## **Supporting Information for**

## A Pre-Solution Mixing Precursor Method for Improving Crystallization Quality of Perovskite Film and Electroluminescent Performance of Perovskite Light-Emitting Diodes

Pengfei Xia,<sup>a</sup> Yao Lu,<sup>b</sup> Hongtao Yu,<sup>b</sup> Yongzhe Li,<sup>a</sup> Wenjing Zhu,<sup>b</sup> Xin Xu,<sup>b</sup> Wenzhu Zhang,<sup>b</sup> Jie Qian,<sup>b</sup> Wei Shen,<sup>b</sup> Lihui Liu,<sup>b</sup> Lingling Deng<sup>\*ab</sup> and Shufen Chen<sup>\*bc</sup>

<sup>a</sup>College of Electronic and Optical Engineering & College of Microelectronics, Nanjing University of Posts & Telecommunications (NUPT), 9 Wenyuan Road, Nanjing 210023, China

<sup>b</sup>Key Laboratory for Organic Electronics and Information Displays & Jiangsu Key Laboratory for Biosensors, Institute of Advanced Materials (IAM), Jiangsu National Synergetic Innovation Center for Advanced Materials (SICAM), Nanjing University of Posts & Telecommunications (NUPT), 9 Wenyuan Road, Nanjing 210023, China

<sup>c</sup>Institute of Flexible Electronics (SIFE), Northwestern Polytechnical University (NPU), 127 West Youyi Road, Xi'an 710072, Shaanxi, China

## Supporting note 1

Lattice/unit constants of DPM and PSM were calculated by Bragg diffraction equation:  $2d\sin\theta = k\lambda$  (k = 1, 2, 3), where d is the lattice/unit constant,  $\theta$  is the diffraction angle, k is the order, and  $\lambda = 1.54$  Å for Cu Ka.<sup>1,2</sup> The lattice constant of 3D phase in DPM and PSM perovskite was calculated as 5.9 Å by (100) peak at 14.97 °. The lattice constants of 16.3 and 22.3 Å were calculated for n = 1 and n = 2 nanosheets by peaks at ~5.40 ° and ~3.95 °, respectively.

## Supporting note 2

According to the method reported by Ahn et al.<sup>3</sup>, we separated the PbBr<sub>2</sub>-DMSO and MABr-PbBr<sub>2</sub>-DMSO complex from the precursor by adding ethanol and diethyl ether to the PbBr<sub>2</sub> and MAPbBr<sub>3</sub> solution, respectively. For the PbBr<sub>2</sub>-DMSO complex, 0.8 mmol PbBr<sub>2</sub> was dissolved in 2 mL DMSO, then anhydrous ethanol was added for separation. For the MABr-PbBr<sub>2</sub>-DMSO complex, 0.8 mmol of PbBr<sub>2</sub> and MABr (molar ratio of 1 : 1) were dissolved in 2 mL DMSO, and then diethyl ether was added for separation. The precipitation of PbBr<sub>2</sub>-DMSO complexes were filtered and dried in vacuum oven for 12 h.



Fig. S1 AFM height images and multiple line scans of (a) DPM (b) PSM film on glass substrate.



Fig. S2 Humidity and air stability of DPM and PSM films. As-prepared DPM and PSM films under (a) ambient light and (c) ultraviolet lamp. After exposure to air for five hours, DPM and PSM films under (b) ambient light and (d) ultraviolet lamp.



Fig. S3 Schematic illustration of perovskite films transferred onto a copper grid for TEM characterization. The perovskite precursor was spin-coated onto a substrate covered with 1,1-bis-(4-bis(4-methyl-phenyl)-amino-phenyl)-cyclohexane (TAPC). The TAPC layer could not be dissolved or destroyed due to the low solubility of TAPC in DMSO. After that, the whole substrate was immersed in toluene. After the TAPC layer was dissolved by toluene, perovskite grains can be stripped from substrate and well dispersed into toluene solvent for further transferring onto a copper grid.



Fig. S4 Statistics of grain size in the DPM and the PSM films.



Fig. S5 Fourier transform infrared spectrometer (FTIR) of DMSO (solution), pure PbBr<sub>2</sub> (powder), PbBr<sub>2</sub>-DMSO (powder) and MABr-PbBr<sub>2</sub>-DMSO (powder) for the S=O vibrations.



Fig. S6 Tyndall effect photographs of DPM and PSM precursor.



Fig. S7 UPS spectrum of DPM and PSM films.



Fig. S8 Current density curves of DPM and PSM devices at negative bias.



Fig. S9 Cross-sectional SEM images of (a) DPM and (b) PSM films.



Fig. S10 (a) Luminance-voltage, (b) current density-voltage and (c) current efficiency-voltage curves of the DPM and PSM devices with  $PbBr_2 : MABr : PEABr = 1 : 0.75 : 0.5$ . (d) Statistical distribution of the current

efficiencies for 70 devices.



Fig. S11 (a, b, c) Luminance, current density and current efficiency curves of the FA<sup>+</sup> doped (FA : MA = 0.3 : 0.7) device as a function of applied bias. (d) EL spectra of FA<sup>+</sup> doped DPM and PSM devices.



Fig. S12 (a, b, c) Luminance, current density and current efficiency curves of the FA<sup>+</sup> doped (FA : MA = 0.7 : 0.3) device as a function of applied bias. (d) EL spectra of FA<sup>+</sup> doped DPM and PSM devices.

Reference

- H. C. Cho, S. H. Jeong, M. H. Park, Y. H. Kim, C. Wolf, C. L. Lee, J. H. Heo, A. Sadhanala, N. Myoung, S. Yoo, S. H. Im, R.H. Friend and T. W. Lee, *Science*, 2015, 250, 1222–1225.
- 2 X. Yang, X. Zhang, J. Deng, Z. Chu, Q. Jiang, J. Meng, P. Wang, L. Zhang, Z. Yin and J. You, *Nat.Commun.*, 2018, 9, 1169.
- 3 N. Ahn, D. Son, I. Jang, S. M. Kang, M. Choi and N. Park, J. Am. Chem. Soc., 2015, 137, 8696-8699.