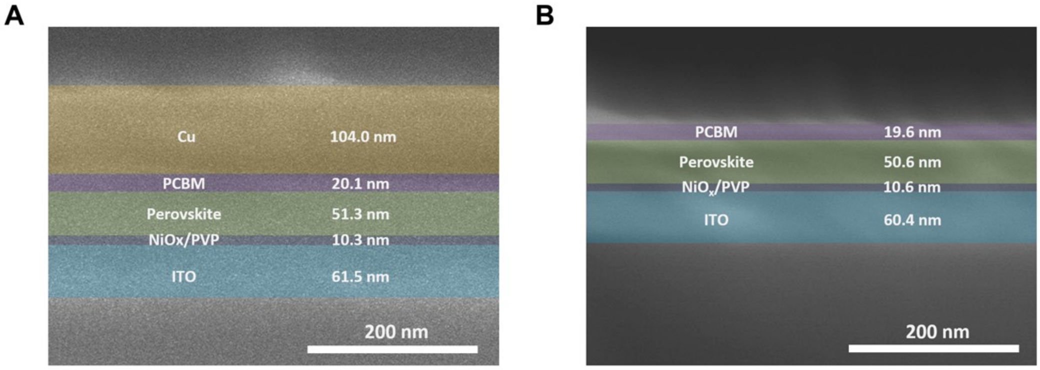

Fig. S4 | Cross-sectional SEM images for ion migration analysis. The device structure is ITO / NiOx / PVP / Perovskite / PCBM / Cu. (A) The entire device structure. (B) The device after the removal of the surface Cu electrodes using scotch tapes.

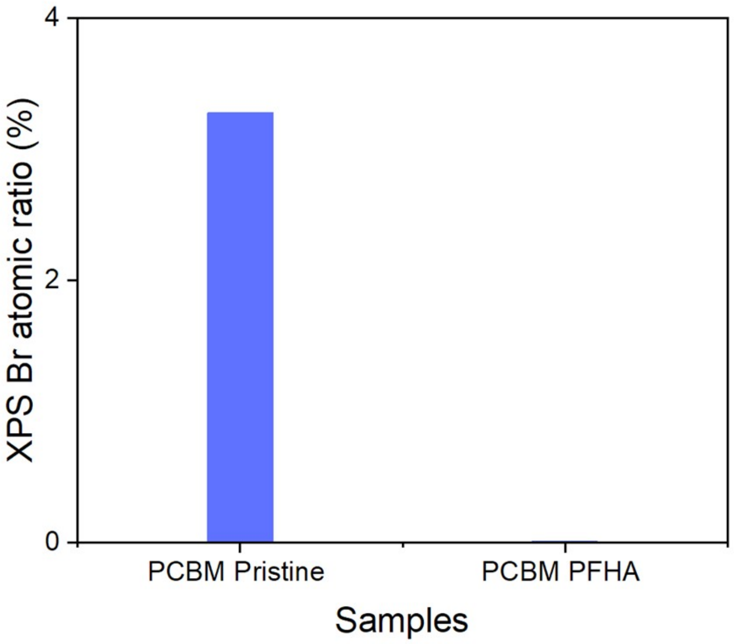

Fig. S5 | XPS Br atomic ratio of pristine and PFHA devices for ion migration analysis.

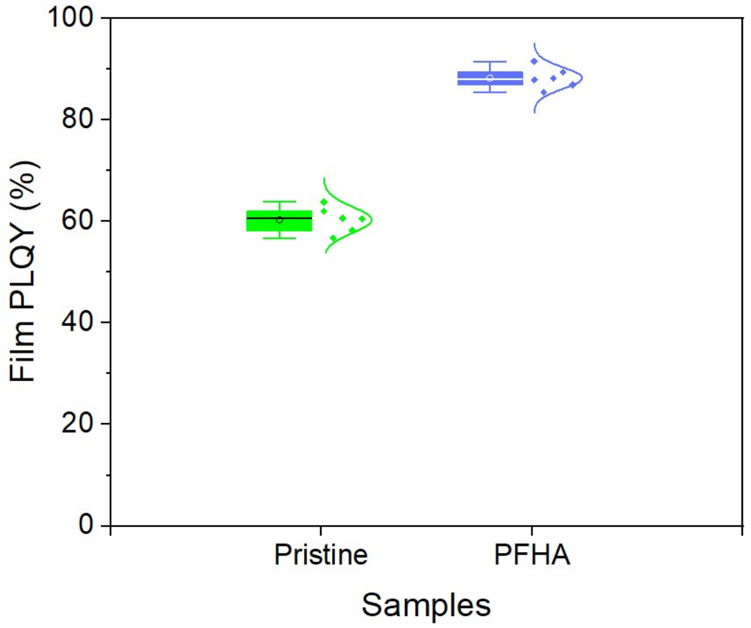

Fig. S6 | PLQY box plots for pristine and PFHA anchored perovskites. In the box plots, the middle bar represents the median, and the box represents the interquartile range; bars extend to 1.5× the interquartile range.

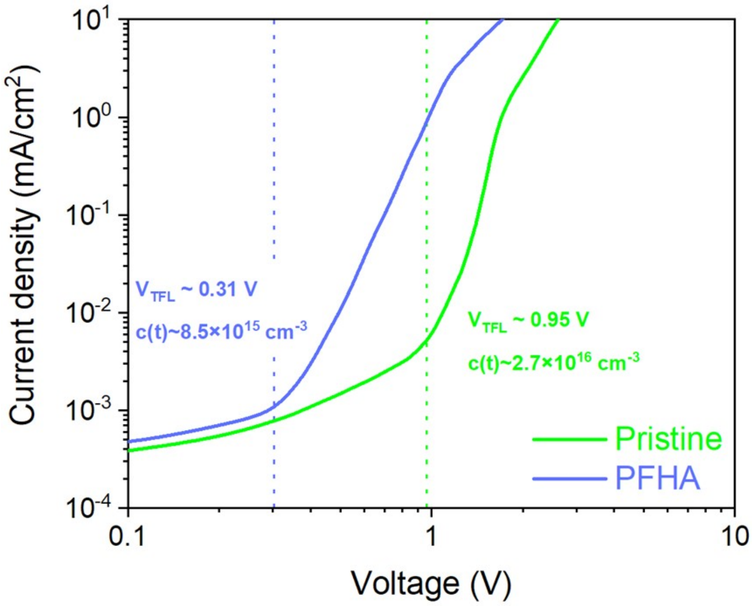

Fig. S7 | Current density versus voltage curve for hole-only devices. Device structure: indium tin oxide (ITO) / nickel oxide (NiOx) / polyvinyl pyrrolidone (PVP) / perovskite / molybdenum oxide (MoOx) / Au.

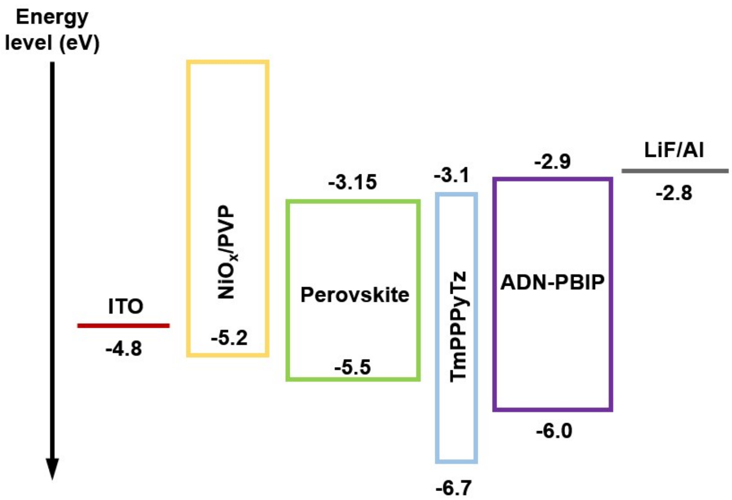

Fig. S8 | Device structure and corresponding energy levels of different layers in PeLEDs.

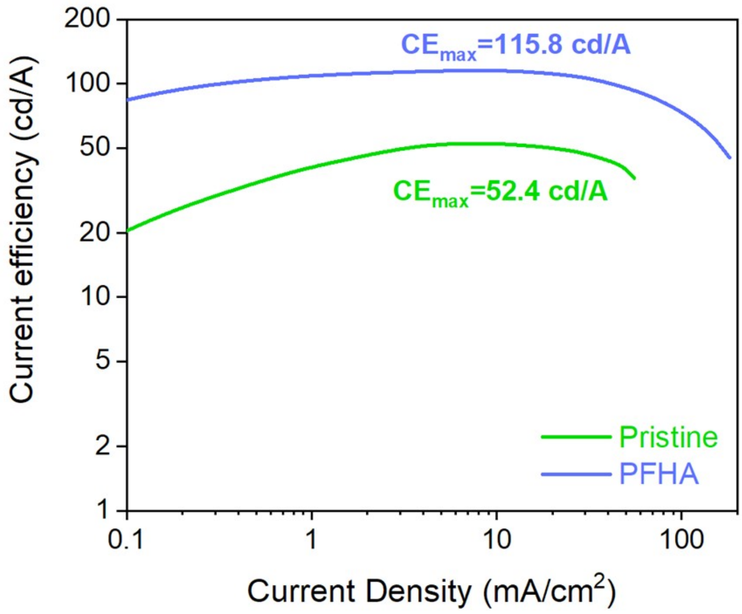

Fig. S9 | Current efficiencies (CE) versus current density of both PeLEDs.

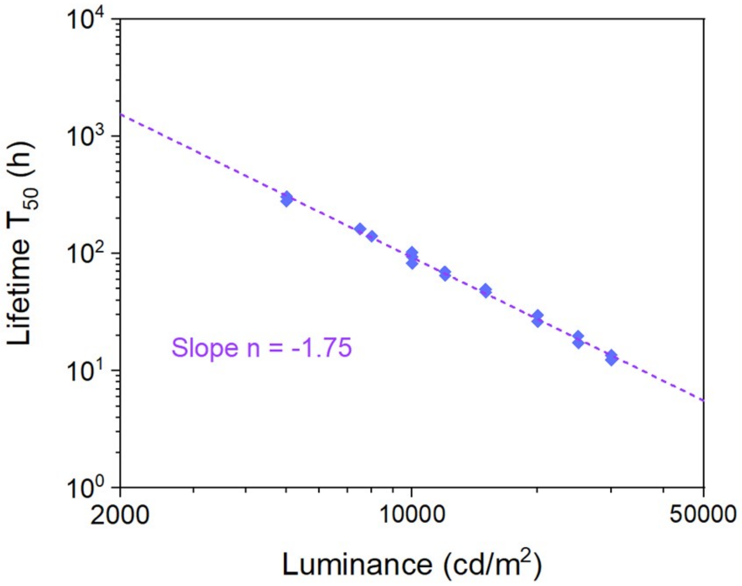

Fig. S10 | Equivalent operational lifetime T is calculated with the relationship of $T/T_0 = (L/L_0)^n$. The calculated T_{50} lifetime at 100 cd/m^2 is over 326,252 hours with the slope n of -1.75.

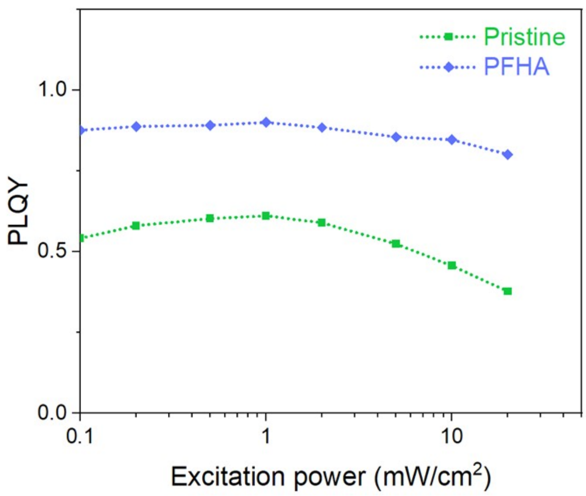

Fig. S11 | Excitation-dependent PLQY of pristine and PFHA films.

Table S1 | Performance of reported green perovskite LEDs with EQE exceeding 20% without optical outcoupling designs.

Perovskites	EQE_{max} (%)	CE_{max} (cd/A)	Operational lifetime (T_{50}, min, reported)	Operational lifetime (T_{50}, hour, equivalent at 100 cd/m^2)	Ref.
FPEABr: $CsPbBr_3$, quasi-2D	20.36	64	6.5 (L_0=10,000 cd/m^2)	342.6	[1]
BABr: $CsPbBr_3$, quasi-2D	20.5	63	25 (L_0=1000 cd/m^2)	23.4	[2]
PEABr:(Cs, FA)$PbBr_3$, quasi-2D	21.4	80	117 (L_0=100 cd/m^2)	1.95	[3]
PEABr:($CsPbBr_3$, quasi-2D	22.49	59.2	52 (L_0=144 cd/m^2)	1.6	[4]
PEABr: $FAPbBr_3$, quasi-2D	22.9	98	390 (L_0=100 cd/m^2)	6.5	[5]
$FA_{0.9}GA_{0.1}PbBr_3$, nanocrystals	23.4	108	132 (L_0=100 cd/m^2)	2.2	[6]
PEABr:(Cs, MA)$PbBr_3$, quasi-2D	25.6	88	115 (L_0=7,200 cd/m^2)	3,411	[7]
PEABr: $CsPbBr_3$, Quasi-core/shell nanoparticles	28.1	95.8	242.4 (L_0=100 cd/m^2)	4.0	[8]
$((FA_{0.7}MA_{0.1}GA_{0.2})_{0.87}$ $Cs_{0.13}PbBr_3$) core/shell	28.9	150.1	31,200 (L_0=1,000 cd/m^2)	29,241	[9]
PEABr: $FAPbBr_3$, quasi-2D	29.5	124.0	1,120.2 (L_0=12,000 cd/m^2)	81,229	[10]
PEABr: $FAPbBr_3$, quasi-2D	30.84	115.32	100.6 (L_0=100.88 cd/m^2)	1.7	[11]
PEABr: $CsPbBr_3$, quasi-2D	32.1	111.7	213.6 (L_0=100 cd/m^2)	3.6	[12]
FPEABr: $FAPbBr_3$, quasi-2D	**27.1**	**115.8**	**6,190 (L_0=10,000 cd/m^2)**	**326,252**	**This work**

EQE_{max}, maximum external quantum efficiency; CE_{max}, maximum current efficiency; L_{max}, maximum luminance; T_{50}, device operating half-life; L_0, initial luminance. The equivalent T_{50} lifetime at 100 cd/m^2 is calculated with the relationship of

$$T/T_0 = (L/L_0)^{-1.75}.$$

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