Supporting Information

Efficient Quasi-two Dimensional Perovskite Light-Emitting Diodes Employing a Cage-type additive

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The detailed calculation process of (external quantum efficiency) EQE as follows:

EQE is a number of photos generated by the LED devices per second (N_{photo} (V)) divided by a number of charges injected to the devices per second ($I(V)/e$)

$$EQE(V) = \frac{N_{photo}}{I(V)/e} \times 100\% \quad (1)$$

Where $I(V)$ is a current (unit: A) passing through the perovskite LED device at an applied bias (V), $N_{photo}(V)$ represents the number of emitted photos per second gathered. E is elementary charge of $1.6*10^{-19}$ C.

The $N_{photo\ (V)}$ is calculated by

$$N_{photo}(V) = \frac{\phi_e}{E_{average} \times 1.6 \times 10^{-19}} \quad (2)$$

Where Φ_e is radiant flux (W). $E_{average}$ (eV) means the average photo energy among the whole EL spectra at a bias. The Φ_e is calculated by

$$\phi_e = \frac{\pi AL}{Km\int V(\lambda)d\lambda}, \tag{3}$$

Where A is the active area of a working PeLED; L is the luminance measuredby PR670. λ is wavelength. Km is a constant. V(λ) is the luminosity function. Then $E_{avergae}$ is calculated by the following equation:

$$E_{average} = \frac{\int F(\lambda)\frac{\lambda}{1240}d\lambda}{\int F(\lambda)d\lambda} \tag{4}$$

Where F（λ）is the photo radiometric value.

It is worth noting that the brightness L is measured by a silicon photoelectric probe (Beijing Normal University Optoelectronic Instrument Factory, ST-86LA) during the calculation of the *EQE* of PeLEDs. In order to ensure the accuracy, we use PR670 to correct the brightness L collected by the silicon photoelectric probe, and obtain the relevant correction coefficient, and then bring the corrected brightness L into the above formula 3 for calculation, and *EQE* can be gotten.

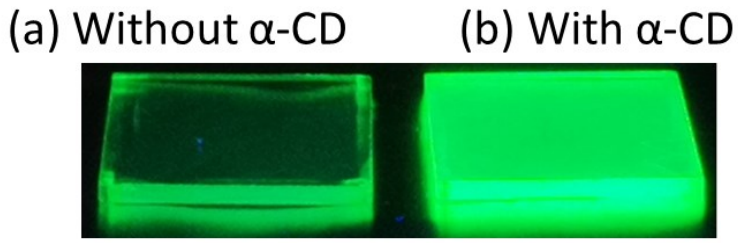

Fig. S1 The fluorescence images taken under 365 nm light excitation, where one is the $PEA_2Cs_{n-1}Pb_nBr_{3n+1}$ film (a) without α-CD; (b) with α-CD.

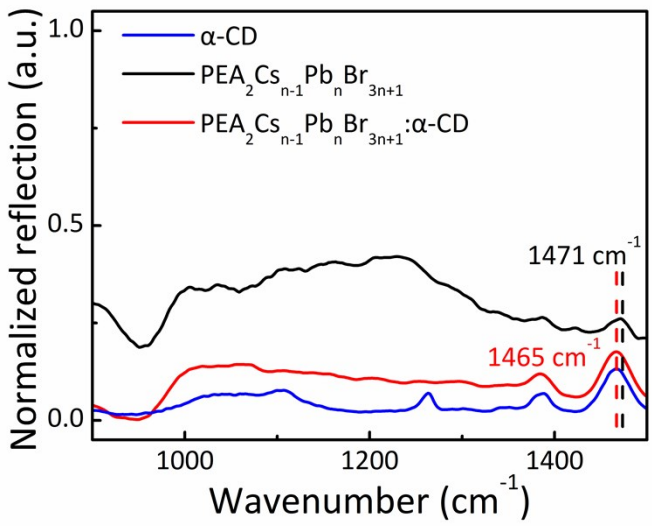

Fig. S2 FTIR spectra of pristine $PEA_2Cs_{n-1}Pb_nBr_{3n+1}$ and $PEA_2Cs_{n-1}Pb_nBr_{3n+1}$:α-CD. All results were collected by measuring solution.

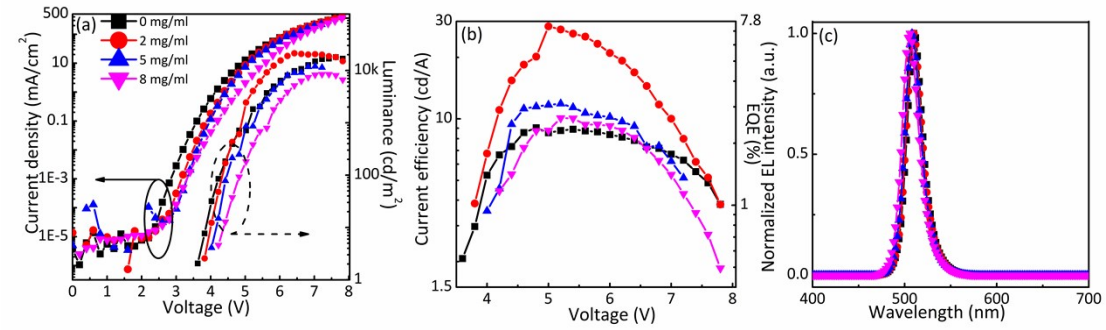

Fig. S3 EL performance of all the PeLEDs with different concentration of α-CD (0 mg/ml, 2 mg/ml, 5 mg/ml and 8 mg/ml): (a) Current density-voltage-luminance (*J-V-L*); (b) Current efficiency-voltage-external quantum efficiency (*CE-V-EQE*); (c) EL spectra under an applied voltage of 6 V.

Table S1 The list of performance of PeLEDs.

α-Cyclodextrin (mg/ml) [a]	$V_{turn\ on}$ (V)[b]	L_{max} (cd/m²)[c]	CE_{max} (cd/A)[d]	*EQE* (%) [e]	EL peak (nm)[f]	*FWHM* (nm)[g]	*CIE* (x, y) [h]
0	3.6	16810	9.0	2.3	510	16	(0.0679, 0.7314)
2	3.8	21268	28.4	7.4	510	16	(0.0644, 0.7238)
5	4	11992	11.9	3.1	508	16	(0.0599, 0.7058)
8	4.2	8456	10.0	2.6	506	16	(0.0533, 0.6671)

[a]Concentration optimization α-CD to improve EL performance of PeLEDs; [b] Turn-on voltage of 1 cd/m²; [c] Maximum luminance; [d] Maximum current efficiency; [e] Maximum external quantum efficiency; [f] Electroluminescence peak under at 6 V; [g] Full width at half maximum at 6 V; [h] Commission International de l'Eclairage (CIE) coordinates at 6 V.

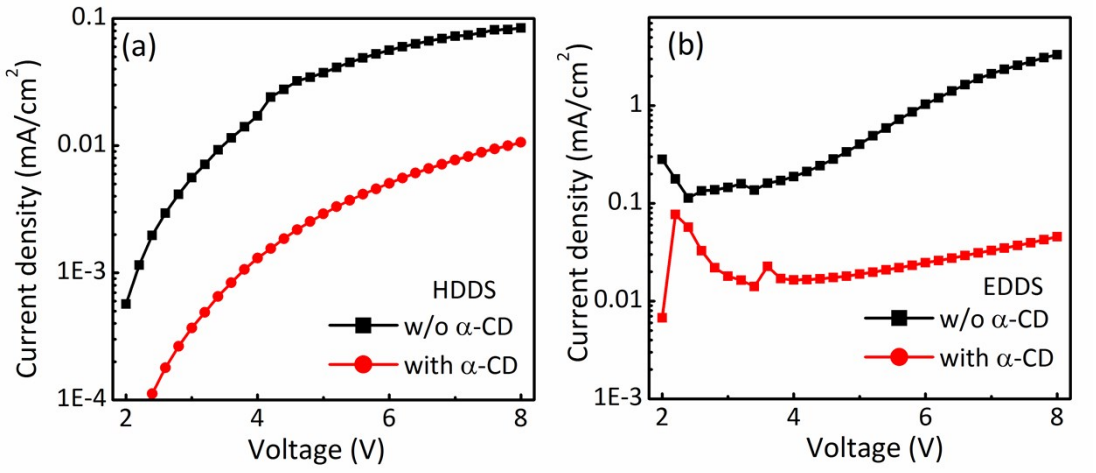

Fig. S4 Current density-voltage (*J-V*) of hole dominated-devices (HDDs) and electron dominated-devices (EDDs) with α-CD and without α-CD. The HDDs and EDDs structures are ITO/PVK/Perovksite/TAPC (65 nm)/Al (120 nm) and ITO/ZnO/PEIE/Perovskite/TPBi (40 nm)/LiF (0.8 nm)/Al (120 nm), respectively.

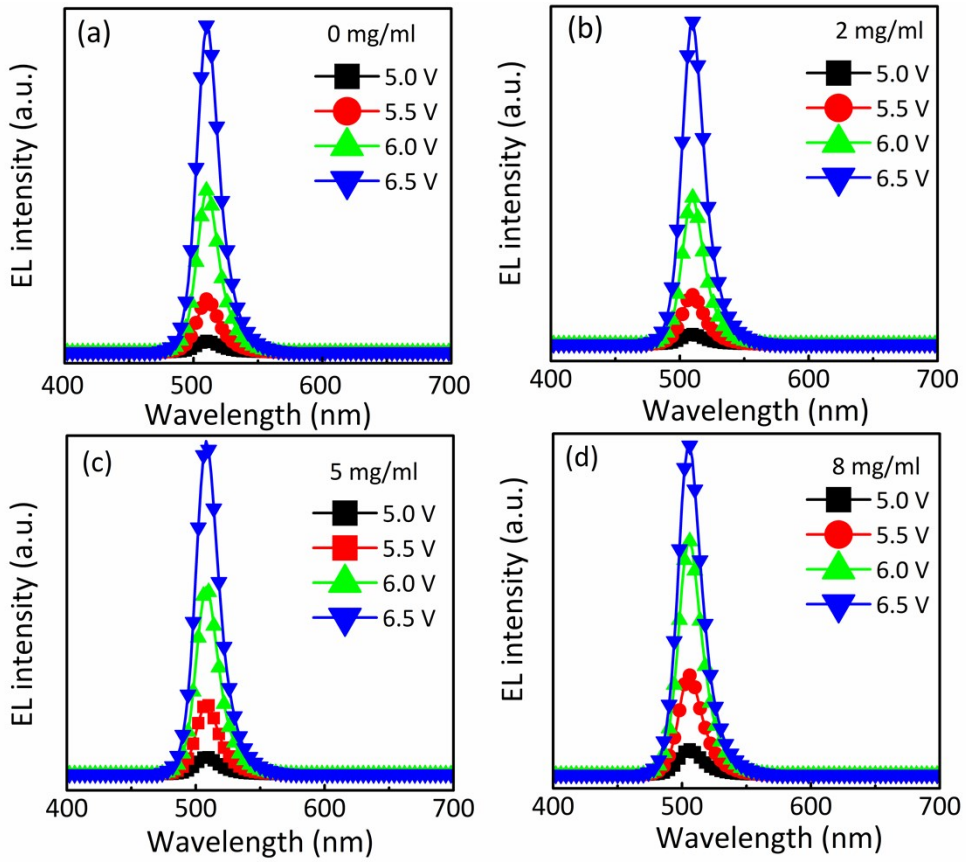

Fig. S5 The EL spectra of PeLEDs based on different concentration of α-CD at different voltages: (a) 0 mg/ml; (b) 2 mg/ml; (c) 5mg/ml; (d) 8 mg/ml.

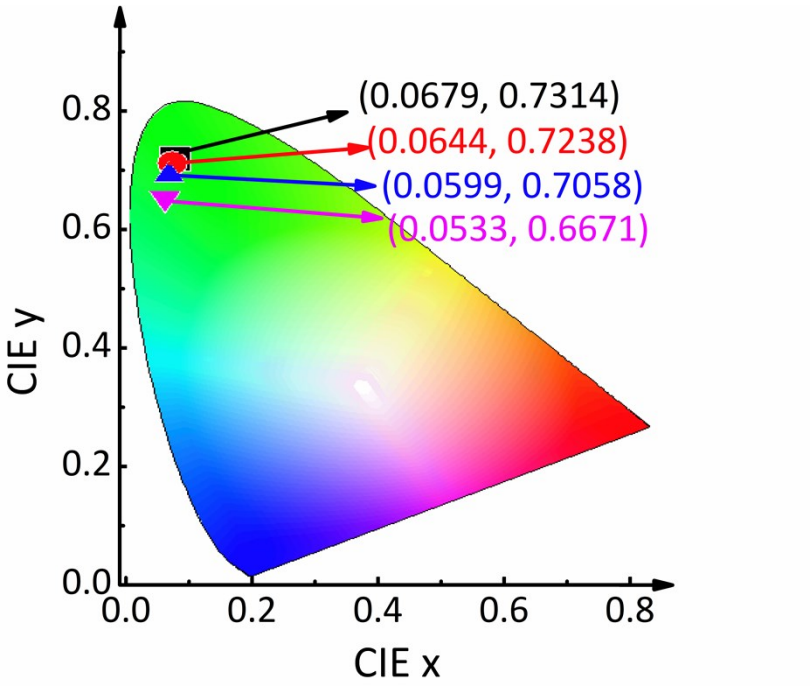

Fig. S6 The commission international de I'Eclairage (CIE) coordinates of PeLEDs based on different concentration of α-CD at an applied voltage of 6.0 V.

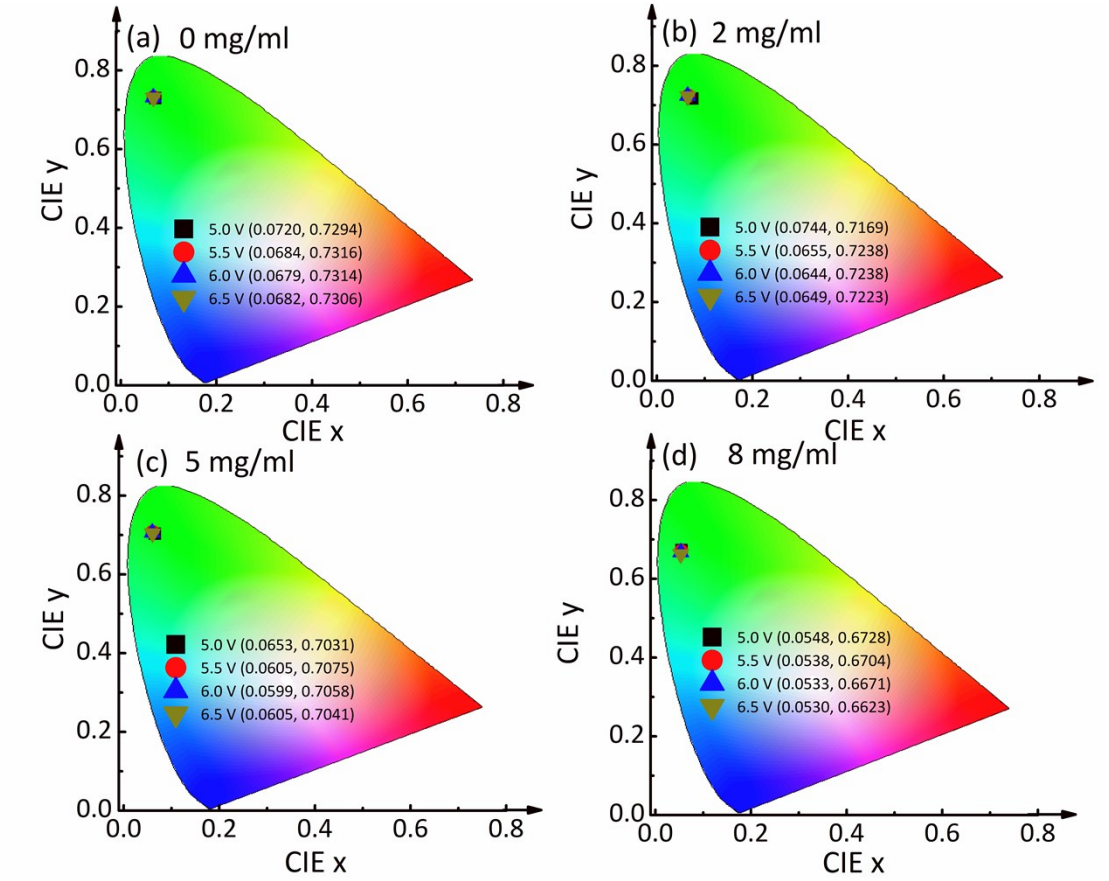

Fig. S7 The commission international de I'Eclairage (CIE) coordinates of PeLEDs based on different concentration of α-CD at different voltages: (a) 0 mg/ml; (b) 2 mg/ml; (c) 5mg/ml; (d) 8 mg/ml.

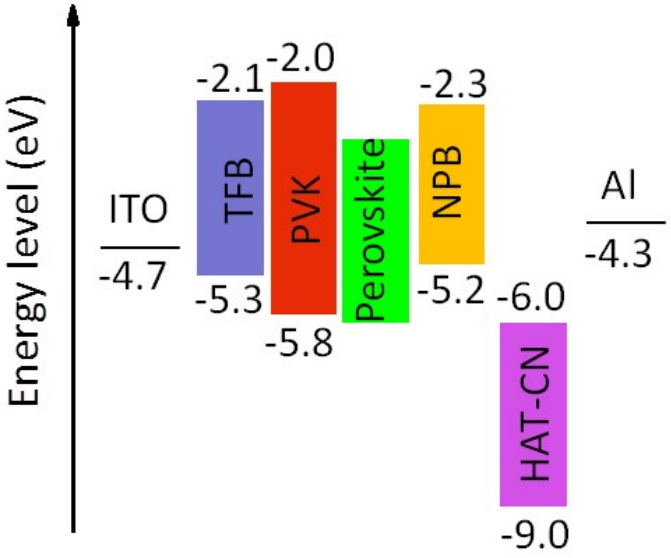

Fig. S8 An energy level diagram of two hole-dominated devices HDD-1 (PVK) and HDD-2 (TFB/PVK). The energy values of NPB and HAT-CN are taken from literatures[1].

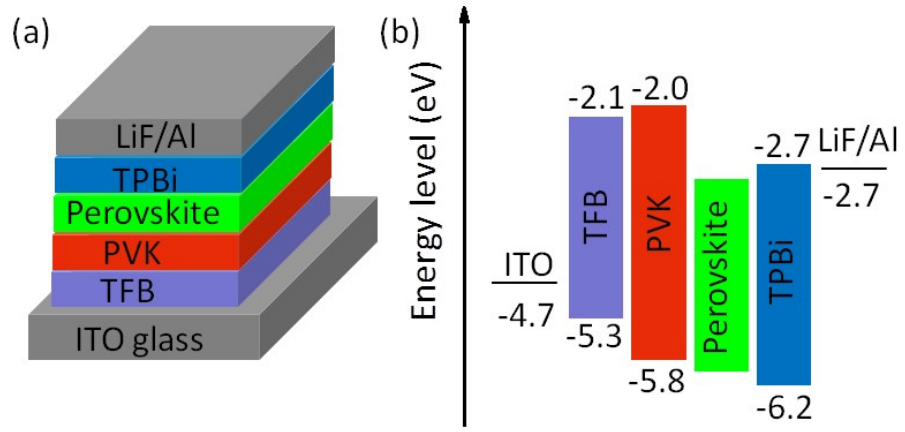

Fig. S9 (a) Device structure diagram of PeLEDs of TFB/PVK served as bilayer HTLs; (b) Energy level diagram of the bilayer TFB/PVK HTLs based PeLEDs.

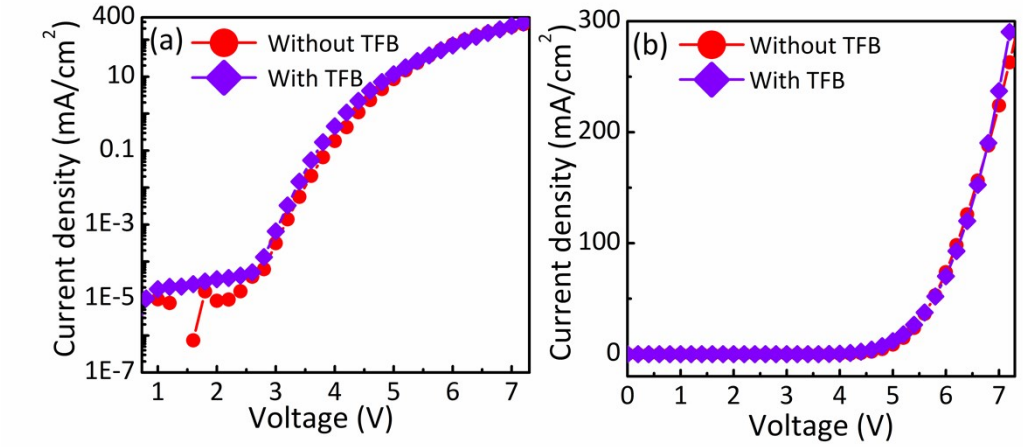

Fig. S10 Current density-voltage (*J-V*) curves of the bilayer of TFB/PVK and the single layer PVK HTLs based PeLEDs, respectively. (a) Logarithmic-linear mode; (b) Linear-linear mode.

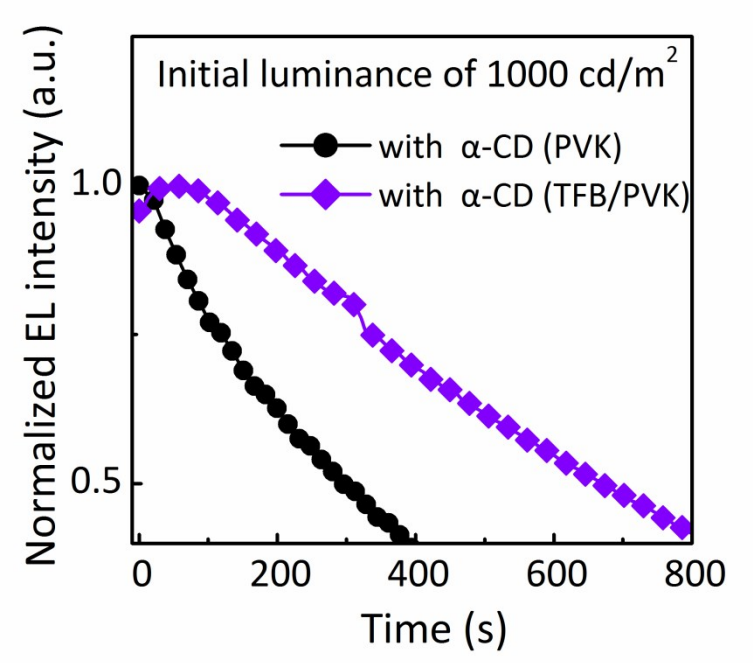

Fig. S11 The half lifetime of PeLEDs based on PVK as a single HTL (black) and TFB/PVK as a double HTLs (violet).

Reference

[1] L. Ding, Y. Q. Sun, H. Chen, F. S. Zu, Z. K. Wang and L. S. Liao, *J. Mater. Chem. C*, 2014, **2**, 10403.