

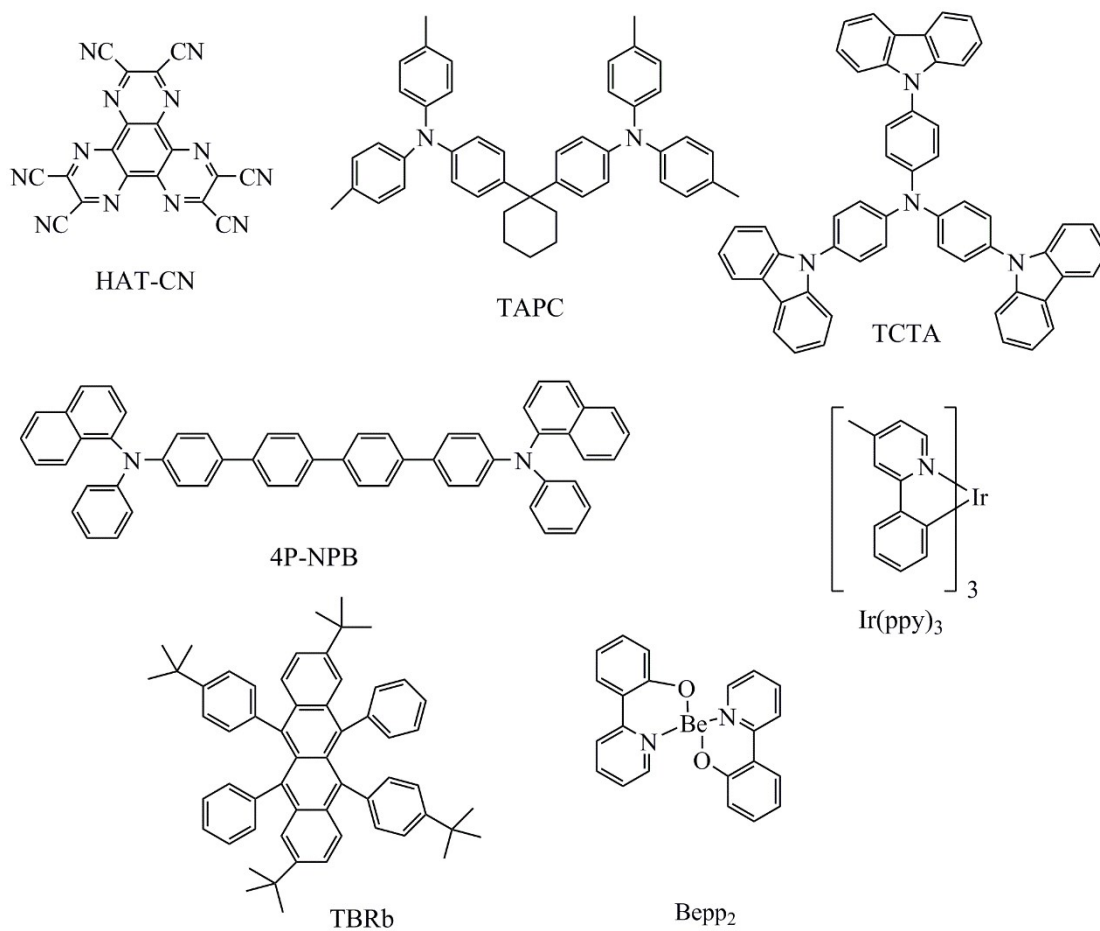
## **High efficiency and long lifetime fluorescent white organic light-emitting diodes by phosphor sensitization to strategically manage singlet and triplet excitons**

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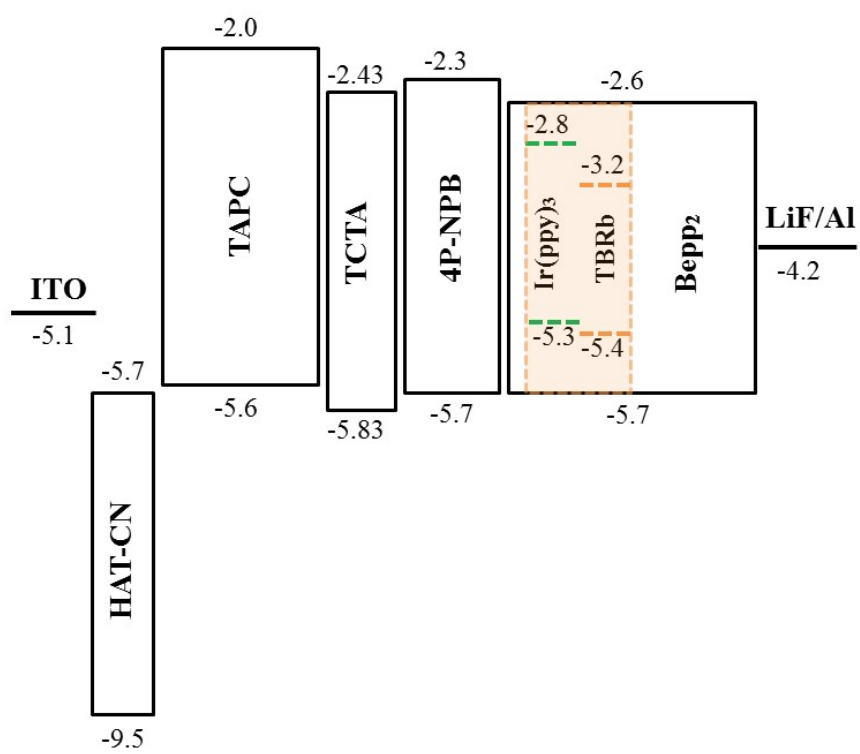
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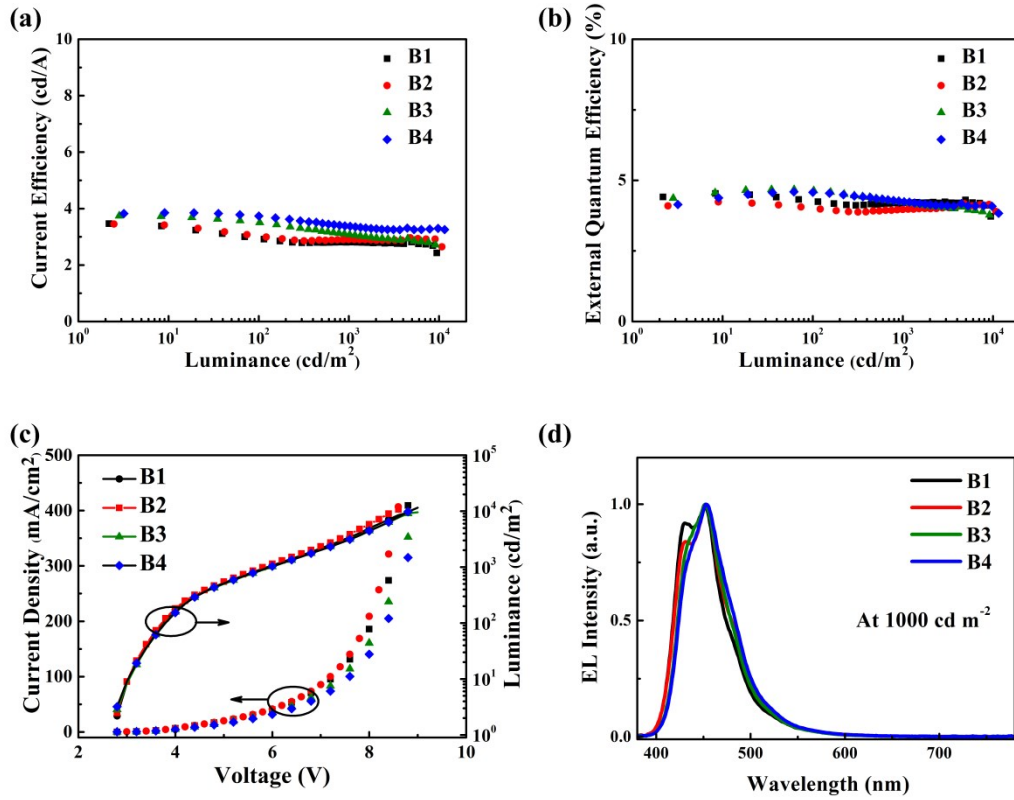
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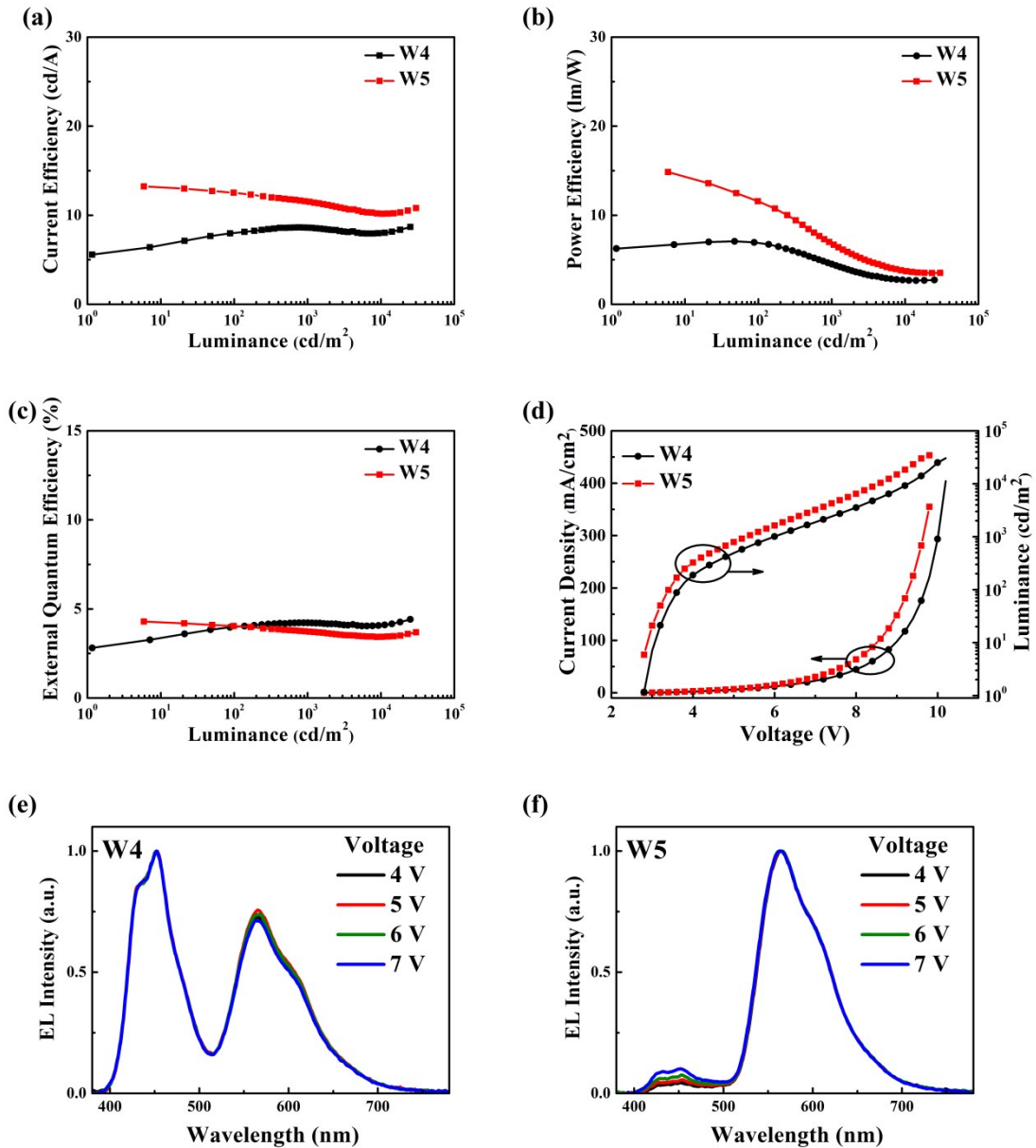
**Fig. S1** Molecular structures of the materials used in this work.



**Fig. S2** Proposed energy level diagram of the resulting fluorescent WOLEDs.



**Fig. S3** EL performances of the resulting blue OLEDs with different EML structures. (a) CE-luminance characteristics. (b) EQE-luminance characteristics. (c) Current density-luminance-voltage characteristics. (d) EL spectra at the luminance of 1000 cd m<sup>-2</sup>. The device structures are ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (10 nm)/EMLs (X nm)/Bepp<sub>2</sub> (50 nm)/LiF (1 nm)/Al, where EMLs are 4P-NPB (10 nm), 4P-NPB (15 nm), 4P-NPB:Bepp<sub>2</sub> (1:1, 10 nm) and 4P-NPB:Bepp<sub>2</sub> (1:1, 15 nm), corresponding to devices B1, B2, B3 and B4, respectively.

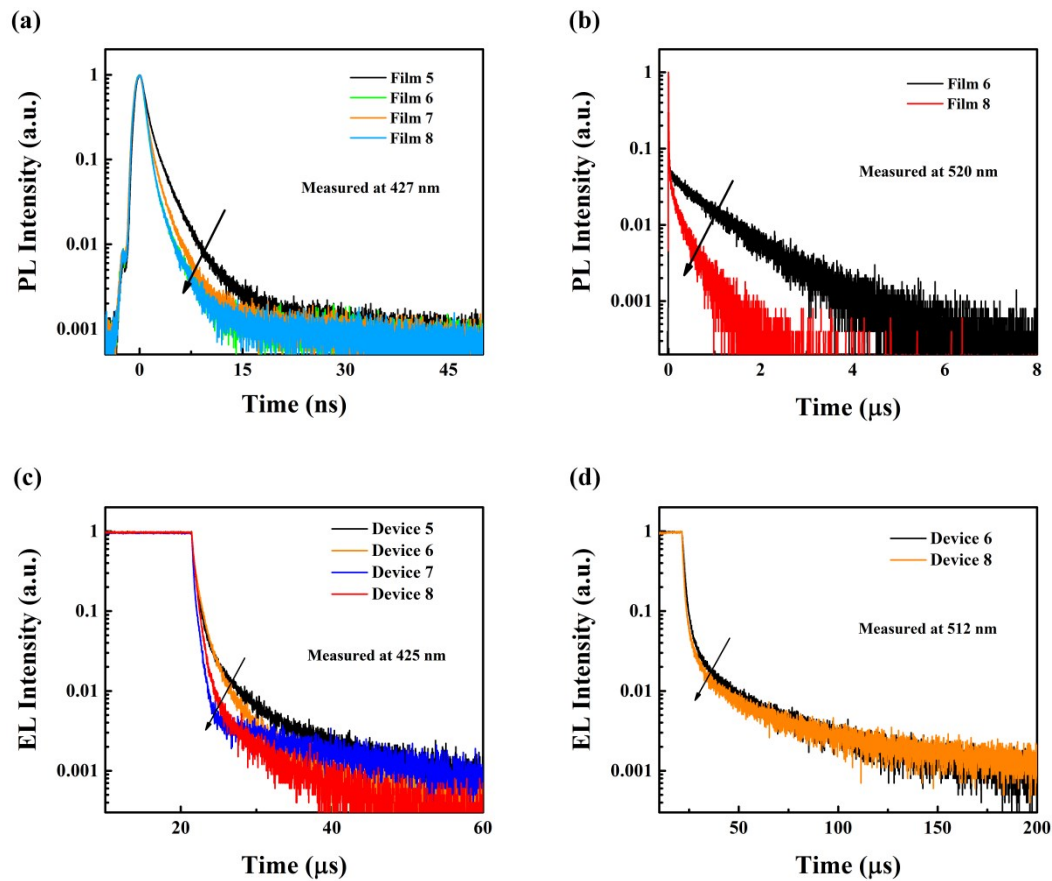


**Fig. S4** EL performances of the comparing WOLEDs (devices W4 and W5) with different EML structures. (a) CE-luminance characteristics. (b) PE-luminance characteristics. (c) EQE-luminance characteristics. (d) Current density-luminance-voltage characteristics. (e) EL spectra of device W4 at different voltages. (f) EL spectra of device W5 at different voltages. The device structures are ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (10 nm)/EMLs (X nm)/Bepp<sub>2</sub> (50 nm)/LiF (1 nm)/Al, where EMLs are 4P-NPB (6 nm)/4P-NPB:6%Ir(ppy)<sub>3</sub>:2%TBRb (3 nm)/4P-NPB (5 nm) and 4P-NPB (8 nm)/4P-NPB:6%Ir(ppy)<sub>3</sub>:2%TBRb (3 nm), corresponding to devices W4 and W5, respectively.

**Table S1.** Summary of the EL performances of the resulting blue and white OLEDs.

Device	$V_{on}^{a)}$ (V)	Max CE <sup>b)</sup> ( $cd A^{-1}$ )	Max PE <sup>b)</sup> ( $lm W^{-1}$ )	Max EQE <sup>b)</sup> (%)	CIE <sup>c)</sup> (x, y)	Performance at the luminance of 1000/5000 $cd m^{-2}$		
						CE ( $cd A^{-1}$ )	PE ( $lm W^{-1}$ )	EQE (%)
B1	2.8	3.5	3.9	4.5	(0.15, 0.07)	2.8/2.7	1.5/1.1	4.2/4.2
B2	2.8	3.5	3.9	4.2	(0.15, 0.08)	2.9/2.9	1.5/1.2	4.0/4.1
B3	2.8	3.7	4.2	4.7	(0.15, 0.08)	3.1/2.9	1.6/1.1	4.2/4.0
B4	2.8	3.9	4.3	4.6	(0.15, 0.09)	3.4/3.3	1.8/1.2	4.2/4.1
W4	2.8	8.6	4.5	4.2	(0.31, 0.28)	8.6/8.0	4.5/2.9	4.2/4.0
W5	2.8	13.2	14.8	4.3	(0.46, 0.49)	11.5/10.4	6.7/4.2	3.7/3.5

<sup>a)</sup> The voltages estimated at 1  $cd m^{-2}$ , <sup>b)</sup> CE, PE and EQE correspond to current efficiency, power efficiency and external quantum efficiency, <sup>c)</sup> Commission International de L'clairage (CIE) measured at the luminance of 1000  $cd m^{-2}$ .



**Fig. S5** (a) Transient PL decay characteristics of films 5, 6, 7 and 8 at the 4P-NPB/Bepp<sub>2</sub> PL emission wavelength of 427 nm. (b) Transient PL decay characteristics of films 6 and 8 at the Ir(ppy)<sub>3</sub> phosphor sensitizer PL emission wavelength of 520 nm. (c) Transient EL decay characteristics of devices 5, 6, 7 and 8 at 4P-NPB/Bepp<sub>2</sub> EL emission wavelength of 425 nm. (f) Transient EL decay characteristics of devices 6 and 8 at Ir(ppy)<sub>3</sub> phosphor sensitizer EL emission wavelength of 512 nm. The film structures are 4P-NPB (8 nm)/Bepp<sub>2</sub> (5 nm)/ X (5 nm)/ Bepp<sub>2</sub> (10 nm), where X are Bepp<sub>2</sub>, Bepp<sub>2</sub>:6%Ir(ppy)<sub>3</sub>, Bepp<sub>2</sub>:2%TBRb and Bepp<sub>2</sub>:6%Ir(ppy)<sub>3</sub>:2%TBRb corresponding to films 5, 6, 7 and 8, respectively. The device structures are ITO/HAT-CN (15 nm)/TAPC (60 nm)/TCTA (5 nm)/4P-NPB (8 nm)/Bepp<sub>2</sub> (5 nm)/ Y (5 nm)/Bepp<sub>2</sub> (40 nm)/LiF (1 nm)/Al, where Y are Bepp<sub>2</sub>, Bepp<sub>2</sub>:6%Ir(ppy)<sub>3</sub>, Bepp<sub>2</sub>:2%TBRb and Bepp<sub>2</sub>:6%Ir(ppy)<sub>3</sub>:2%TBRb, corresponding to devices 5, 6, 7 and 8, respectively.

## 1. Calculation of Förster energy transfer (FET)

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

Where  $R_0$  is the Förster energy transfer radius,  $\kappa^2$  is the orientation factor usually assuming to be 2/3,  $n$  is the refractive index about 1.7,  $\Phi_D$  is the PLQY of donor,  $N_A$  is the Avogadro's number, and

$\int_0^\infty F_D(\lambda)\varepsilon_A(\lambda)\lambda^4 d\lambda$  is the spectral overlap integral between the PL spectrum of host and the absorption spectrum of guest.

$$K_{ET} = \frac{1}{\tau_D} \left( \frac{R_0}{R_{DA}} \right)^6 \quad (S2)$$

$$\eta_{ET} = \frac{K_{ET}}{K_{ET} + \frac{1}{\tau_D}} = \frac{1}{1 + \left( \frac{R_0}{R_{DA}} \right)^6} \quad (S3)$$

Where  $\tau_D$  is the decay lifetime of host without the guest,  $R_0$  is the Förster energy transfer radius and  $R_{DA}$  is the distant between host and guest. And  $R_{DA}$  can be calculated by using:

$$R_{DA} = \left( N_G \times \frac{4\pi}{3} \right)^{-\frac{1}{3}} \quad (S4)$$

$$N_G = \beta \times \rho \times N_A / M_C \quad (S5)$$

Where  $N_G$  is the quantity of guest material in a unit volume,  $\beta$  is the fraction of the guest material,  $\rho$  is the density of the film assuming to be 1 g cm<sup>-3</sup>,  $N_A$  is the Avogadro's number and  $M_C$  is the molecular weight of the guest material.

## 2. Calculation of Dexter energy transfer rate constant (DXT)

$$K_{DT} = \frac{2\pi}{h} C^2 J e^{-2R_{DA}/L} \quad (S6)$$

Where C is a constant in the units of energy,  $R_{DA}$  is the intermolecular distance between host and guest and L is their van der Waals radii.