

## Supporting Information

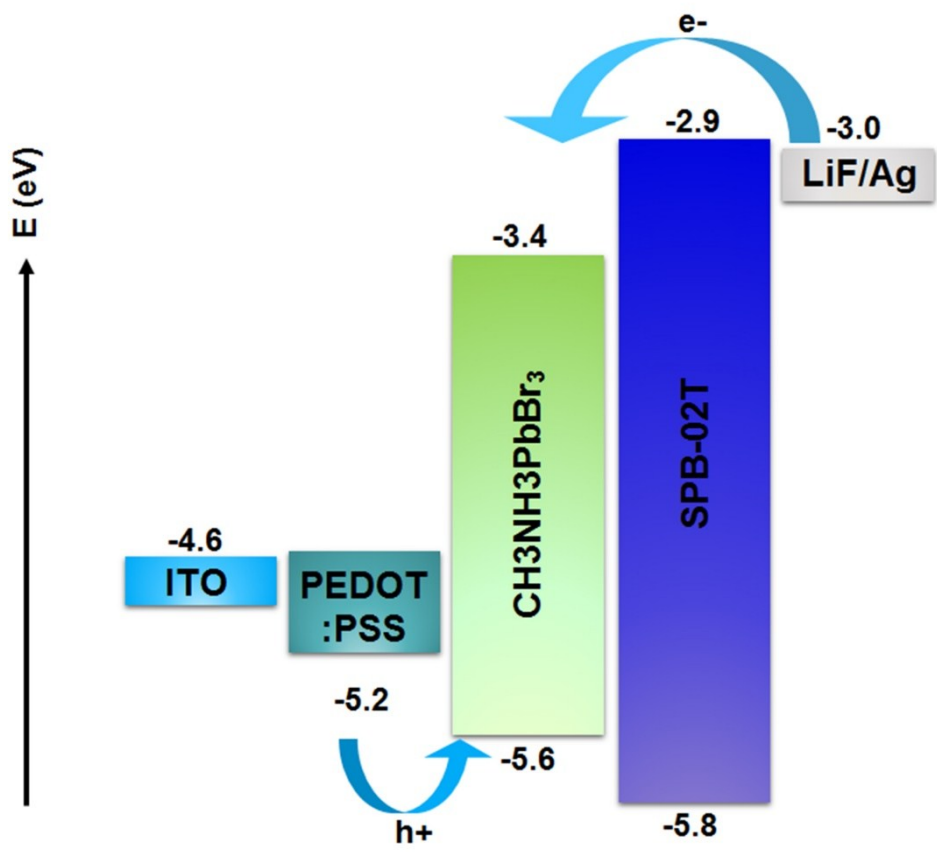
# High-Performance Perovskite Light-emitting Diodes via Morphological Control of Perovskite Film

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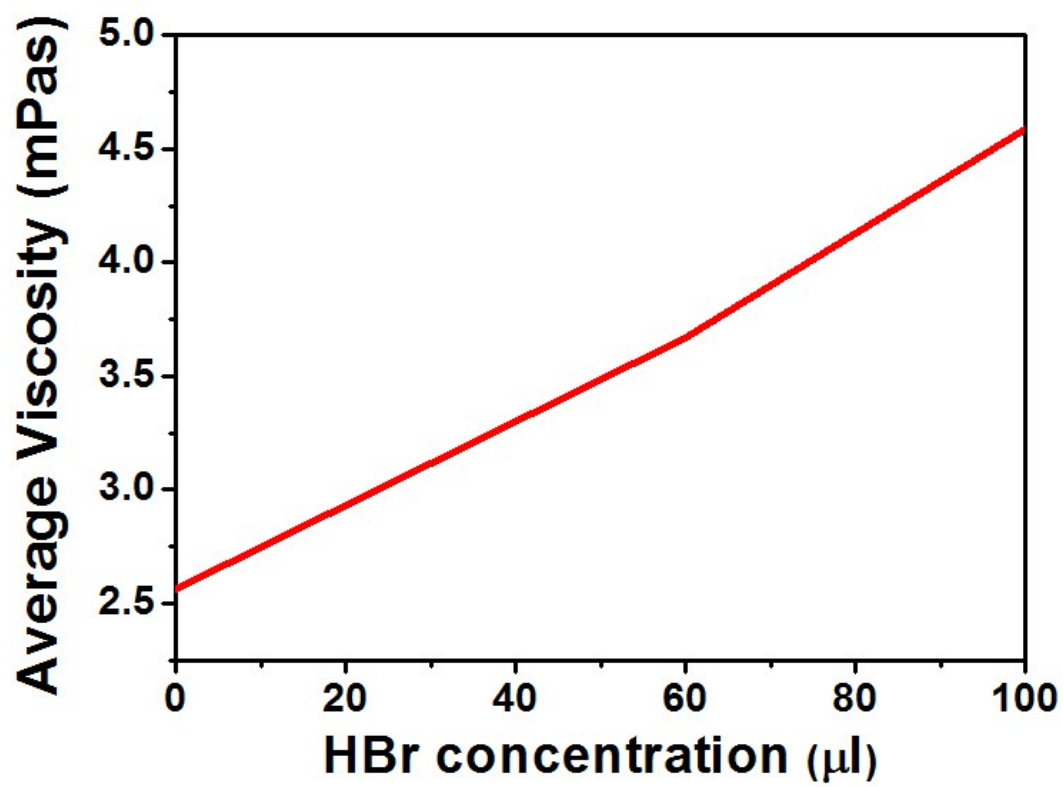
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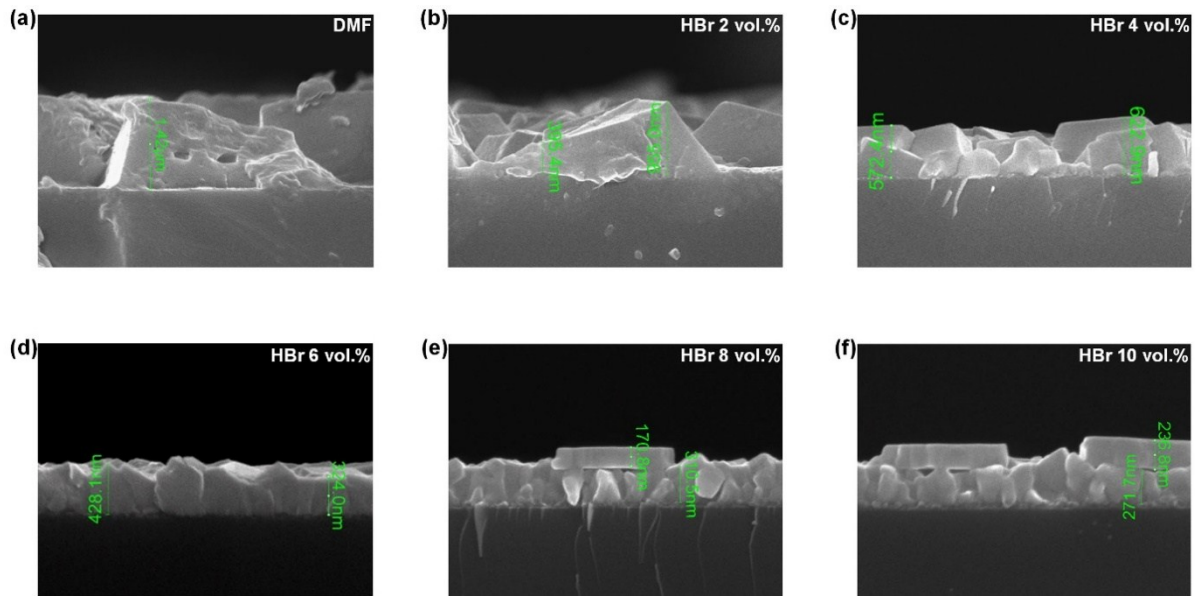
<sup>‡</sup>These authors contributed equally to this work.



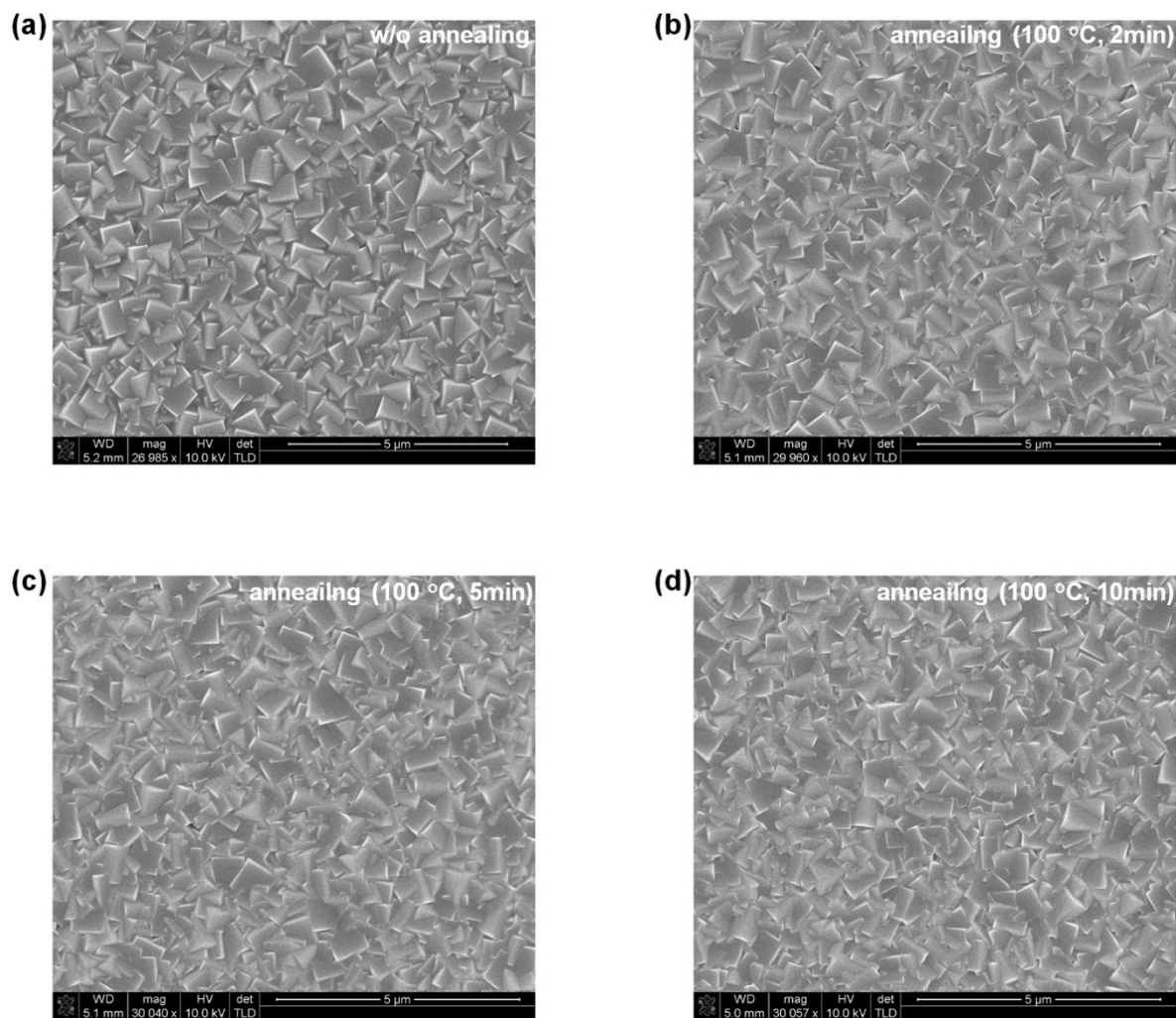
**Figure S1.** Energy levels of the various device components of the PeLEDs.



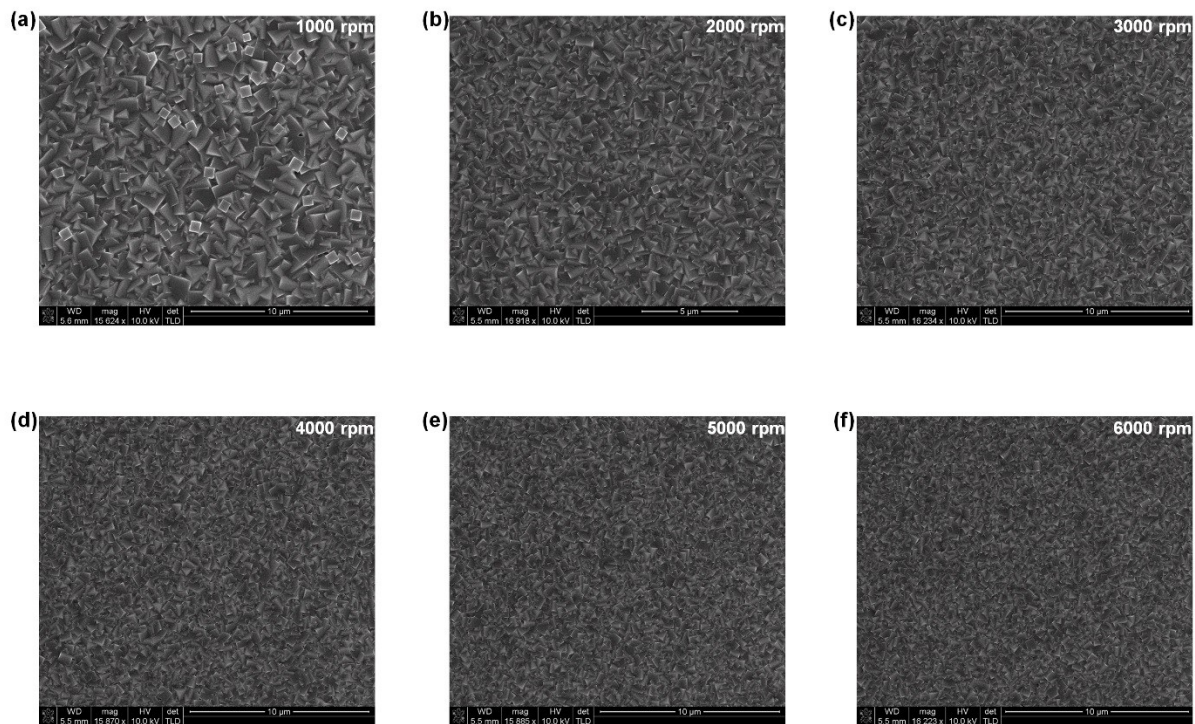
**Figure S2.** Average viscosity data gathered by rheometer; the concentration of HBr in the  $\text{MAPbBr}_3$  precursor solution ranged from 0 to 100  $\mu\text{L}$ .



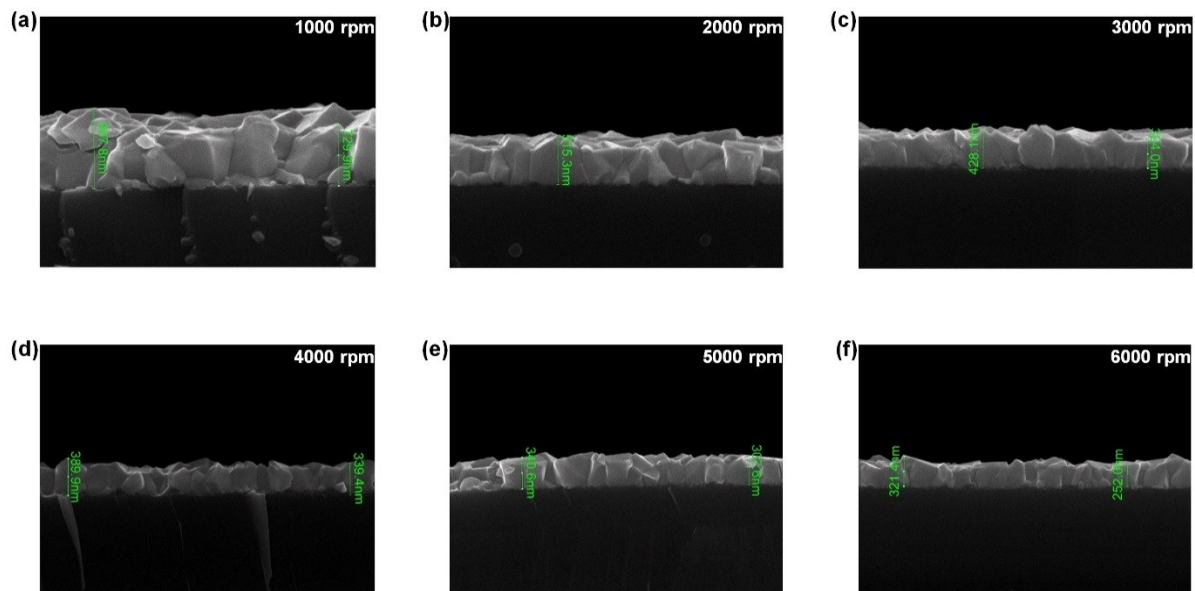
**Figure S3.** Cross-sectional SEM images of MAPbBr<sub>3</sub> layers with different volume ratios of HBr in the DMF/HBr cosolvent. The green line indicates the thickness of the MAPbBr<sub>3</sub> layers.



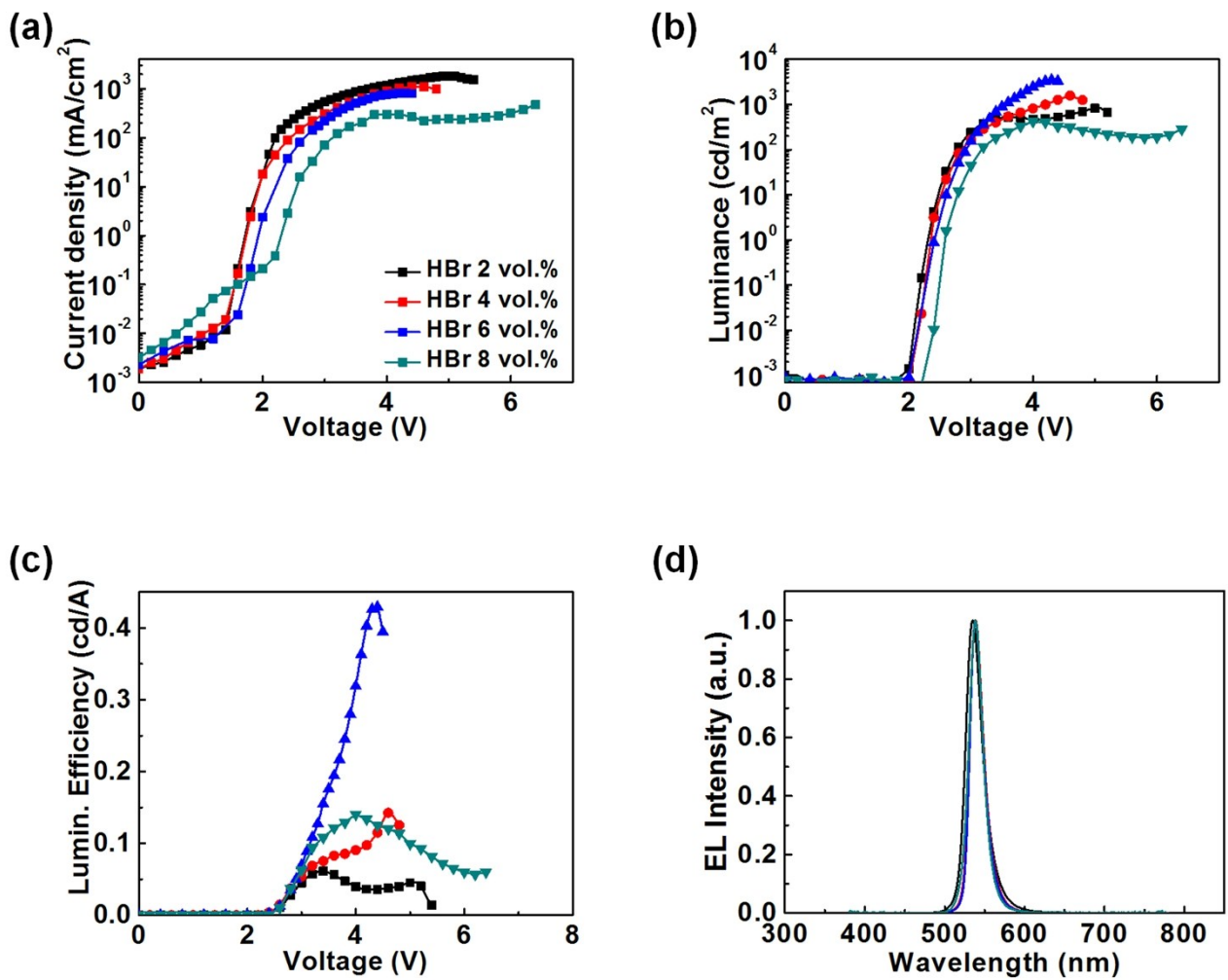
**Figure S4.** SEM images showing the top-view of the MAPbBr<sub>3</sub> films prepared using 6 vol.% of HBr in the DMF/HBr cosolvent; the films were deposited onto a PEDOT:PSS substrate at 100 °C and at different annealing times.



**Figure S5.** SEM images showing the top-view of the MAPbBr<sub>3</sub> films prepared using 6 vol.% of HBr in the DMF/HBr cosolvent; the films were deposited onto a PEDOT:PSS substrate using different spin speeds.

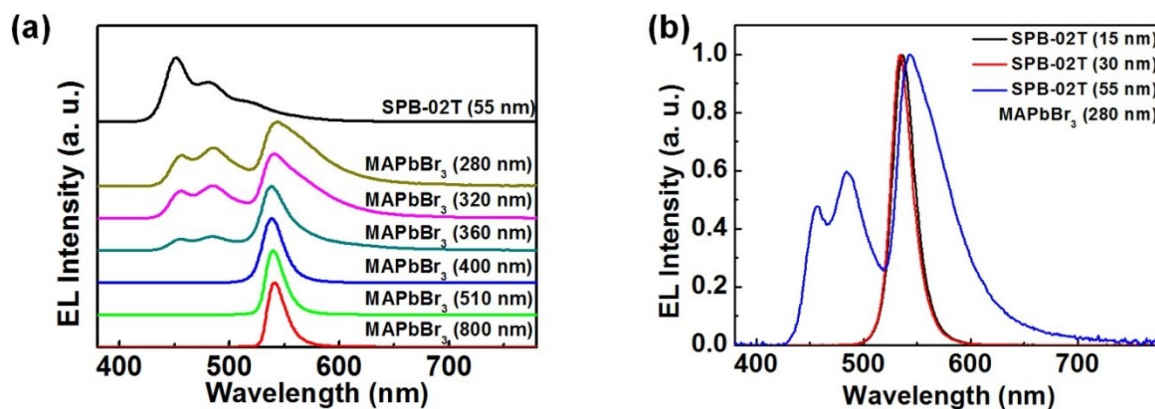


**Figure S6.** Cross-sectional SEM images of the MAPbBr<sub>3</sub> films prepared using 6 vol.% of HBr in the DMF/HBr cosolvent; the films were deposited onto a PEDOT:PSS substrate at different spin speeds.

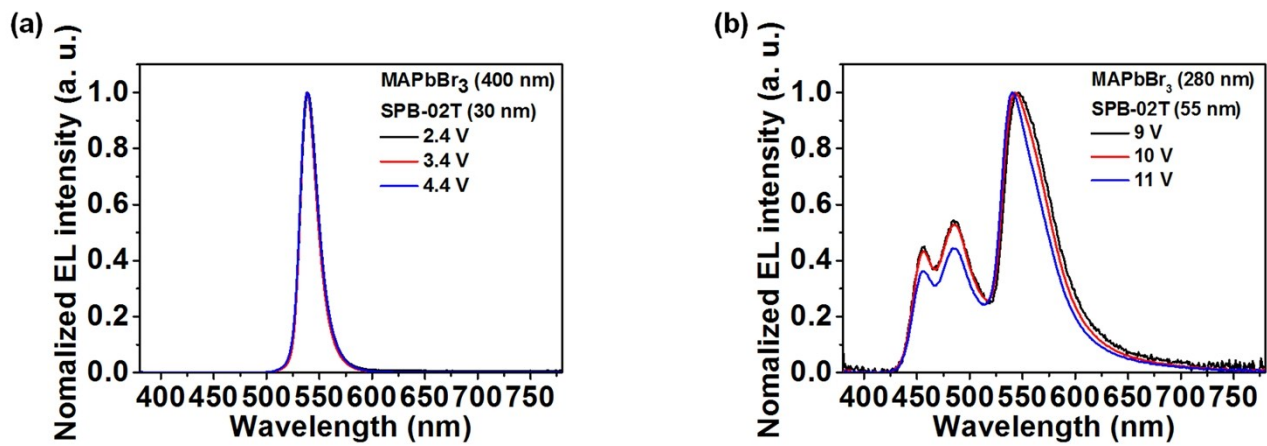


**Figure S7.** (a) *J-V*, (b) *L-V*, and (c) *LE-V* characteristic and (d) electroluminescence (EL) spectra of PeLED devices with the MAPbBr<sub>3</sub> layers deposited using different concentrations of HBr in the DMF/HBr cosolvent.

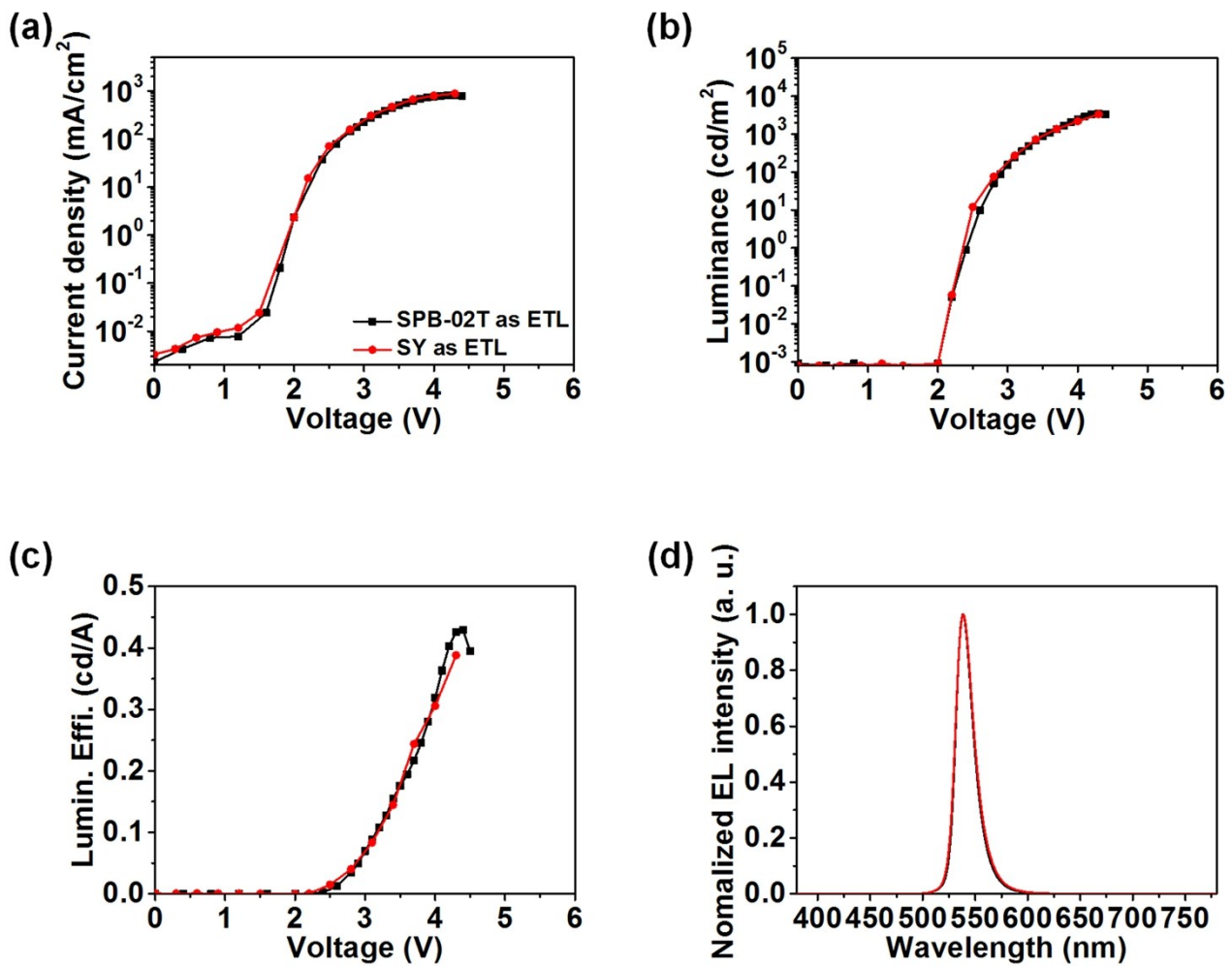




**Figure S8.** (a) EL spectra of PeLEDs prepared with different spin speeds of the MAPbBr<sub>3</sub> precursor solution and with 55-nm-thick SPB-02T. (b) EL spectra of the PeLEDs prepared with 6 vol.% of HBr in the DMF/HBr cosolvent; the films were deposited at a spin speed of 6,000 rpm (280-nm thickness of MAPbBr<sub>3</sub>) and with different thicknesses of SPB-02T (15-55 nm) as electron transport layers.



**Figure S9.** EL spectra of the device with (a) 400 nm-thick MAPbBr<sub>3</sub> and 30 nm-thick SPB-02T and (b) 280 nm-thick MAPbBr<sub>3</sub> and 55 nm-thick SPB-02T under applied voltage.



**Figure S10.** (a)  $J$ - $V$ , (b)  $L$ - $V$ , and (c)  $LE$ - $V$  characteristic and (d) Normalized EL spectra of PeLEDs (ITO/PEDOT:PSS/MAPbBr<sub>3</sub> (400 nm)/SPB-02T (30 nm, black-line) or SY (30 nm, red-line)/LiF/Ag).

**Table S1.** Summary of the device performances of PeLEDs with MAPbBr<sub>3</sub> prepared using different concentration of HBr in the DMF/HBr cosolvent.

<b>Devices configuration</b> ITO/PEDOT:PSS/MAPbBr <sub>3</sub> (adding HBr)/SPB-02T/LiF/Ag	<b>L<sub>max</sub> [cd/m<sup>2</sup>]</b> @ bias	<b>LE<sub>max</sub> [cd/A]</b> @ bias
HBr 2 vol.%	820 @ 5.0	0.06 @ 3.4
HBr 4 vol.%	1575 @ 4.6	0.14 @ 4.6
HBr 6 vol.%	3490 @ 4.3	0.43 @ 4.3
HBr 8 vol.%	422 @ 4.0	0.14 @ 4.0

**Table S2. Comparison of our work with previous literature**

Previous literature	structure	Emission Color	$L_{\max}$ [cd/m <sup>2</sup> ]	$LE_{\max}$ [cd/A]	$EQE_{\max}$ [%]
S1 [Adv. Mater., 2015]	conventional	Green (Ref.)	-	-	-
		Green	20,000	-	0.8
S2 [Adv. Mater., 2015]	conventional	Green (Ref.)	118	0.11	0.026
		Green	545	0.22	0.051
S3 [Nat. Nanotech., 2014]	inverted	Green	364	0.3	0.1
S4 [Adv. Mater., 2015]	inverted	Green (Ref.)	1.38	0.00165	0.000393
		Green	417	0.577	0.125
S5 [Adv. Mater., 2015]	inverted	Green (Ref.)	0.2	-	-
		Green	550	-	-
S6 [Nano Lett., 2015]	inverted	Green (Ref.)	~200	X	0.01
		Green	580	X	1.2
<b>Our work</b>	<b>inverted</b>	<b>Green</b>	<b>3490</b>	<b>0.43 @ 4.3</b>	<b>0.10 @ 4.3</b>

**Table S3.** Summary of the device performances of PeLEDs (ITO/PEDOT:PSS/MAPbBr<sub>3</sub> (400 nm)/SPB-02T (30 nm, black-line) or SY (30 nm, red-line)/LiF/Ag).

<b>Devices configuration</b>	<b>L<sub>max</sub> [cd/m<sup>2</sup>] @ bias</b>	<b>LE<sub>max</sub> [cd/A] @ bias</b>
<b>ITO/PEDOT:PSS/MAPbBr<sub>3</sub>/SPB-02T/LiF/Ag</b>	<b>3490 @ 4.3</b>	<b>0.43 @ 4.3</b>
<b>ITO/PEDOT:PSS/MAPbBr<sub>3</sub>/SY/LiF/Ag</b>	<b>3313 @ 4.3</b>	<b>0.39 @ 4.3</b>

## Supplementary References

- S1. J. Wang, N. Wang, Y. Jin, J. Si, J. Tan, H. Du, L. Cheng, X. Dai, S. Bai, H. He, Z. Ye, M. L. Lai, R. H. Friend, W. Huang, *Adv. Mater.* **2015**, *27*, 2311.
- S2. J. C. Yu, D. B. Kim, G. Baek, B. R. Lee, E. D. Jung, S. Lee, J. H. Chu, D. Lee, K. J. Choi, S. Cho, M. H. Song, *Adv. Mater.* **2015**, *27*, 3492.
- S3. Z. K. Tan, R. S. Moghaddam, M. L. Lai, P. Docampo, R. Higler, F. Deschler, M. Price, A. Sadhanala, L. M. Pazos, D. Credgington, F. Hanusch, T. Bein, H. J. Snaith, R. H. Friend, *Nature nanotechnology* **2014**, *9*, 687.
- S4. Y. H. Kim, H. Cho, J. H. Heo, T. S. Kim, N. Myoung, C. L. Lee, S. H. Im, T. W. Lee, *Adv. Mater.* **2015**, *27*, 1248.
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- S6. G. Li, Z. Tan, D. Di, M. L. Lai, L. Jiang, J. H. Lim, R. H. Friend, N. C. Greenham, *Nano Lett.* **2015**, *15*, 2640.