

Electronic Supplementary Information

High efficiency blue/green/yellow/red fluorescent organic light-emitting diodes sensitized by phosphors: General design rules and electroluminescence performance analysis

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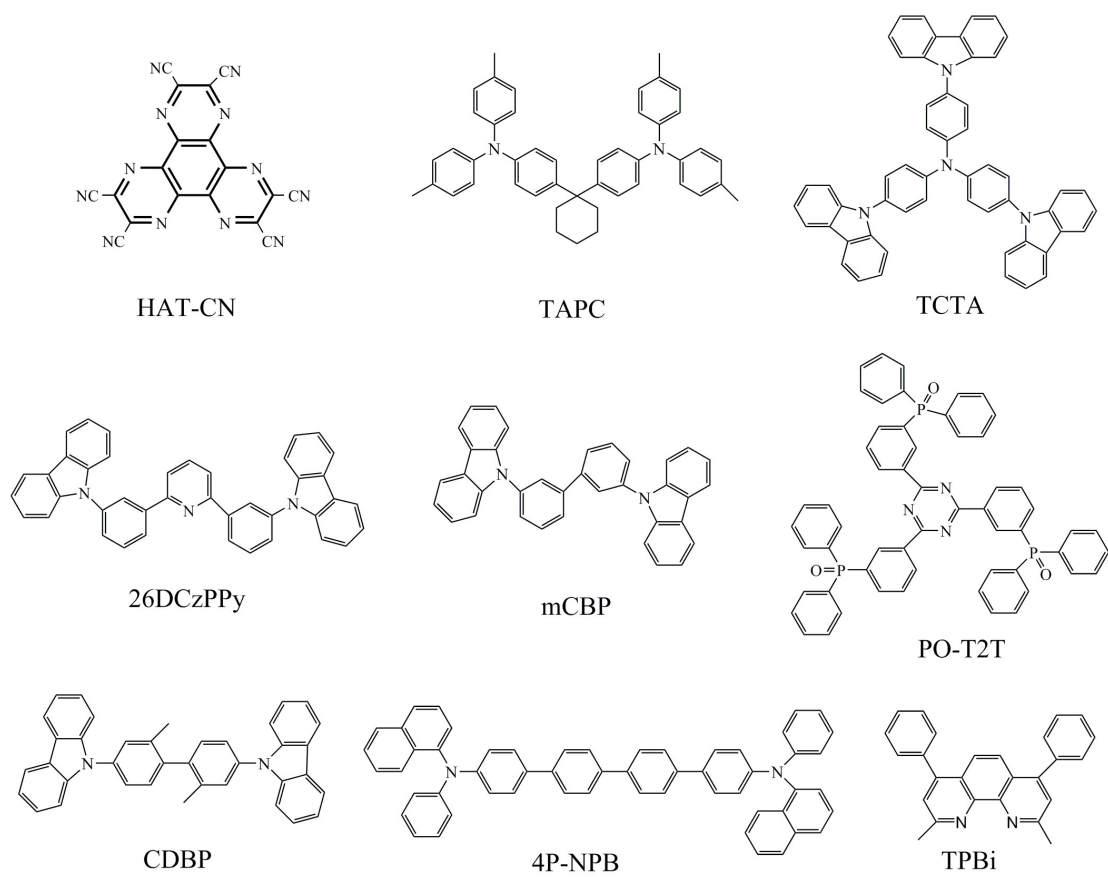


Fig. S1 Chemical structures of the materials used in this study.

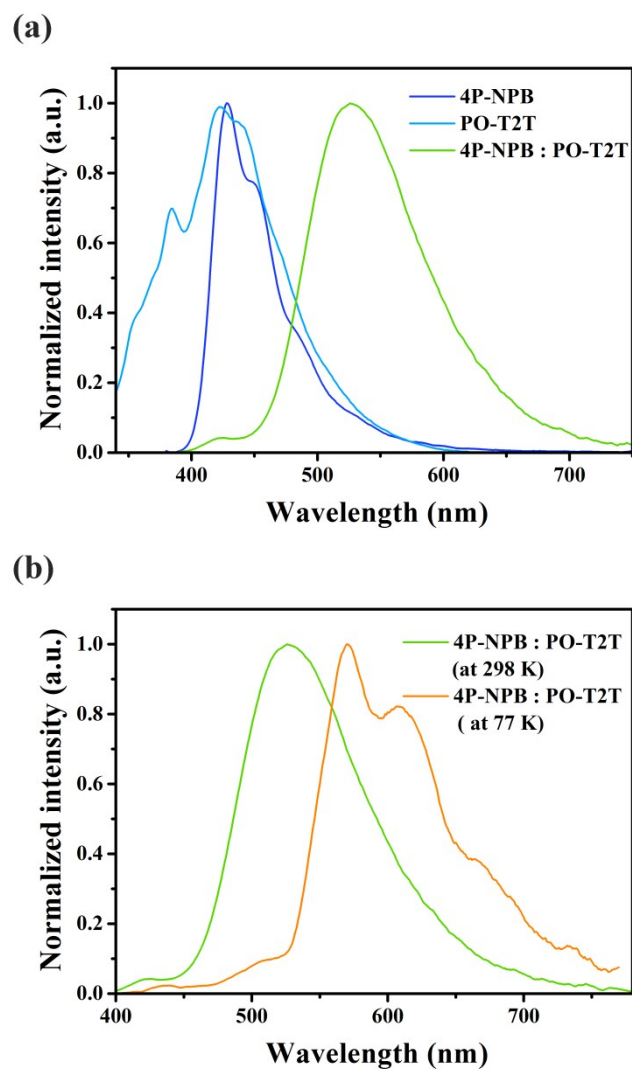


Fig.S2 (a) PL spectra of 4P-NPB, PO-T2T and 4P-NPB:PO-T2T thin films. (b) PL spectra of 4P-NPB:PO-T2T (1:1) thin film at 298 and 77 K.

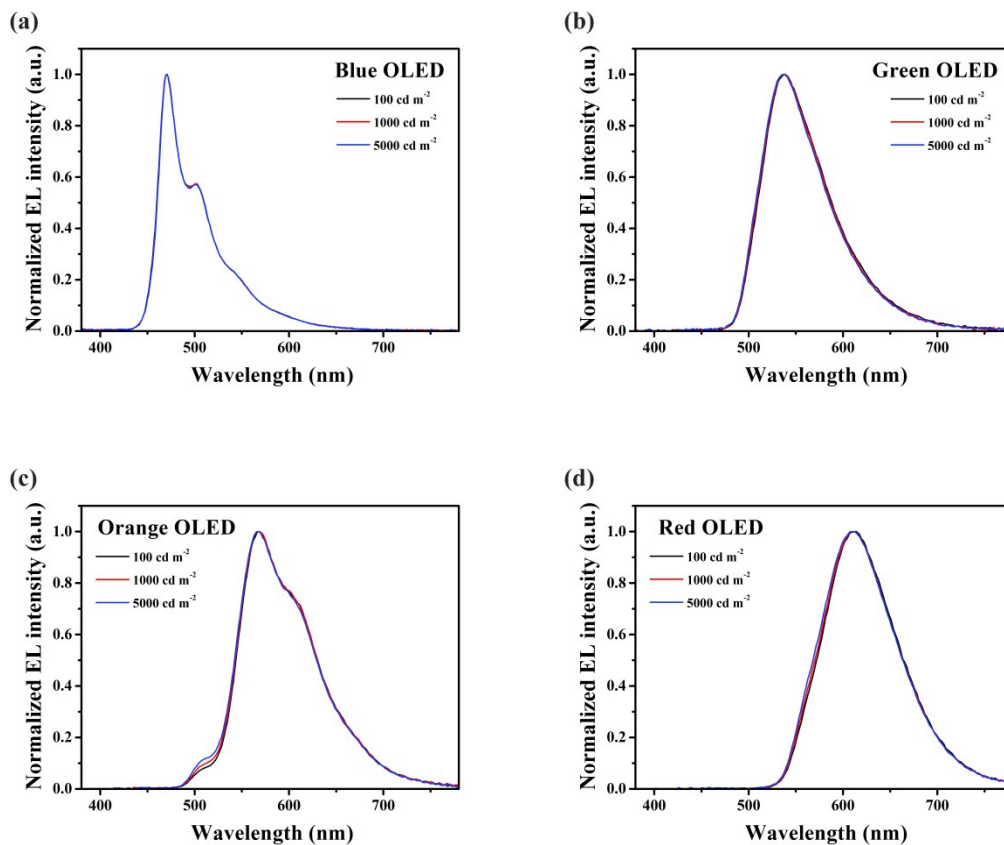


Fig. S3 EL spectra of the resulting phosphor sensitized fluorescent OLEDs at different luminance.

(a), (b), (c) and (d) correspond to blue, green, yellow and red fluorescent OLEDs, respectively.

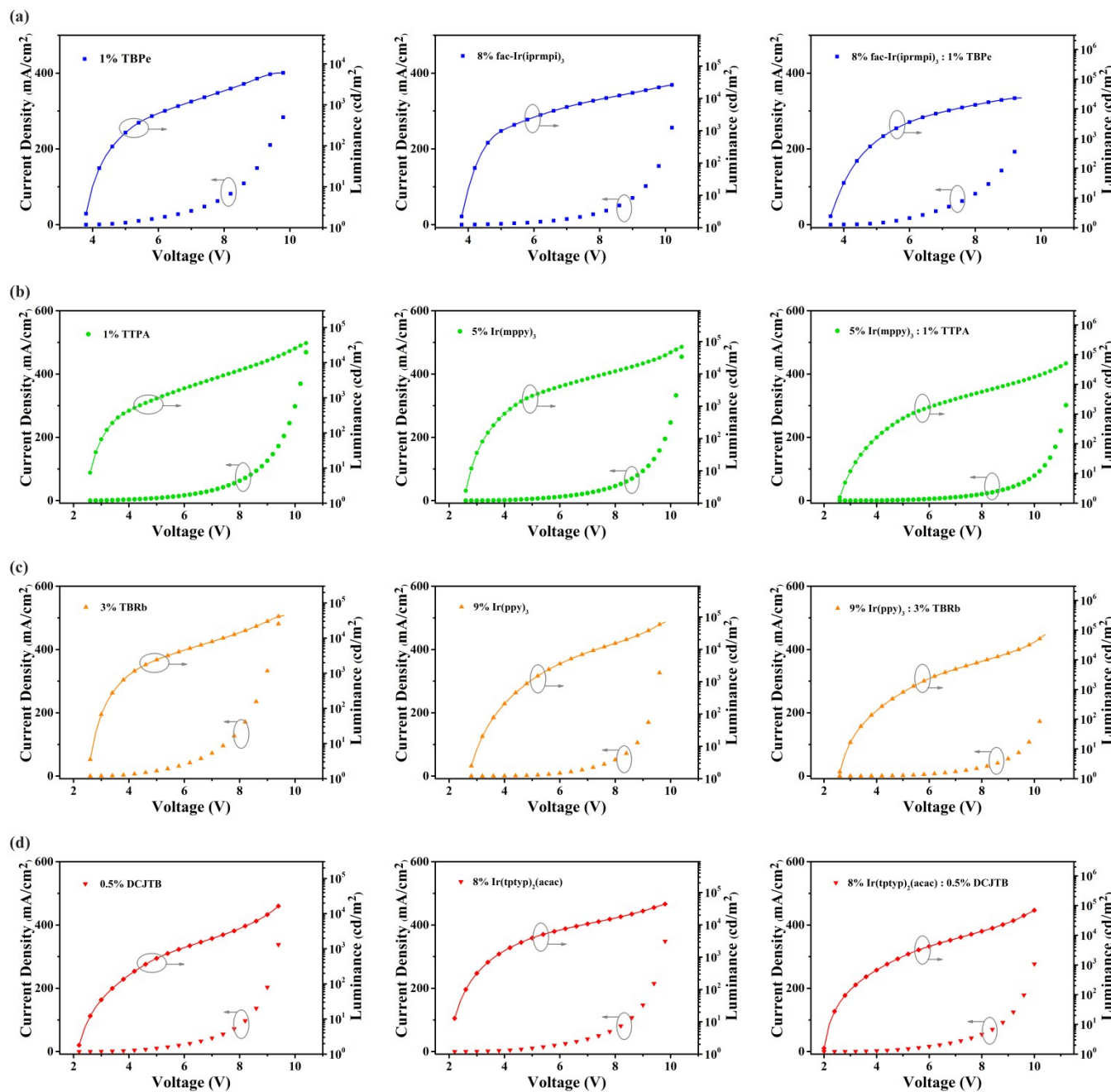


Fig. S4 Current density-luminance-voltage (J-L-V) characteristics of the fabricated OLEDs based on only fluorescent emitters, only phosphor sensitizers and co-doped phosphor sensitizers and fluorescent emitters. (a), (b), (c) and (d) correspond to blue, green, yellow and red fluorescent OLEDs, respectively.

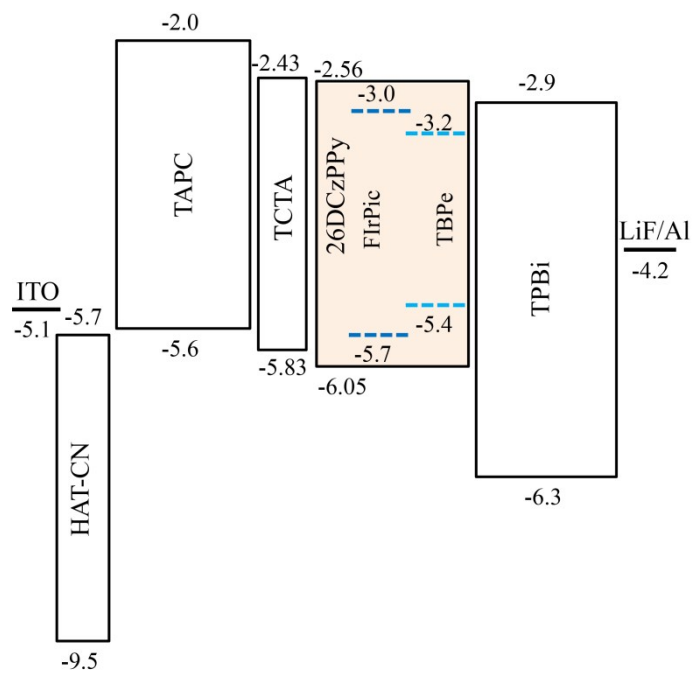


Fig. S5 Schematic diagram of the phosphor sensitized blue fluorescent OLEDs based on FIrpic as sensitizer.

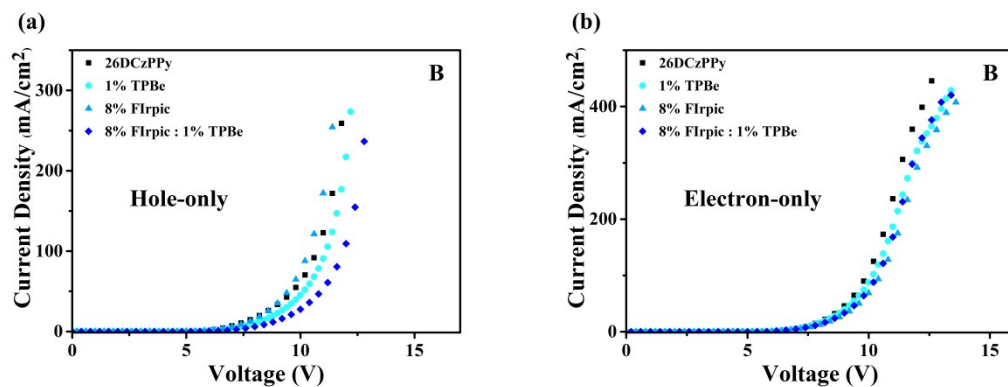


Fig. S6 Current density-voltage (J-V) characteristics of the hole-only (a) and electron-only (b) devices based on FIrpic as sensitizer. The structure of the hole-only devices is: ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (10 nm)/EMLs (20 nm)/TCTA (10 nm)/TAPC (60 nm)/HAT-CN (15 nm)/Al. The structure of the electron-only devices is: ITO/LiF (1nm)/TPBi (45 nm)/EMLs (20 nm)/TPBi (45 nm)/LiF (1 nm)/Al. And the EMLs are 26DCzPPy, 26DCzPPy:1 wt% TPBe, 26DCzPPy:8 wt% FIrpic and 26DCzPPy:8 wt% FIrpic:1 wt% TPBe.

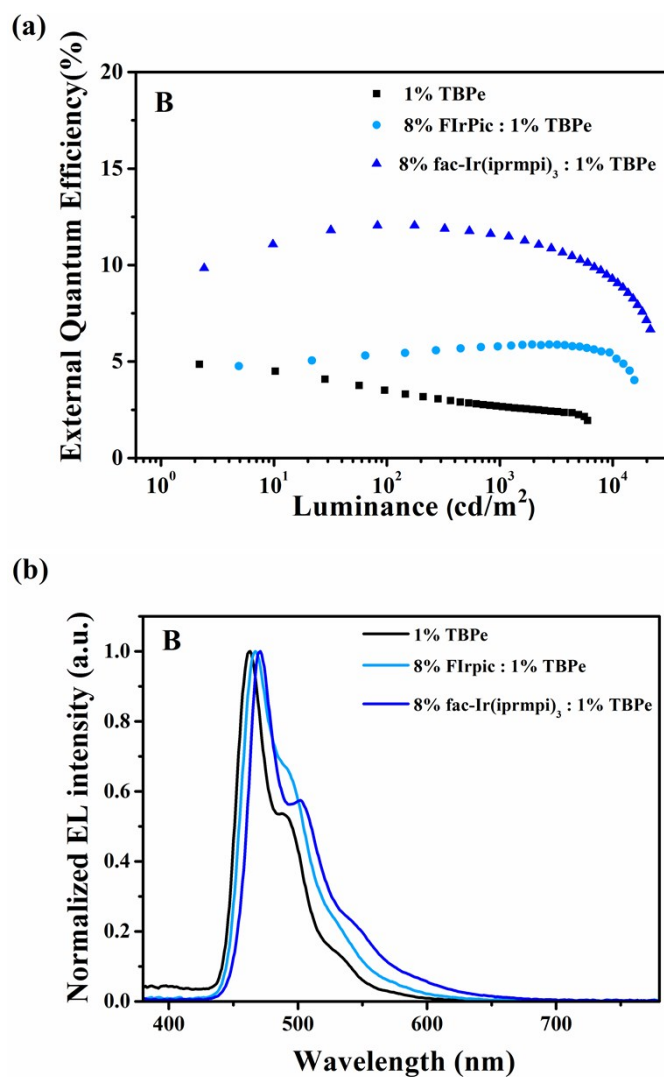


Fig. S7 (a) EQE-luminance characteristics of the blue OLEDs based on TBPe, FIrpic sensitized TBPe and fac-Ir(iprmpi)₃ sensitized TBPe. (b) EL spectra of the blue OLEDs based on TBPe, FIrpic sensitized TBPe and fac-Ir(iprmpi)₃ sensitized TBPe at 1000 cd m⁻². The structure of the blue OLED based on FIrpic sensitized TBPe is: ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (10 nm)/26DCzPPy:8 wt% FIrpic:1 wt% TBPe (20 nm)/TPBi (45 nm)/LiF (1 nm)/Al.

Table S1 EL performances of the blue OLEDs based on TBPe, FIrpic sensitized TBPe and fac-Ir(iprpmi)₃ sensitized TBPe.

Dopant	Voltage (V)		EQE (%)		CE (cd A ⁻¹)	
	Turn-on/1000/5000 cd m ⁻²	Max./1000/5000 cd m ⁻²	Max./1000/5000 cd m ⁻²	Max./1000/5000 cd m ⁻²	Max./1000/5000 cd m ⁻²	Max./1000/5000 cd m ⁻²
TBPe	3.8/6.8/9.4		4.9/2.7/2.1		6.5/3.4/2.7	
FIrpic+TBPe	4.4/6.0/7.8		5.9/5.8/5.8		9.7/9.5/9.6	
fac-Ir(iprpmi)₃+TBPe	3.6/5.2/6.4		12.1/11.5/10.3		23.9/22.9/20.5	

Supplementary Note 1 Estimation of Förster transfer radius

Förster transfer radius (R_0) was estimated from the overlap of PL spectrum of donor and the extinction spectrum of acceptor by using the follow equation:

$$R_0^6 = \frac{9000(\ln 10)\kappa^2\Phi_{PL}}{128\pi^5N_A n^4} \int_0^\infty F_D(\lambda)\varepsilon_A(\lambda)\lambda^4 d\lambda \quad (S1)$$

where λ is the wavelength, $F_D(\lambda)$ is the spectrum distribution of donor (measured in quanta and normalized to unity on a wavelength scale), $\varepsilon_A(\lambda)$ is the molar decadic extinction coefficient of acceptor, κ^2 is orientation factor, Φ_{PL} is the PL quantum yield of donor, N_A is Avogadro's number, n is the refractive index of the solvent.

Table S2 Förster transfer radii from hosts and phosphor sensitizers to fluorescent emitters in the resulting phosphor sensitized OLEDs.

EL color	Förster transfer radii ^a (nm)	Förster transfer radii ^b (nm)
Blue	6.06	3.88
Green	7.77	5.74
Yellow	6.37	6.07
Red	7.90	6.55

^{a)} Förster transfer radii from hosts to fluorescent emitters. ^{b)} Förster transfer radii from phosphor sensitizers to fluorescent emitters.

Supplementary Note 2 Structures of the single-carrier devices

The blue hole-only devices: ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (10 nm)/EMLs (20 nm)/TCTA (10 nm)/TAPC (60 nm)/HAT-CN (15 nm)/Al. EMLs are 26DCzPPy, 26DCzPPy:1 wt% TBPe, 26DCzPPy:8wt% fac-Ir(iprpmi)₃ and 26DCzPPy:8wt% fac-Ir(iprpmi)₃:1wt% TBPe.

The blue electron-only devices: ITO/LiF (1 nm)/TPBi (45 nm)/EMLs (20 nm)/TPBi (45 nm)/LiF (1 nm)/Al. EMLs are 26DCzPPy, 26DCzPPy:1 wt% TBPe, 26DCzPPy:8 wt% fac-Ir(iprpmi)₃ and 26DCzPPy:8 wt% fac-Ir(iprpmi)₃:1 wt% TBPe.

The green hole-only devices: ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (5 nm)/CDBP (5 nm)/EMLs (20 nm)/CDBP (5 nm)/TCTA (5 nm)/TAPC (60 nm)/HAT-CN (15 nm)/Al. EMLs are CDBP:PO-T2T, CDBP:PO-T2T:1 wt% TTPA, CDBP:PO-T2T:5 wt% Ir(mppy)₃ and CDBP:PO-T2T:5 wt% Ir(mppy)₃:1 wt% TTPA.

The green electron-only devices: ITO/LiF (1 nm)/PO-T2T (45 nm)/EMLs (20 nm)/PO-T2T (45 nm)/LiF (1 nm)/Al. EMLs are CDBP:PO-T2T, CDBP:PO-T2T:1 wt% TTPA, CDBP:PO-T2T:5 wt% Ir(mppy)₃ and CDBP:PO-T2T:5 wt% Ir(mppy)₃:1 wt% TTPA.

The yellow hole-only devices: ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (5 nm)/mCBP (5 nm)/EMLs (20 nm)/mCBP (5 nm)/TCTA (5 nm)/TAPC (60 nm)/HAT-CN (15 nm)/Al. EMLs are mCBP:PO-T2T, mCBP:PO-T2T:3 wt% TBRb, mCBP:PO-T2T:9 wt% Ir(ppy)₃ and mCBP:PO-T2T:9 wt% Ir(ppy)₃:3 wt% TBRb.

The yellow electron-only devices: ITO/LiF (1 nm)/PO-T2T (45 nm)/EMLs (20 nm)/PO-T2T (45 nm)/LiF (1 nm)/Al. EMLs are mCBP:PO-T2T, mCBP:PO-T2T:3 wt% TBRb, mCBP:PO-T2T:9 wt% Ir(ppy)₃ and mCBP:PO-T2T:9 wt% Ir(ppy)₃:3 wt% TBRb.

The red hole-only devices: ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (5 nm)/4P-NPB (8 nm)/EMLs (20 nm)/4P-NPB (8 nm)/TCTA (5 nm)/TAPC (60 nm)/HAT-CN (15 nm)/Al. EMLs are 4P-NPB:PO-T2T, 4P-NPB:PO-T2T:0.5 wt% DCJTb, 4P-NPB:PO-T2T:8 wt% Ir(tptpy)₂(acac) and 4P-NPB:PO-T2T:8 wt% Ir(tptpy)₂(acac):0.5 wt% DCJTb.

The red electron-only devices: ITO/LiF (1 nm)/PO-T2T (45 nm)/EMLs (20 nm)/PO-T2T (45 nm)/LiF (1 nm)/Al. EMLs are 4P-NPB:PO-T2T, 4P-NPB:PO-T2T:0.5 wt% DCJTb, 4P-NPB:PO-T2T:8 wt% Ir(tptpy)₂(acac) and 4P-NPB:PO-T2T:8 wt% Ir(tptpy)₂(acac):0.5 wt% DCJTb.