

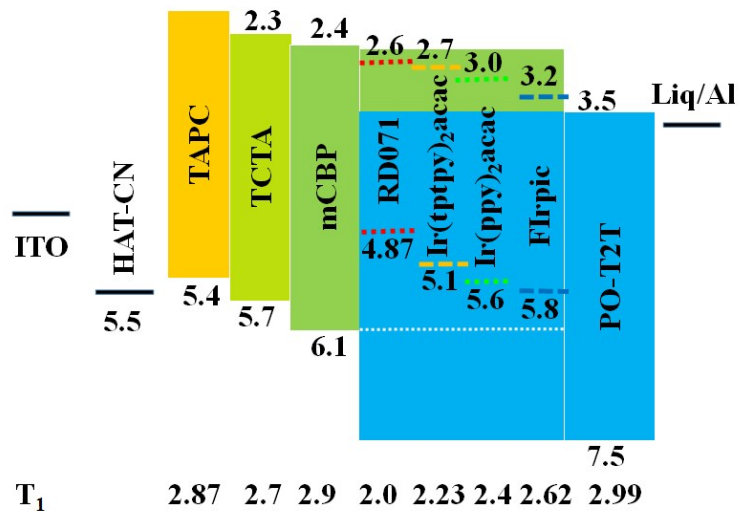
**Electronic Supplementary Information**

**Precise Regulation of Emissive Layer for Ultra-High Performance White  
Organic Light-Emitting Diodes in Exciplex Forming Co-host System**

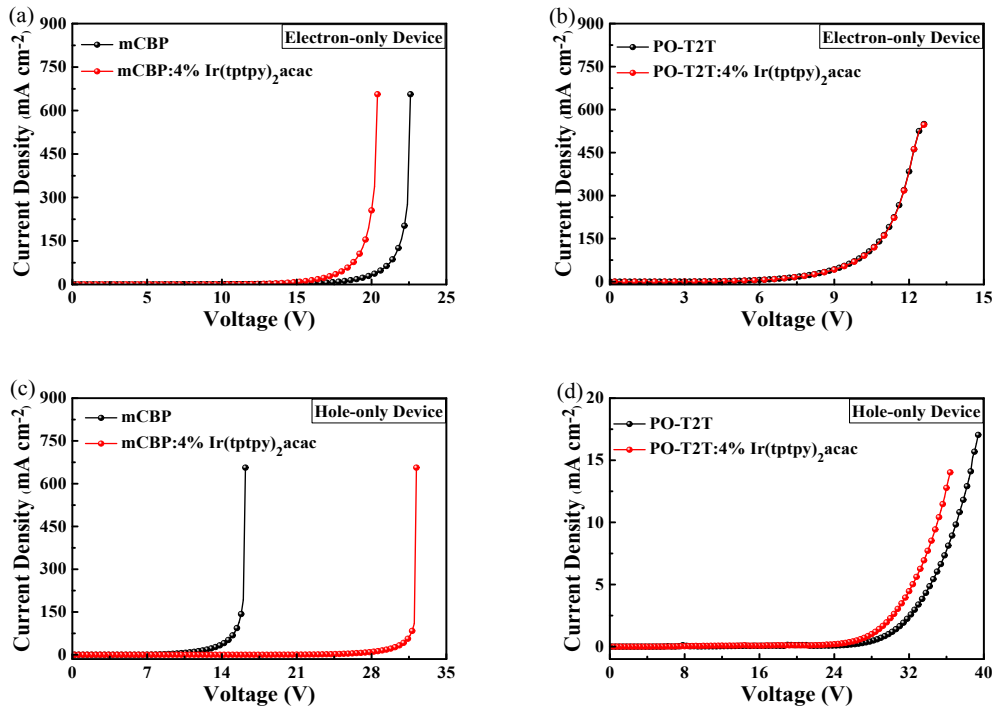
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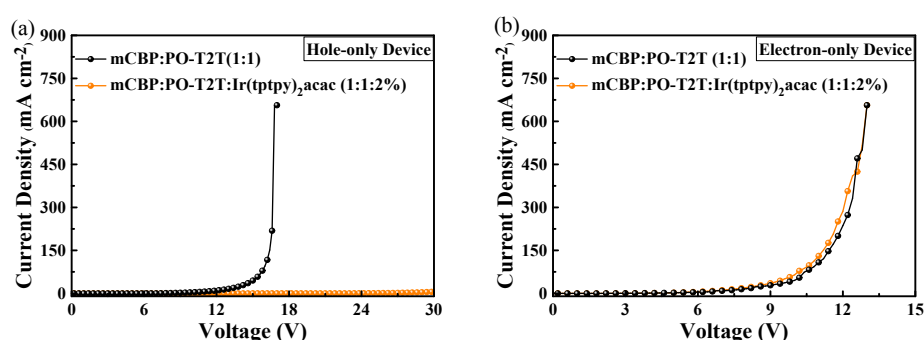


**Fig. S1.** Proposed energy levels of the organic materials used in our WOLEDs.

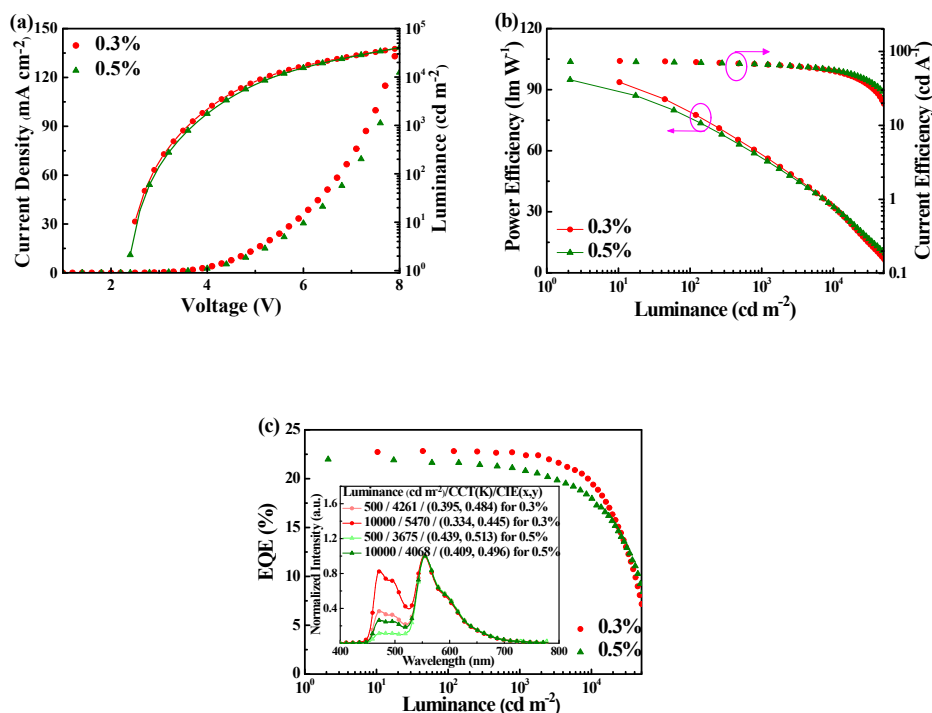


**Fig. S2.** Current density-voltage characteristics of electron-only devices based on orange dopant doped mCBP (a) and PO-T2T (b) host, and hole-only devices based on orange dopant doped mCBP (c) and PO-T2T (d) host. The hole-only device structure: ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP (6 nm) or mCBP: Ir(tppy)<sub>2</sub>acac (4%, 6 nm) / mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm) / mCBP (5 nm) / TCTA (5 nm) / TAPC (60 nm) / HAT-CN (15 nm) / Al (150 nm), and ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm) / PO-T2T (6 nm) or PO-T2T: Ir(tppy)<sub>2</sub>acac (4%, 6 nm) / mCBP (5 nm) / TCTA (5 nm) / TAPC (60 nm) / HAT-CN (15 nm) / Al (150 nm). The electron-only device structure: ITO / Liq (1.5 nm) / PO-T2T (45 nm) / mCBP (6 nm) or mCBP: Ir(tppy)<sub>2</sub>acac (4%, 6 nm) / mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm), and ITO / Liq (1.5

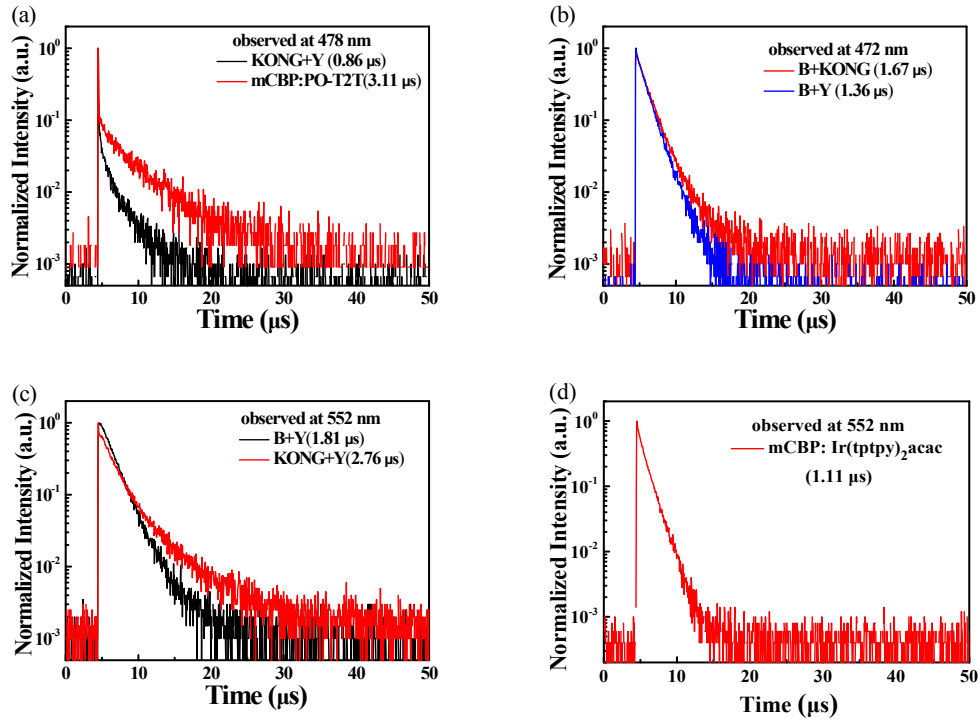
nm) / PO-T2T (45 nm) / mCBP: PO-T2T: Flrpic (1:1:10%, 12 nm) / PO-T2T (6 nm)  
 or PO-T2T: Ir(tppy)<sub>2</sub>acac (4%, 6 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm).



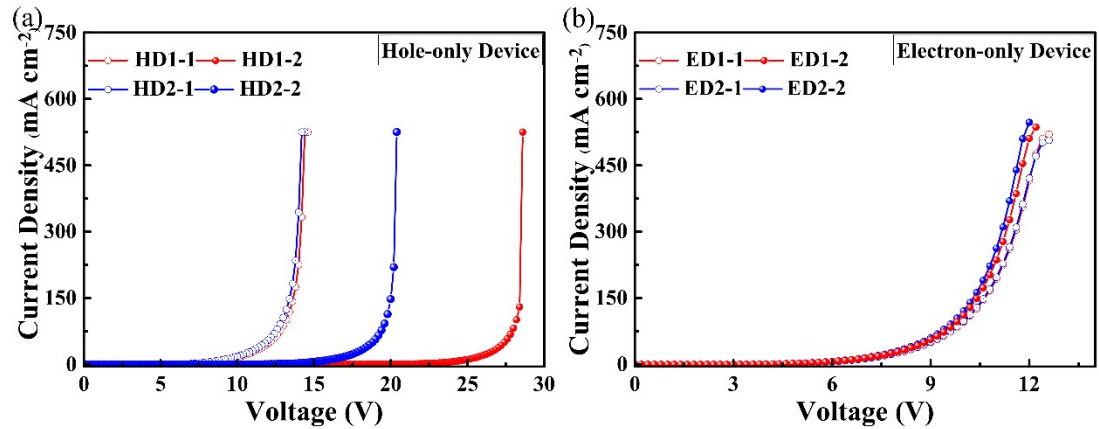
**Fig. S3.** Current density-voltage characteristics of hole-only (a) and electron-only (b) devices based on mCBP: PO-T2T exciplex and Ir(tppy)<sub>2</sub>acac doped mCBP: PO-T2T exciplex. The hole-only device structure: ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T (1:1, 15 nm) or mCBP: PO-T2T: Ir(tppy)<sub>2</sub>acac (1:1:2%, 15 nm) / mCBP (5 nm) / TCTA (5 nm) / TAPC (60 nm) / HAT-CN (15 nm) / Al (150 nm). The electron-only device structure: ITO / Liq (1.5 nm) / PO-T2T (45 nm) / mCBP: PO-T2T (1:1, 15 nm) or mCBP: PO-T2T: Ir(tppy)<sub>2</sub>acac (1:1:2%, 15 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm).



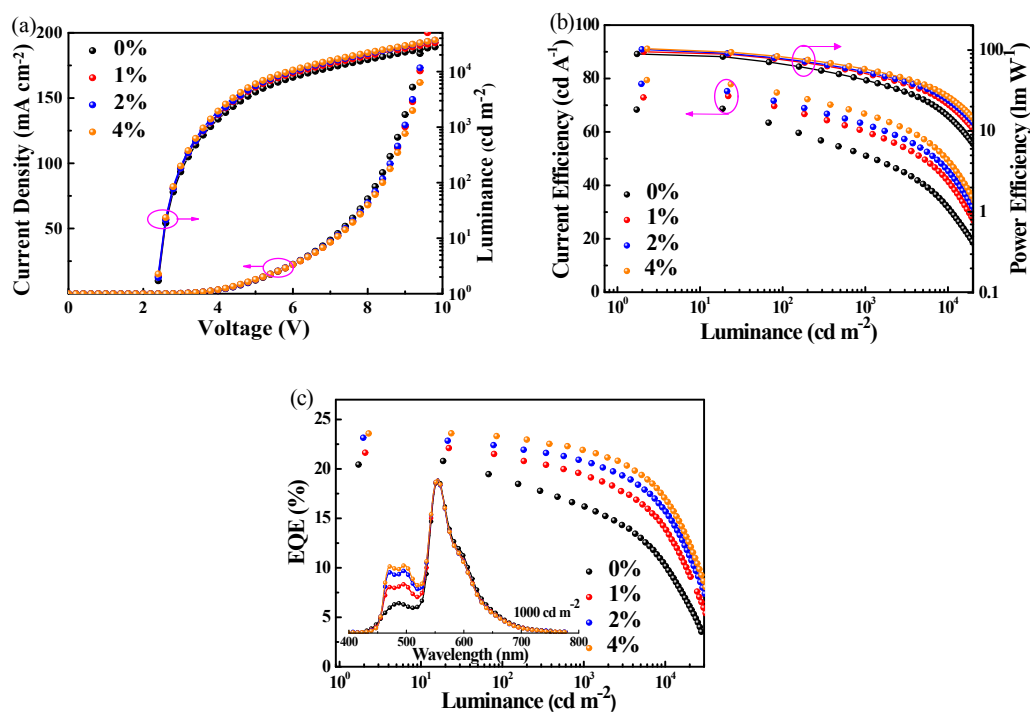
**Fig. S4.** EL performance of WOLEDs with the structure of ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T: FIrpic: Ir(tppy)<sub>2</sub>acac (1:1:10%:xxx, 15 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm) in different Ir(tppy)<sub>2</sub>acac concentrations of 0.3% and 0.5%. (a) Current density and luminance versus driving voltage characteristics. (b) Current efficiency and power efficiency versus luminance characteristics. (c) EQE versus luminance characteristics. Inset: EL spectra of WOLEDs at the luminance of 500 and 10000 cd m<sup>-2</sup>.



**Fig. S5.** PL decay curves of the different films measured at 478 nm (a), 478 nm (b) and 552 nm (c), (d), respectively, with an excitation wavelength of 340 nm. The film structure of KONG+Y is mCBP: PO-T2T (1:1, 12 nm) / mCBP: PO-T2T: Ir(tptpy)<sub>2</sub>acac (1:1:1%, 6 nm). The film structure of mCBP: PO-T2T is mCBP: PO-T2T (1:1, 30 nm). The film structure of B+KONG is mCBP: PO-T2T: FIrpc (1:1:10%, 12 nm) / mCBP: PO-T2T (1:1, 6 nm). The film structure of B+Y is mCBP: PO-T2T: FIrpc (1:1:10%, 12 nm) / mCBP: PO-T2T: Ir(tptpy)<sub>2</sub>acac (1:1:1%, 6 nm). The film structure of mCBP: Ir(tptpy)<sub>2</sub>acac is mCBP: Ir(tptpy)<sub>2</sub>acac (3%, 20 nm).



**Fig. S6.** Current density-voltage characteristics of hole-only devices (a) and electron-only devices (b). The hole-only device structure: ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / XXX / mCBP (5 nm) / TCTA (5 nm) / TAPC (60 nm) / HAT-CN (15 nm) / Al (150 nm). The electron-only device structure: ITO / Liq (1.5 nm) / PO-T2T (45 nm) / XXX / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm). HD1-1 and ED1-1: mCBP: PO-T2T (1:1, 6 nm) / mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm). HD1-2 and ED1-2: mCBP: PO-T2T: Ir(tp<sub>2</sub>py)<sub>2</sub>acac (1:1:1%, 6 nm) / mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm). HD2-1 and ED2-1: mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm) / mCBP: PO-T2T (1:1, 6 nm). HD2-2 and ED2-2: mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm) / mCBP: PO-T2T: Ir(tp<sub>2</sub>py)<sub>2</sub>acac (1:1:1%, 6 nm).



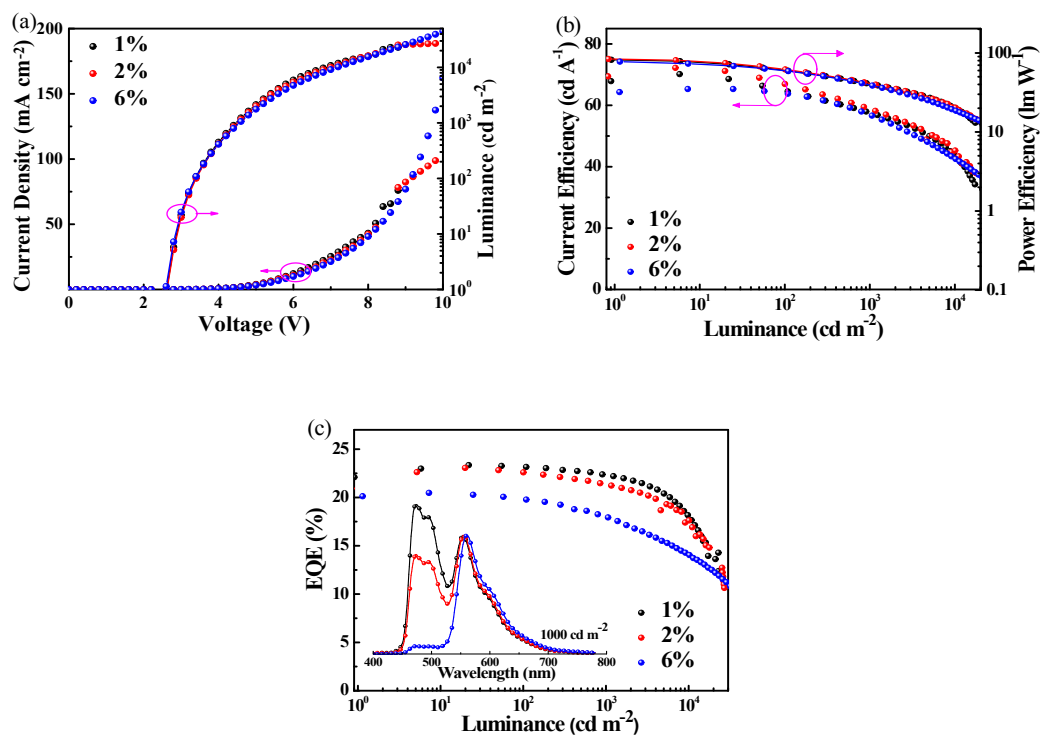
**Fig. S7.** EL performance of WOLEDs with the structure of ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T: FIrpic (1:1:XXX, 12 nm) / mCBP: PO-T2T: Ir(tp<sub>2</sub>py)<sub>2</sub>acac (1:1:1%, 6 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm) in different concentrations of FIrpic from 0 to 4%. (a) Current density and luminance versus driving voltage characteristics. (b) Current efficiency and power efficiency versus luminance characteristics. (c) EQE versus luminance characteristics. Inset: EL spectra of WOLEDs at the luminance of 1000 cd m<sup>-2</sup>.



**Table S1.** Summary of key EL parameters for white devices with different concentrations of FIrpic.

<b>FIrpic concentration</b>	<b>V<sub>on</sub><sup>a</sup></b> [V]	<b>PE<sub>max/1000</sub><sup>b</sup></b> [lm W <sup>-1</sup> ]	<b>CE<sub>max/1000</sub><sup>b</sup></b> [cd A <sup>-1</sup> ]	<b>EQE<sub>max/1000</sub><sup>b</sup></b> [%]	<b>Roll-off<sub>1000</sub><sup>c</sup></b>	<b>CCT<sup>c</sup></b> [K]	<b>CIE(x, y)<sup>c</sup></b>	<b>CRI<sup>c</sup></b>
<b>0</b>	2.4	89.4/42.2	68.7/51.2	20.8/16.2	22.1%	3994	(0.414, 0.498)	44
<b>1%</b>	2.4	95.4/51.5	72.9/60.2	22.1/19.4	12.2%	4428	(0.387, 0.490)	46
<b>2%</b>	2.4	102.0/54.4	78.0/62.8	23.2/20.8	10.3%	4766	(0.368, 0.480)	48
<b>4%</b>	2.4	103.9/58.0	79.4/66.7	23.9/21.9	8.4%	4785	(0.367, 0.481)	48

<sup>a</sup> At a luminance of 1 cd m<sup>-2</sup>; <sup>b</sup> The maximum efficiencies and values taken at 1000 cd m<sup>-2</sup>; <sup>c</sup> Measured at 1000 cd m<sup>-2</sup>.

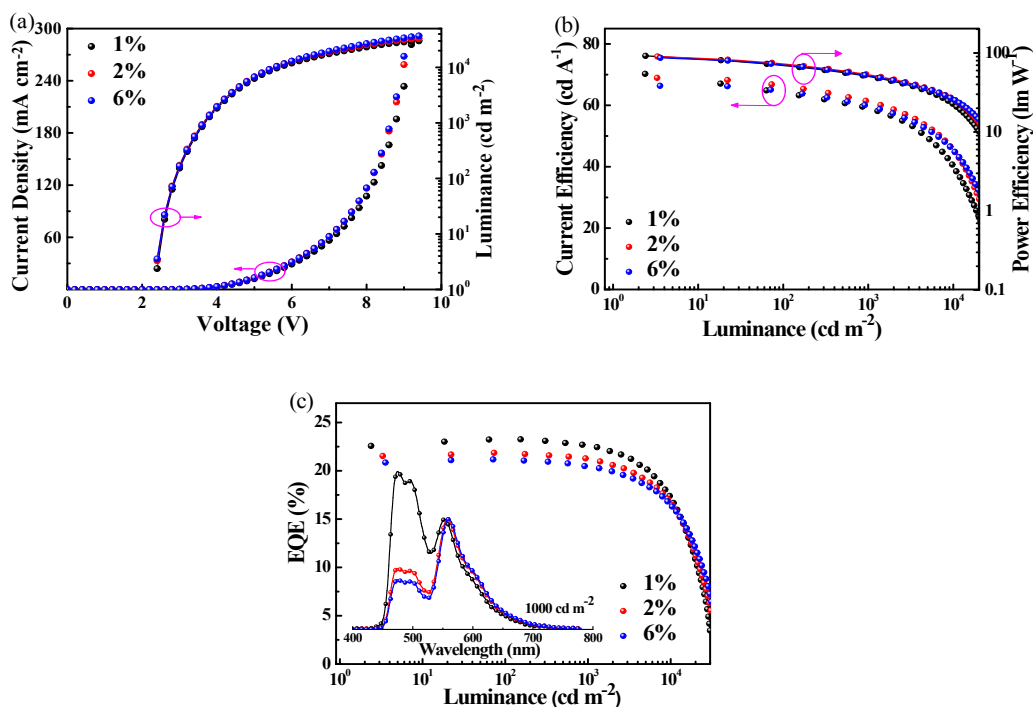


**Fig. S8.** EL performance of WOLEDs with the structure of ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP:Ir(tptpy)<sub>2</sub>acac (XXX, 6 nm) / mCBP: PO-T2T: Flrpic (1:1:10%, 12 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm) in different concentrations of Ir(tptpy)<sub>2</sub>acac from 1% to 6%. (a) Current density and luminance versus driving voltage characteristics. (b) Current efficiency and power efficiency versus luminance characteristics. (c) EQE versus luminance characteristics. Inset: EL spectra of WOLEDs at the luminance of 1000 cd m<sup>-2</sup>.

**Table S2.** Summary of key EL parameters for white devices with different concentrations of Ir(tptpy)<sub>2</sub>acac in mCBP host.

<b>Ir(tptpy)<sub>2</sub>acac concentration</b>	<b>V<sub>on</sub><sup>a</sup></b> [V]	<b>PE<sub>max/1000</sub><sup>b</sup></b> [lm W <sup>-1</sup> ]	<b>CE<sub>max/1000</sub><sup>b</sup></b> [cd A <sup>-1</sup> ]	<b>EQE<sub>max/1000</sub><sup>b</sup></b> [%]	<b>Roll-off<sub>1000</sub><sup>c</sup></b>	<b>CCT<sup>c</sup></b> [K]	<b>CIE(x, y)<sup>c</sup></b>	<b>CRI<sup>c</sup></b>
<b>1%</b>	2.4	81.9/38.9	70.2/56.8	23.3/22.2	4.7%	6725	(0.293, 0.424)	53
<b>2%</b>	2.4	83.8/39.7	72.2/58.2	23.1/21.2	8.2%	5544	(0.332, 0.448)	53
<b>6%</b>	2.4	77.6/38.7	65.3/65.7	20.5/17.9	12.7%	3248	(0.466, 0.505)	37

<sup>a</sup> At a luminance of 1 cd m<sup>-2</sup>; <sup>b</sup> The maximum efficiencies and values taken at 1000 cd m<sup>-2</sup>; <sup>c</sup> Measured at 1000 cd m<sup>-2</sup>.

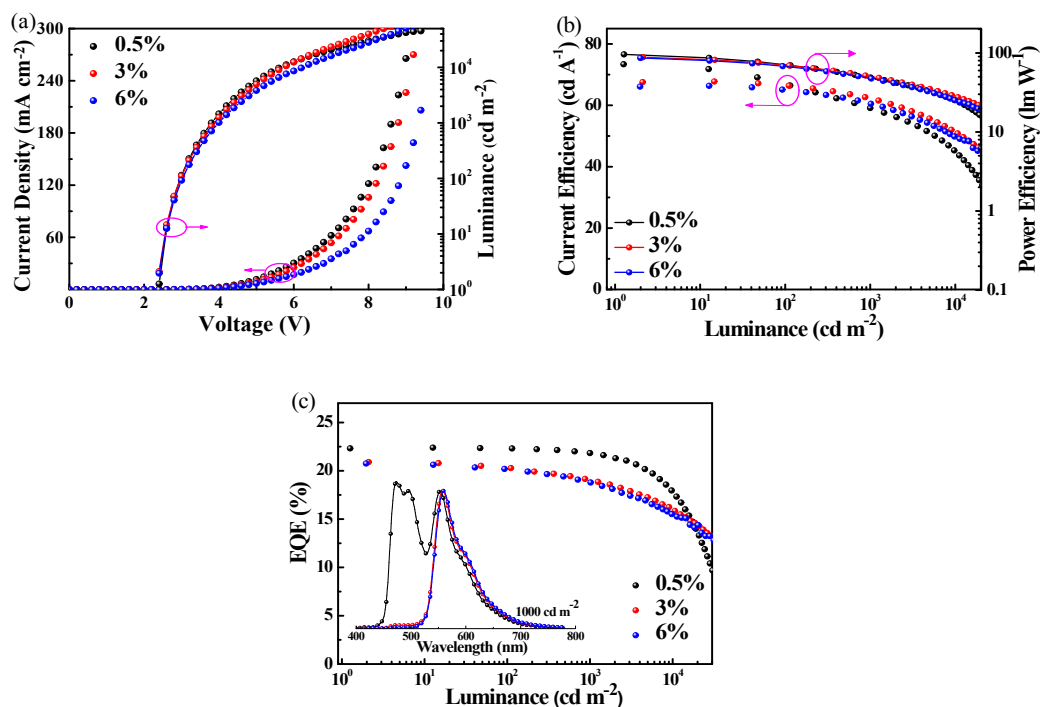


**Fig. S9.** EL performance of WOLEDs with the structure of ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T: FIrpic (1:1:10%, 12 nm) / PO-T2T: Ir(tppy)<sub>2</sub>acac (XXX, 6 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm) in different concentrations of Ir(tppy)<sub>2</sub>acac from 1% to 6%. (a) Current density and luminance versus driving voltage characteristics. (b) Current efficiency and power efficiency versus luminance characteristics. (c) EQE versus luminance characteristics. Inset: EL spectra of WOLEDs at the luminance of 1000 cd m<sup>-2</sup>.

**Table S3.** Summary of key EL parameters for white devices with different concentrations of Ir(tp<sub>2</sub>py)<sub>2</sub>acac in PO-T2T host.

Ir(tp <sub>2</sub> py) <sub>2</sub> acac concentration	V <sub>on</sub> <sup>a</sup>	PE <sub>max/1000</sub> <sup>b</sup>	CE <sub>max/1000</sub> <sup>b</sup>	EQE <sub>max/1000</sub> <sup>b</sup>	Roll-off <sub>1000</sub> <sup>c</sup>	CCT <sup>c</sup>	CIE(x, y) <sup>c</sup>	CRI <sup>c</sup>
	[V]	[lm W <sup>-1</sup> ]	[cd A <sup>-1</sup> ]	[%]		[K]		
<b>0</b>	2.4	91.9/48.5	70.3/58.2	23.3/22.5	3.4%	7183	(0.278, 0.427)	49
<b>1%</b>	2.4	90.2/51.6	68.9/60.7	21.9/21.2	3.2%	5349	(0.340, 0.457)	53
<b>4%</b>	2.4	86.8/51.4	66.4/59.7	21.1/20.4	3.3%	4305	(0.390, 0.474)	51

<sup>a</sup> At a luminance of 1 cd m<sup>-2</sup>; <sup>b</sup> The maximum efficiencies and values taken at 1000 cd m<sup>-2</sup>; <sup>c</sup> Measured at 1000 cd m<sup>-2</sup>.

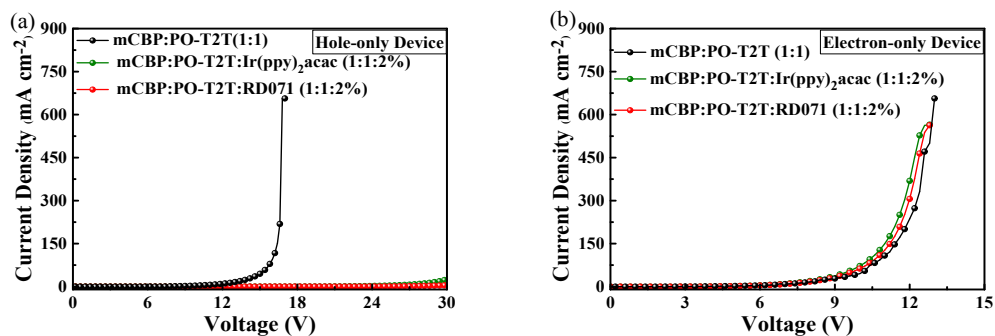


**Fig. S10.** EL performance of WOLEDs with the structure of ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T: Ir(tppy)<sub>2</sub>acac (1:1:XXX, 6 nm) / mCBP: PO-T2T: Flpic (1:1:10%, 12 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm) in different concentrations of Ir(tppy)<sub>2</sub>acac from 0.5% to 6%. (a) Current density and luminance versus driving voltage characteristics. (b) Current efficiency and power efficiency versus luminance characteristics. (c) EQE versus luminance characteristics. Inset: EL spectra of WOLEDs at the luminance of 1000 cd m<sup>-2</sup>.

**Table S4.** Summary of key EL parameters for white devices with different concentrations of Ir(tp<sub>2</sub>py)<sub>2</sub>acac in mCBP: PO-T2T host.

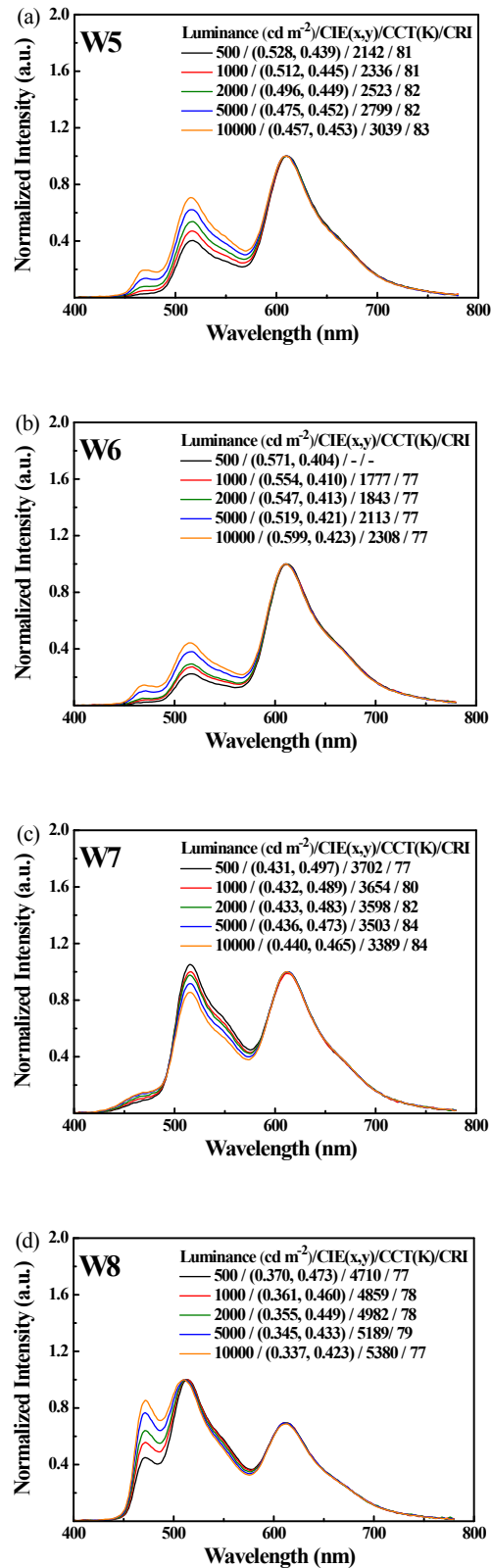
<b>Ir(tp<sub>2</sub>py)<sub>2</sub>acac concentration</b>	<b>V<sub>on</sub><sup>a</sup></b> [V]	<b>PE<sub>max/1000</sub><sup>b</sup></b> [lm W <sup>-1</sup> ]	<b>CE<sub>max/1000</sub><sup>b</sup></b> [cd A <sup>-1</sup> ]	<b>EQE<sub>max/1000</sub><sup>b</sup></b> [%]	<b>Roll-off<sub>1000</sub></b>	<b>CCT<sup>c</sup></b> [K]	<b>CIE(x, y)<sup>c</sup></b>	<b>CRI<sup>c</sup></b>
<b>0.5%</b>	2.4	96.0/48.8	73.4/59.1	22.4/21.8	2.7%	6333	(0.303, 0.438)	52
<b>3%</b>	2.4	88.4/49.8	67.8/62.1	20.9/19.0	9.1%	3315	0.467, 0.519)	34
<b>4%</b>	2.4	86.5/47.5	66.1/60.5	20.8/18.8	9.6%	3160	(0.477, 0.515)	32

<sup>a</sup> At a luminance of 1 cd m<sup>-2</sup>; <sup>b</sup> The maximum efficiencies and values taken at 1000 cd m<sup>-2</sup>; <sup>c</sup> Measured at 1000 cd m<sup>-2</sup>.



**Fig. S11.** Current density-voltage characteristics of hole-only (a) and electron-only (b) devices based on mCBP: PO-T2T exciplex host at different phosphors doping. The hole-only device structure: ITO / HAT-CN (15 nm) / TAPC (60 nm) / TCTA (5 nm) / mCBP (5 nm) / mCBP: PO-T2T (1:1, 15 nm) or mCBP: PO-T2T: Ir(ppy)<sub>2</sub>acac (1:1:2%, 15 nm) or mCBP: PO-T2T:RD071 (1:1:2%, 15 nm) / mCBP (5 nm) / TCTA (5 nm) / TAPC (60 nm) / HAT-CN (15 nm) / Al (150 nm). The electron-only device structure: ITO / Liq (1.5 nm) / PO-T2T (45 nm) / mCBP: PO-T2T (1:1, 15 nm) or mCBP: PO-T2T: Ir(ppy)<sub>2</sub>acac (1:1:2%, 15 nm) or mCBP: PO-T2T:RD071 (1:1:2%, 15 nm) / PO-T2T (45 nm) / Liq (1.5 nm) / Al (150 nm).





**Fig. S12.** EL spectra of three-color WOLEDs (W5-8) at different luminance from 500 to 10000 cd m<sup>-2</sup>.

**Table S5.** Summary of key EL parameters for three-color white devices.

Three-color device	$V_{on}$ <sup>a</sup>	$PE_{max/1000}$ <sup>b</sup>	$CE_{max/1000}$ <sup>b</sup>	$EQE_{max/1000}$ <sup>b</sup>	Roll-off <sub>1000</sub>	$CCT$ <sup>c</sup>	$CIE(x, y)$ <sup>c</sup>	CRI <sup>c</sup>
	[V]	[lm W <sup>-1</sup> ]	[cd A <sup>-1</sup> ]	[%]		[K]		
<b>W5</b>	2.4	44.3/32.4	40.2/39.2	21.8/19.7	9.6%	2336	(0.512,0.445)	81
<b>W6</b>	2.4	39.2/27.2	34.3/33.3	22.0/19.4	11.8%	1777	(0.554,0.410)	77
<b>W7</b>	2.4	63.0/35.1	52.2/42.2	22.0/17.9	18.6%	3654	(0.432,0.489)	80
<b>W8</b>	2.4	69.6/41.2	55.9/50.3	23.4/22.1	5.6%	4859	(0.361,0.460)	78

<sup>a</sup> At a luminance of 1 cd m<sup>-2</sup>; <sup>b</sup> The maximum efficiencies and values taken at 1000 cd m<sup>-2</sup>; <sup>c</sup> Measured at 1000 cd m<sup>-2</sup>.