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• **Supplementary File** •

Stable $\alpha - CsPbI_3$ with Extremely Red Emission for Expanding the Color Gamut

Yong ZHANG[1], Xin WEI[1], Lei GAO[1], Weijie ZHAO[1], Changjiu SUN[2], Junli WEI[2], Mingjian YUAN[2], Zhenhua NI[1*], Junpeng LU[1*] & Hongwei LIU[3*]

[1]*School of Physics and Key Laboratory of MEMS of the Ministry of Education, Southeast University,Nanjing* 211189, *China;*
[2]*Key Laboratory of Advanced Energy Materials Chemistry (Ministry of Education), Renewable Energy Conversion and Storage Center (RECAST), College of Chemistry, Nankai University,Tianjin* 300071, *China;*
[3]*Jiangsu Key Lab on Opto-Electronic Technology, School of Physics and Technology, Nanjing Normal University, Nanjing* 210023, *China*

Appendix A Supplementary Figure

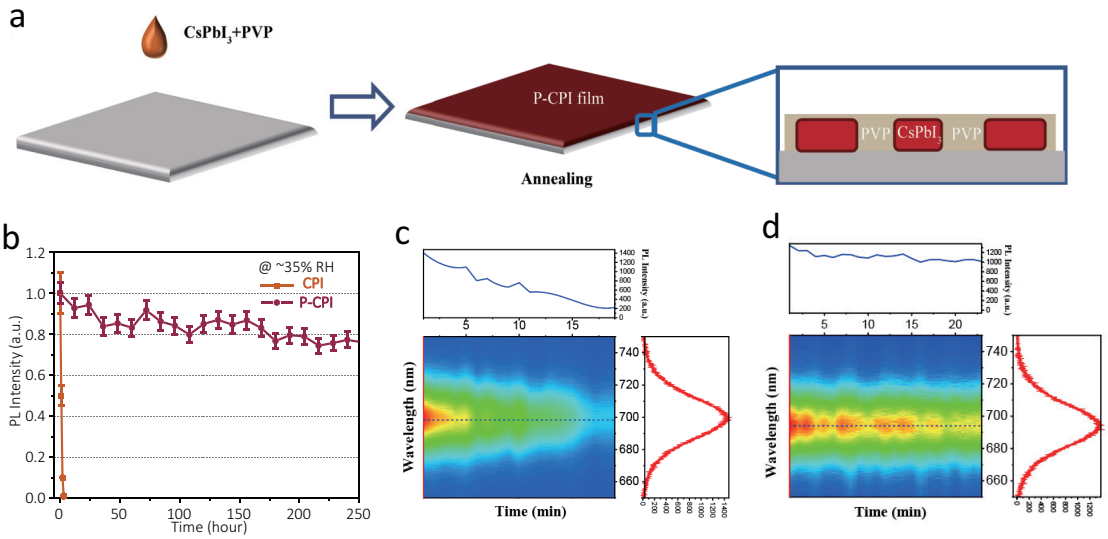

Figure A1 (a) the encapsulation schematic of P-CPI. (b) The PL spectra of different samples in ambient conditions. The PL of CPI (c) and P-CPI (d) in constant electric field (8V/μm) measured in vacuum.

The films were deposited on the cleaned quartz substrates and placed in the atmosphere of 25℃ and 35 %RH. It can be observed from the PL spectra of films (Fig. S1) that the pristine sample underwent a quick phase transition, from α-$CsPbI_3$ to δ-phase. The PL intensity of pristine film decreased with time rapidly. In contrast, slow decay is observed in the film introduced 20 wt% PVP.

* Corresponding author (email: zhni@seu.edu.cn, phyljp@seu.edu.cn, phylhw@njnu.edu.cn)

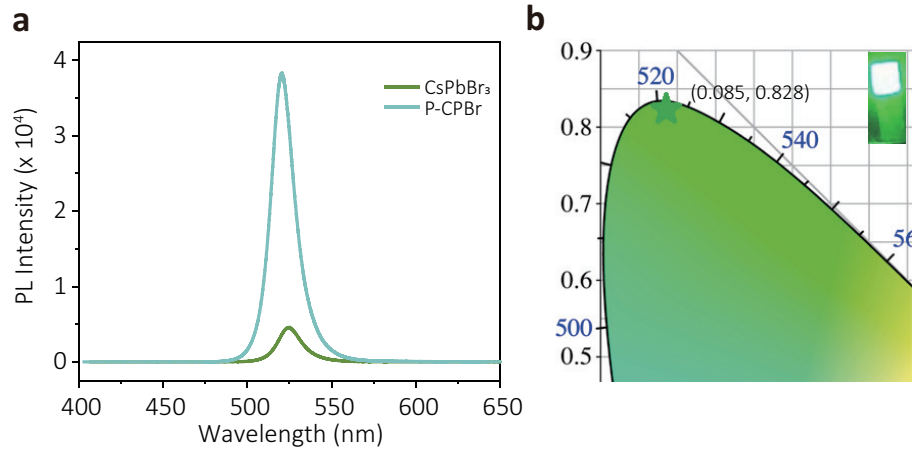

Figure A2 (a) The PL spectra of CsPbBr3 and P-CPBr. (b) The CIE coordinates of P-CPBr. Insert shows the photograph of the PeLED in operation.

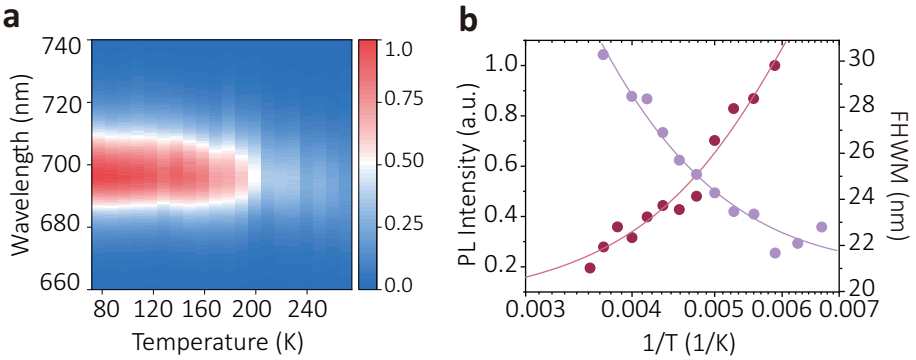

Figure A3 (a) The PL mapping of pristine CPI, acquired from 77 K to 280 K. (b) The PL intensity and FWHM as a function of 1/T extracted from (a).

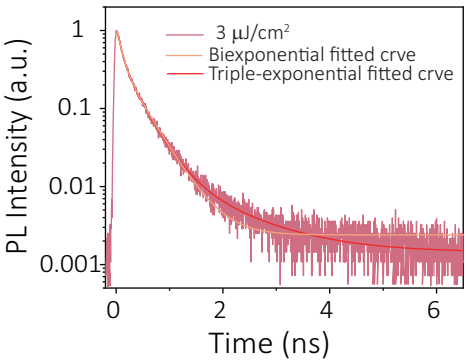

Figure A4 The TRPL of P-CPI under high excitation power. Under high excitation power, the data can be well fitted by triple-exponential rather than biexponential. In this case, the Auger recombination is observed.

Appendix B Supplementary Table

Table B1 Summary of wide color gamut based on perovskite.

Ref in Figure 2(c)	Red (wavelength or coordinate in CIE 1931)	Green (wavelength orcoordinate in CIE 1931)	Blue (wavelength or coordinate in CIE 1931)	NTSC	Rec.2020
[1]	NA	(0.170, 0.757)	NA	102%	76%
[2]	(0.708, 0.291)	(0.092, 0.779)	(0.138, 0.268)	90%	NA
[3]	NA	NA	NA	138%	103%
[4]	622nm	525nm	NA	125%	NA
[5]	NA	NA	NA	132%	98%
[6]	630nm	527nm	450nm	105%	NA
[7]	NA	(0.177, 0.7732)	(0.6992, 0.2988)	127%	95%
[8]	(0.73, 0.29)	(0.22, 0.75)	(0.14, 0.08)	120%	NA
This work	(0.728, 0.272)	(0.085, 0.828)	(0.171, 0.013)	151%	113%

Table B2 Binding energy (E_b) and LO phonon-carrier Frölich coupling intensity obtained from temperature-dependent PL.

Film	E_b (meV)	Γ_0 (meV)	Γ_{LO}	$\hbar\omega_{LO}$(meV)
Pristine CPI	72.2±3.1	21.1±0.2	178.5±53.1	69.3±6.5
P-CPI	77.1±1.7	19.0±0.2	118.6±16.1	58.8±3.1

Table B3 Binding energy (E_b) and LO phonon-carrier Frölich coupling intensity obtained from temperature-dependent PL.

Film	k_1 (s^{-1})	k_2 (s^{-1} cm^3)
Pristine CPI	1.9×10^7	1.1×10^{-8}
P-CPI	1.2×10^7	1.3×10^{-8}

References

1 Yu D, Cao F, Gao Y et al. Room?Temperature Ion?Exchange?Mediated Self?Assembly toward Formamidinium Perovskite Nanoplates with Finely Tunable, Ultrapure Green Emissions for Achieving Rec. 2020 Displays. Adv Funct Mater, 2018, 28: 1800248.

2 Kim H P, Kim J, Kim B S et al. High-Efficiency, Blue, Green, and Near-Infrared Light-Emitting Diodes Based on Triple Cation Perovskite. Adv Opt Mater, 2017, 5: 1600920.

3 Cheng R, Shen H, Chen Z et al. Preparation of heterostructure quantum dots towards wide-colour-gamut display. Materials Letters, 2019, 254: 171-174.

4 Xie Q, Wu D, Wang X et al. Branched capping ligands improve the stability of cesium lead halide (CsPbBr3) perovskite quantum dots. J of Mater Chem C, 2019, 7: 11251-11257.

5 Ma K, Du X-Y, Zhang Y-W et al. In situ fabrication of halide perovskite nanocrystals embedded in polymer composites via microfluidic spinning microreactors. J of Mater Chem C, 2017, 5: 9398-9404.

6 Park D H, Han J S, Kim W et al. Facile synthesis of thermally stable CsPbBr3 perovskite quantum dot-inorganic SiO2 composites and their application to white light-emitting diodes with wide color gamut. Dyes and Pigments, 2018, 149: 246-252.

7 Qasim K, Wang B, Zhang Y et al. Solution-Processed Extremely Efficient Multicolor Perovskite Light-Emitting Diodes Utilizing Doped Electron Transport Layer. Adv Funct Mater, 2017, 27: 1606874.

8 Wright A D, Verdi C, Milot R L et al. Electron?phonon coupling in hybrid lead halide perovskites. Nat Commun, 2016, 7: 11755.