

# Supporting Information

## Boosting Perovskite Light-Emitting-Diodes Performance via

### Tailoring Interfacial Contact

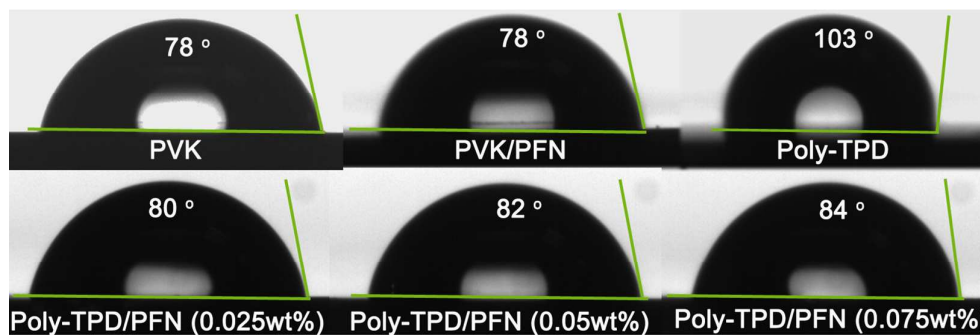
*Yatao Zou<sup>1‡</sup>, Muyang Ban<sup>1‡</sup>, Yingguo Yang<sup>2</sup>, Sai Bai<sup>3</sup>, Chen Wu<sup>1</sup>, Yujie Han<sup>1</sup>, Tian Wu<sup>1</sup>, Yeshe Tan<sup>1</sup>, Qi Huang<sup>1</sup>, Xingyu Gao<sup>2</sup>, Tao Song<sup>1\*</sup>, Qiao Zhang<sup>1\*</sup>, and Baoquan Sun<sup>1\*</sup>*

<sup>1</sup>Jiangsu Key Laboratory for Carbon-Based Functional Materials & Devices, Institute of Functional Nano & Soft Materials (FUNSOM) and Collaborative Innovation Center of Suzhou Nano Science and Technology, Soochow University, 199 Ren'ai Road, Suzhou 215123, People's Republic of China

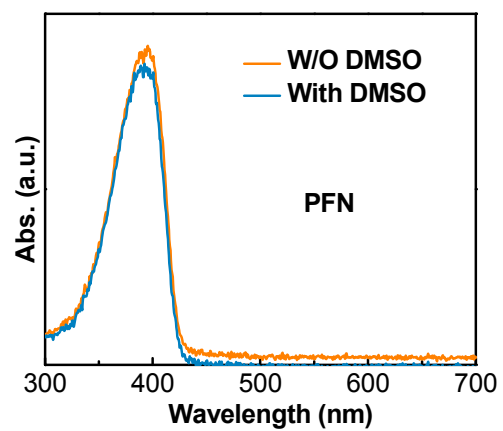
<sup>2</sup>Shanghai Synchrotron Radiation Facility (SSRF), Shanghai Institute of Applied Physics, Chinese Academy of Sciences, 239 Zhangheng Road, Pudong New Area, Shanghai 201204, China

<sup>3</sup>Department of Physics, Chemistry and Biology (IFM), Linköping University, SE-581 83 Linköping, Sweden

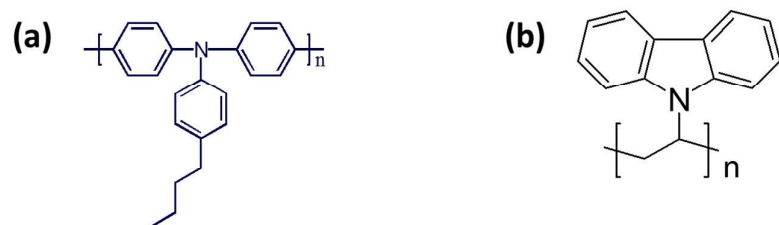
\*Corresponding Author: [tsong@suda.edu.cn](mailto:tsong@suda.edu.cn); [qiaozhang@suda.edu.cn](mailto:qiaozhang@suda.edu.cn); [bqsun@suda.edu.cn](mailto:bqsun@suda.edu.cn).



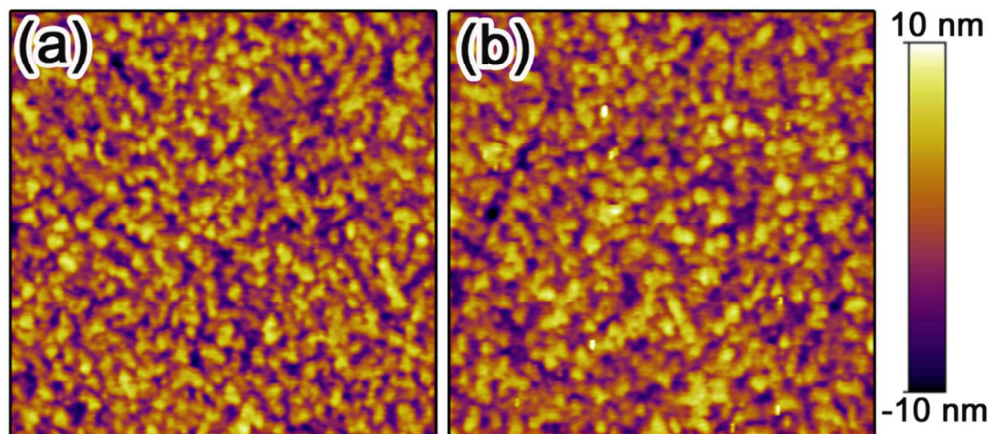
**Figure S1** Water contact angle images on PVK, PVK/PFN, poly-TPD, and poly-TPD/PFN with different PFN concentration. Contact angle values are depicted in each image.



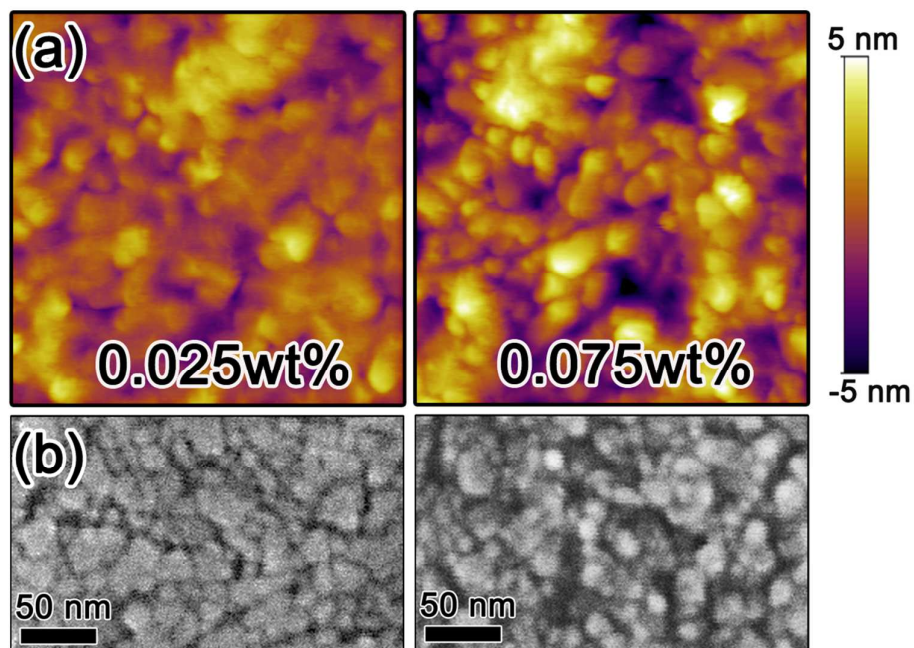
**Figure S2.** UV-vis absorption spectra of PFN layer before and after DMSO spin coating.



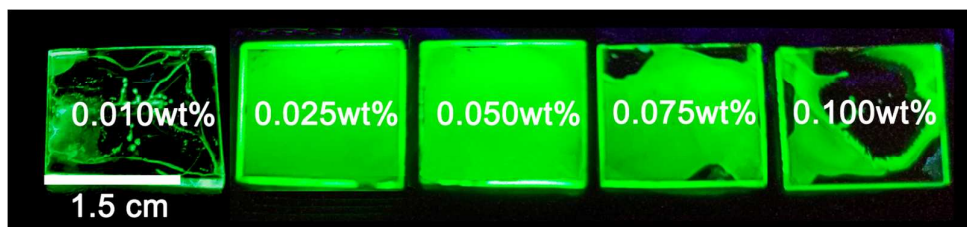
**Figure S3** Molecular structures of (a) Poly-TPD, (b) PVK.



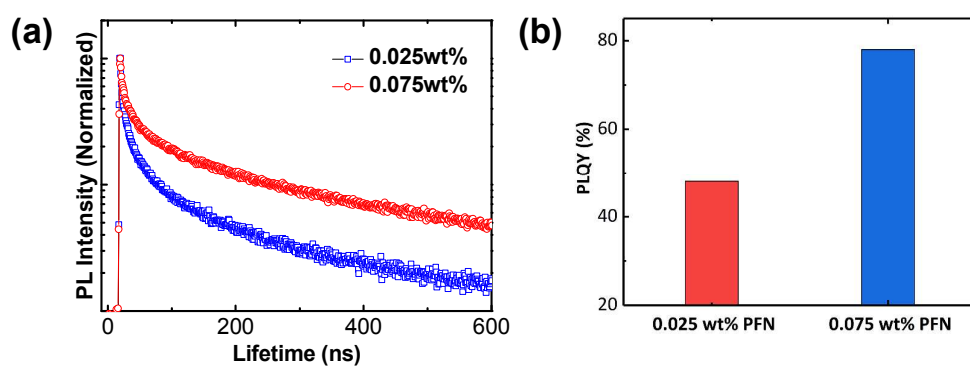
**Figure S4** AFM height topography images of poly-TPD films covered (a) without and (b) with PFN coating layer. The RMS values for pristine poly-TPD and poly-TPD/PFN are exactly same with values of  $\sim 1.1$  nm. The AFM images are  $2\ \mu\text{m} \times 2\ \mu\text{m}$ .



**Figure S5** (a) AFM, (b) SEM height topography image of perovskite on poly-TPD/PFN with different PFN concentration. All AFM image sizes are 500 nm×500 nm.

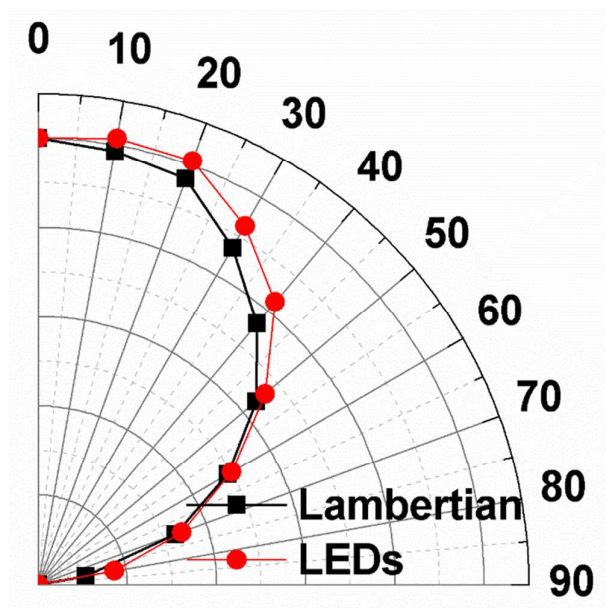


**Figure S6** Photographs of perovskite morphologies deposited on poly-TPD/PFN with different PFN concentration under 365 nm UV light illumination. PFN with concentration from 0.010wt% to 0.100wt% (from left to right).

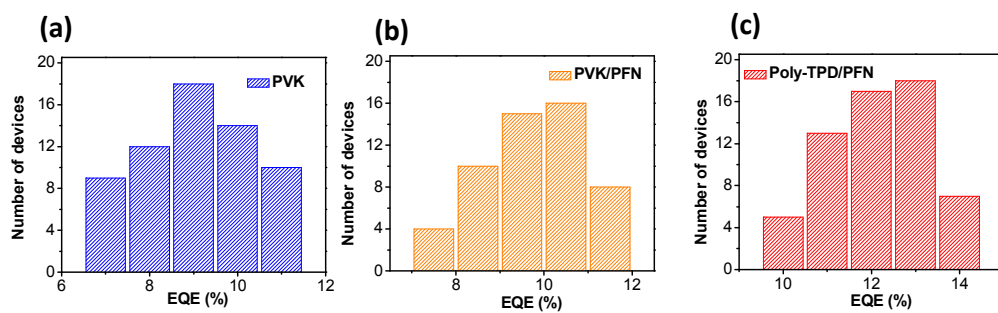


**Figure S7** (a) PL lifetime and (b) PLQY characteristics of perovskite films on poly-TPD/PFN with different PFN concentration.

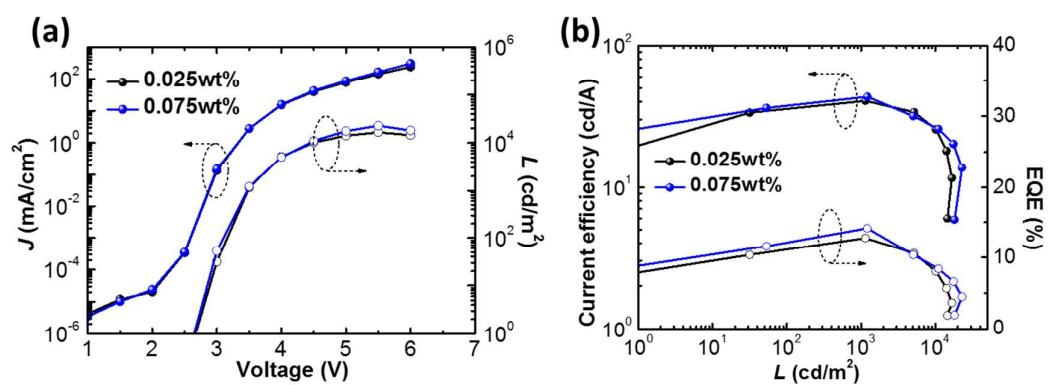




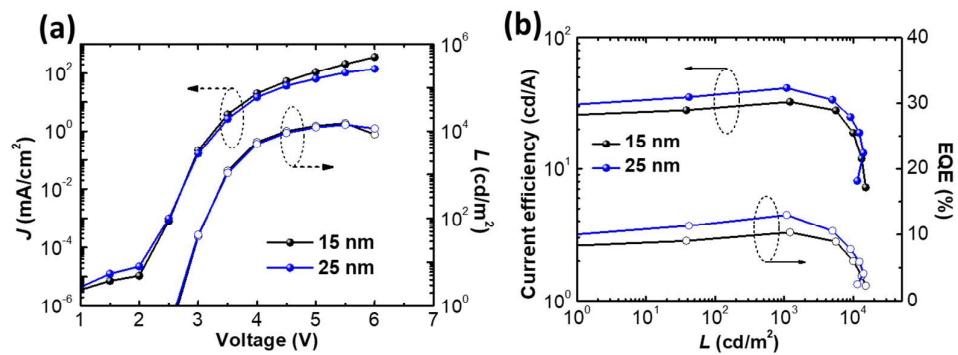
**Figure S8** EL emission angle distribution profile of perovskite LEDs devices compared to the standard Lambertian one.



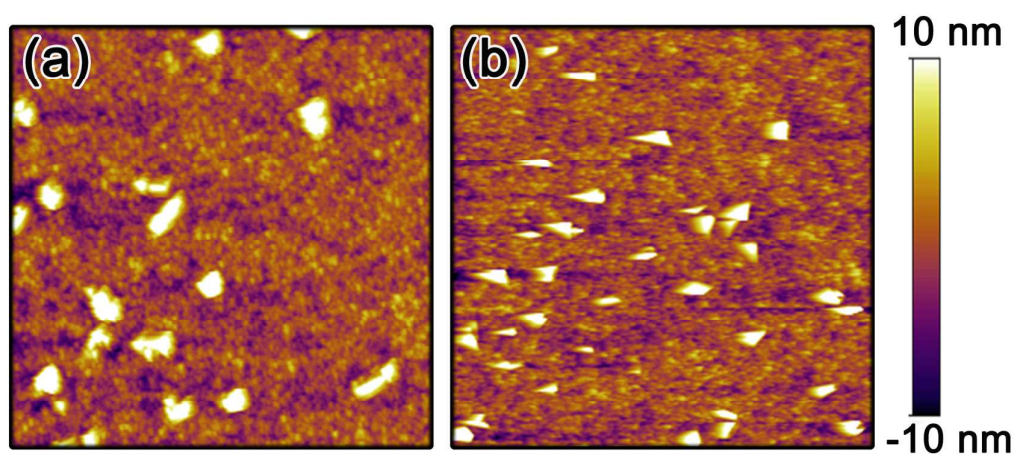
**Figure S9** EQE histogram of ~60 LEDs fabricated on different HTLs. (a) PVK. (b) PVK/PFN. (c) Poly-TPD/PFN. The PFN concentration is 0.050wt%.



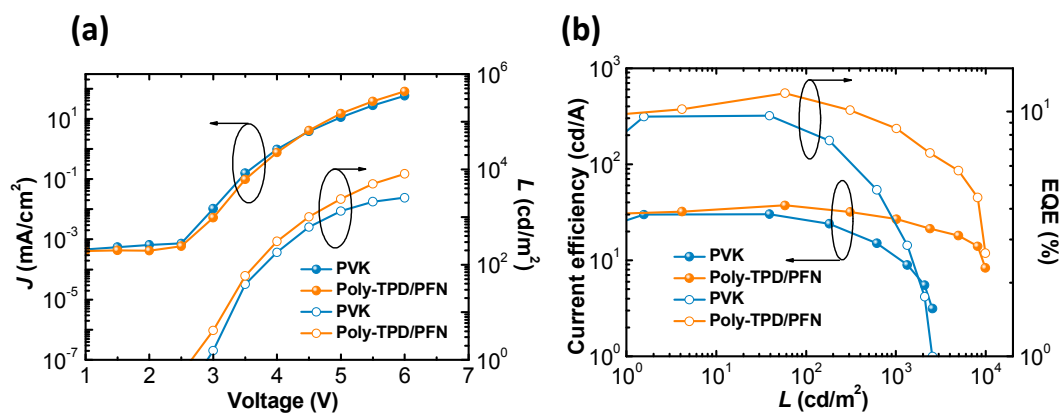
**Figure S10** Electrical output characteristics of the devices based on poly-TPD/PFN HTLs with different PFN thickness. (a) J-V-L characterization; (b) Current efficiency-L-EQE curve.



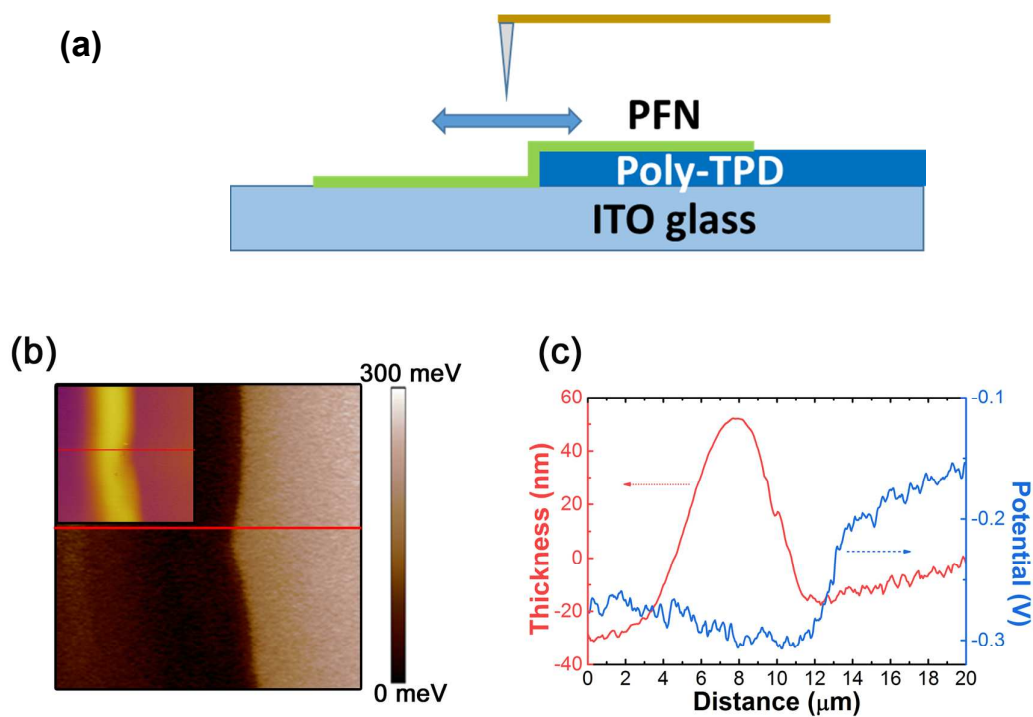
**Figure S11** Electrical output characteristics of the devices based on poly-TPD/PFN (0.050wt%) with different TPBi thickness. (a) J-V-L characterization; (b) Current efficiency-L-EQE curve.



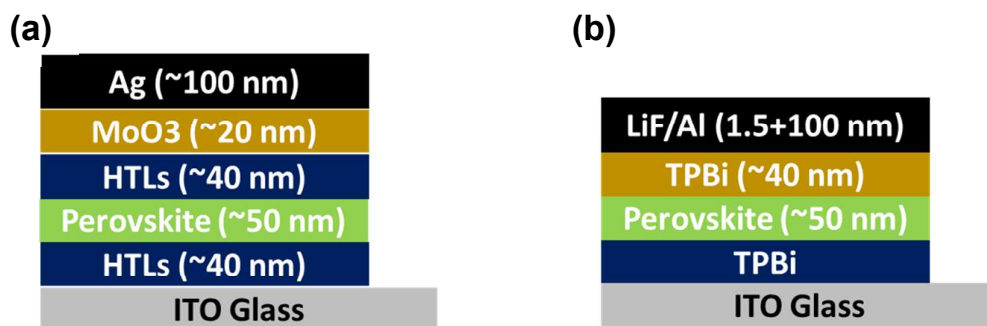
**Figure S12.** AFM height images of perovskite films deposited from the precursor solution with extra PFN (0.02 mg/mL) on (a) PVK (b) poly-TPD/PFN. Here, poly-TPD/PFN layer is deposited by a PFN concentration of 0.050wt%. All AFM sizes are 5 μm×5 μm.



**Figure S13.** Electrical outputs of LED devices fabricated with PFN in the perovskite precursor solution on PVK or poly-TPD/PFN as HTL. (a) J-V-L curve. (b) CE-L-EQE curve.

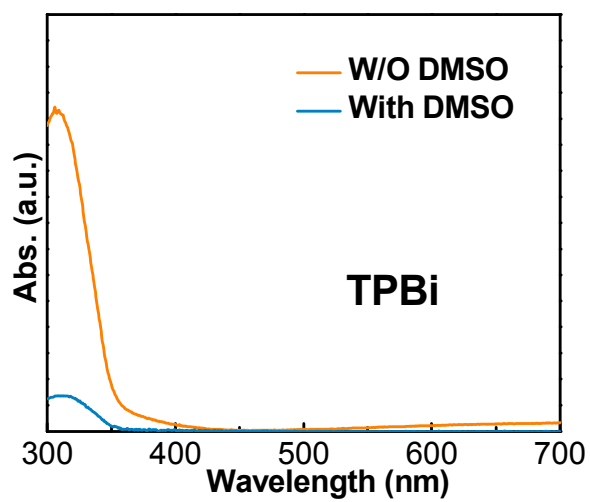


**Figure S14** (a) Schematic illustration of experimental set-up for surface potential of ITO/poly-TPD/PFN interlayer probed by SKPM. A ~30-nm-thick poly-TPD layer is deposited on half-side ITO glass, and then completely covered a thin PFN layer to form a distinct interface. (b) SKPM profile of ITO/poly-TPD/PFN interface. Inset shows the height image of the corresponding image. The AFM image size is 20 μm by 20 μm. (c) Cross-section line profile of height and surface potential images in (b).

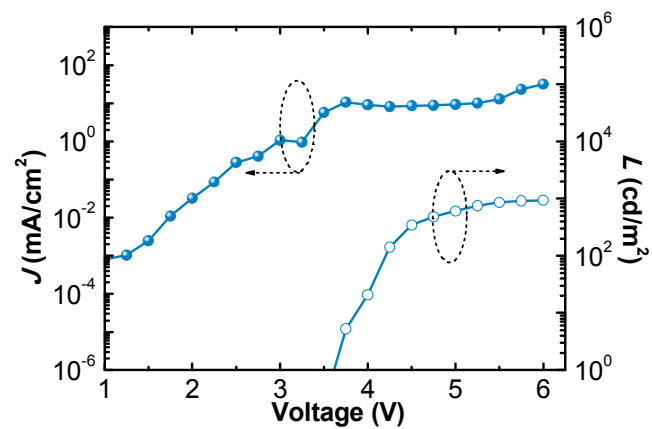


**Figure S15** Single carrier device structure of (a) hole-only device and (b) electron-only device. Here, the HTLs are PVK, PVK/PFN, and poly-TPD/PFN. The PFN concentration is 0.05wt%.





**Figure S16.** UV-vis absorption spectra of a ~200 nm-thick-TPBi layer with and without quick DMSO washing.



**Figure S17.** J-V-L curve of device with structure of ITO/perovskite (~50 nm)/TPBi (~20 nm)/LiF (~1.5 nm)/Al (~100 nm).

**Table S1** Summarized PL lifetime of perovskite deposited on poly-TPD/PFN, where PFN concentration are 0, 0.025wt%, 0.050wt% and 0.075wt%, respectively.

PFN concentration (wt%)	$\tau_1$ (ns)	$\tau_2$ (ns)	$\tau_3$ (ns)	$\tau_{\text{average}}$ (ns)
<b>0</b>	67.8	446.8	7.6	37.8
<b>0.025</b>	79.7	486.8	8.3	53.7
<b>0.050</b>	89.6	510.7	9.4	65.3
<b>0.075</b>	116.5	600.1	11.2	121.6

**Table S2** Electrical output characteristics of the devices based on poly-TPD/PFN as HTL with different PFN concentration. Here, the thickness of poly-TPD is ~45 nm.

PFN concentration (wt%)	$L_{\max}$ (cd m <sup>-2</sup> )	$\eta_p$ (lm W <sup>-1</sup> )	$\eta_A$ (cd A <sup>-1</sup> )	EQE (%)
<b>0.025</b>	16690	36.4	40.5	<b>12.8</b>
<b>0.075</b>	22790	38.8	43.2	<b>13.8</b>

**Table S3** Electrical output characteristics of the devices based on poly-TPD/PFN with different thickness of TPBi. Here, the thickness of poly-TPD is ~45 nm and the PFN concentration is 0.050wt%.

TPBi thickness (nm)	$L_{\max}$ (cd m <sup>-2</sup> )	$\eta_p$ (lm W <sup>-1</sup> )	$\eta_A$ (cd A <sup>-1</sup> )	EQE (%)
<b>15</b>	15120	29.11	32.43	<b>10.34</b>
<b>25</b>	13980	37.10	41.33	<b>13.01</b>