Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Electronic Supplementary Information

High Efficiency Warm White Organic Light-Emitting Diodes with Precise Confinement of Charge Carriers and Excitons in Exciplex Host System

Shian Ying, Jiakun, Yuan, Shuai, Zhang, Qian Sun, Yanfeng Dai, Xianfeng Qiao, Dezhi Yang, Jiangshan Chen, and Dongge Ma*

Center for Aggregation-Induced Emission
Institute of Polymer Optoelectronic Materials and Devices, State Key Laboratory of Luminescent Materials and Devices, South China University of Technology, Guangzhou 510640, People's Republic of China
*E-mail: msdgma@scut.edu.cn

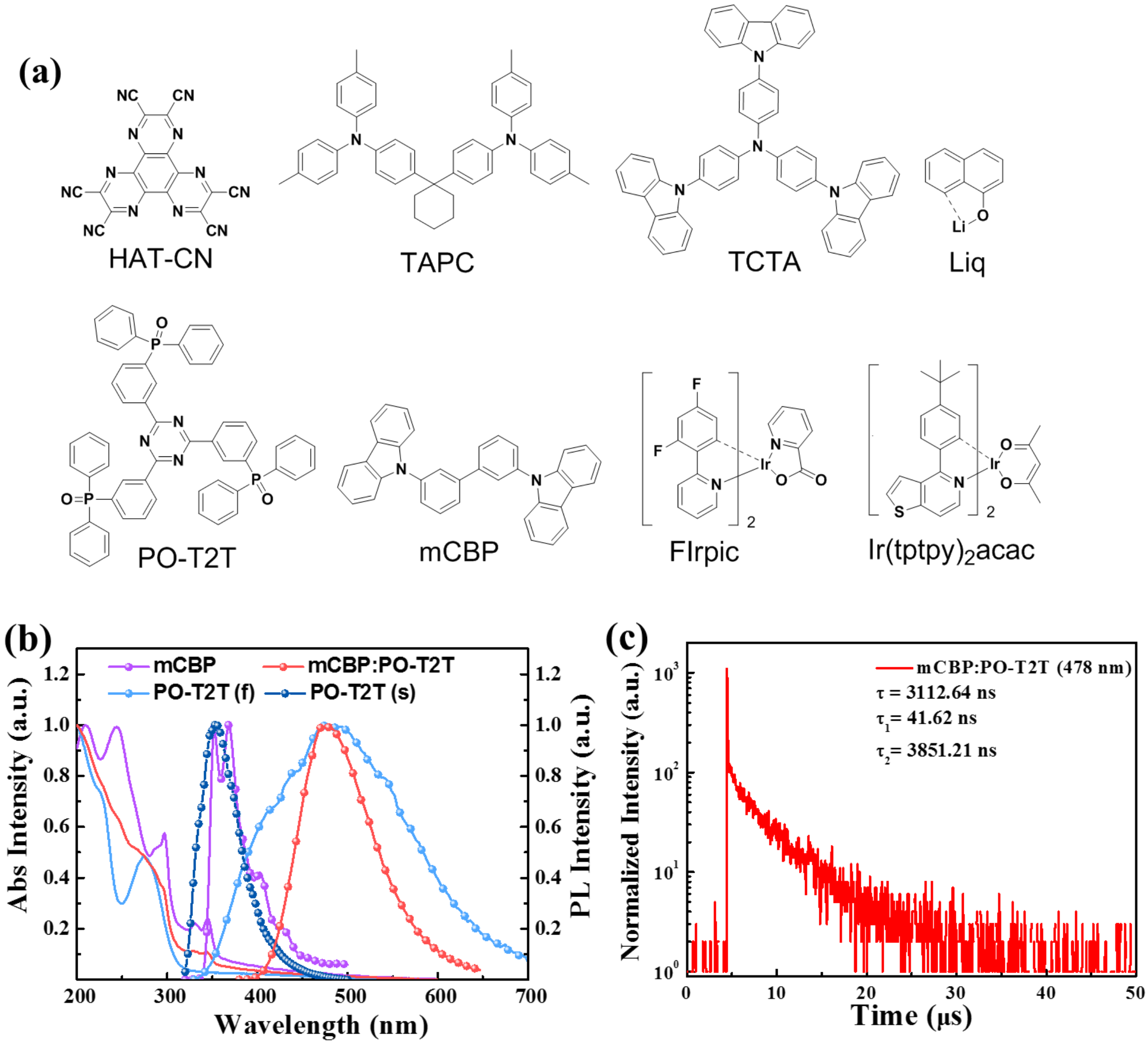

Fig. S1. (a) Molecular structures of the organic materials used in this work. (b) UV-vis absorption spectra and PL spectra of mCBP (in film), PO-T2T (in dichloromethane and film) and mCBP: PO-T2T (in film). (c) Transient PL decay of the mCBP: PO-T2T mixed film at 478 nm with 340 nm excitation under ambient atmosphere.

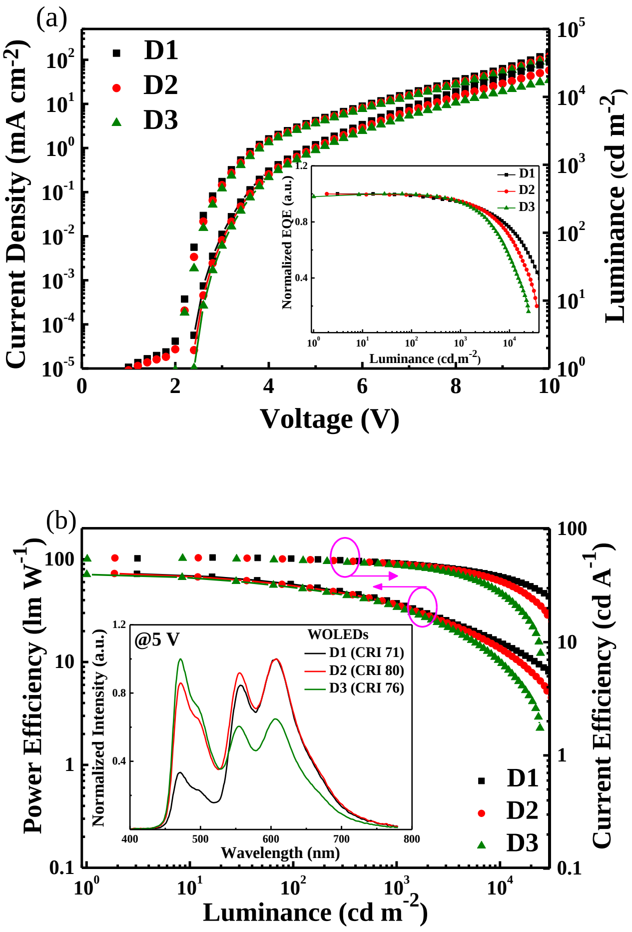

Fig. S2. (a) Current density and luminance versus voltage characteristics of devices D1-D3. Insert: Normalized external quantum efficiency versus luminance characteristics of devices D1-D3. (b) Current efficiency and power efficiency versus luminance characteristics of devices D1-D3. Insert: EL spectra and CRI of devices D1-D3 at 5 V. ITO/ HAT-CN (15 nm)/ TAPC (60 nm)/ TCTA (5 nm)/ mCBP (5 nm)/ mCBP: PO-T2T: FIrpic (x:y:10%, 5 nm)/ mCBP: PO-T2T: Ir(tptpy)$_2$acac (1:1:1.5%, 3 nm)/ mCBP: PO-T2T: RD071 (1:1:2%, 5 nm)/ PO-T2T (45 nm)/ LiF (1 nm)/ Al (150 nm). D1: x=2, y=1; D2: x=1, y=1; D3: x=1, y=2.

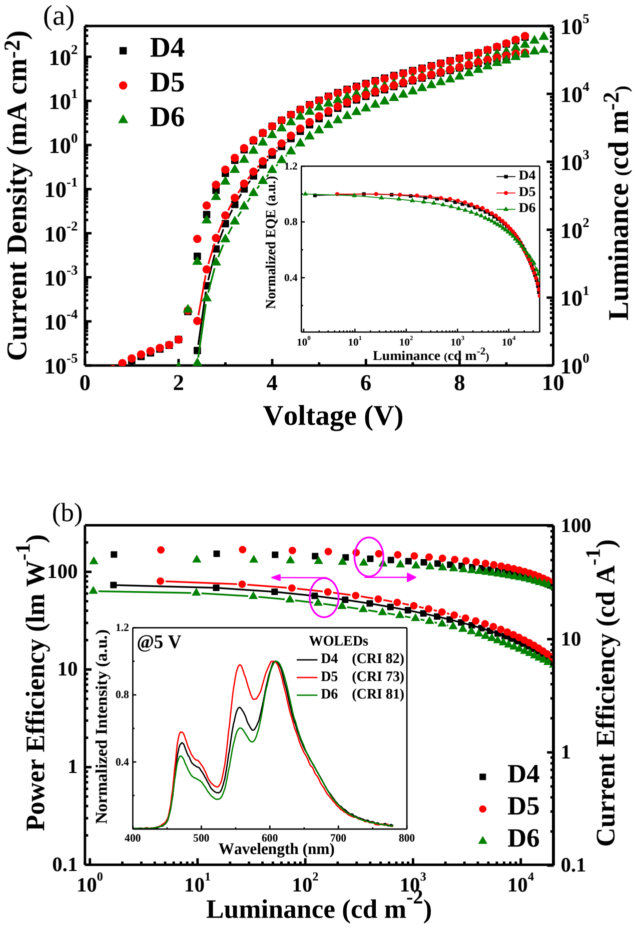

Fig. S3. (a) Current density and luminance versus voltage characteristics of devices D4-D6. Insert: Normalized external quantum efficiency versus luminance characteristics of devices D4-D6. (b) Current efficiency and power efficiency versus luminance characteristics of devices D4-D6. Insert: EL spectra and CRI of devices at 5 V. ITO/ HAT-CN (15 nm)/ TAPC (60 nm)/ TCTA (5 nm)/ mCBP (5 nm)/ mCBP: PO-T2T: FIrpic (2:1:10%, 5 nm)/ mCBP: PO-T2T: $Ir(tptpy)_2acac$ (x:y:1.5%, 3 nm)/ mCBP: PO-T2T: RD071 (m:n:2%, 5 nm)/ PO-T2T (45 nm)/ LiF (1 nm)/ Al (150 nm). D4: x=1, y=1, m=2, n=1; D5: x=1, y=1, m=1, n=2; D6: x=1, y=1, m=2, n=1.

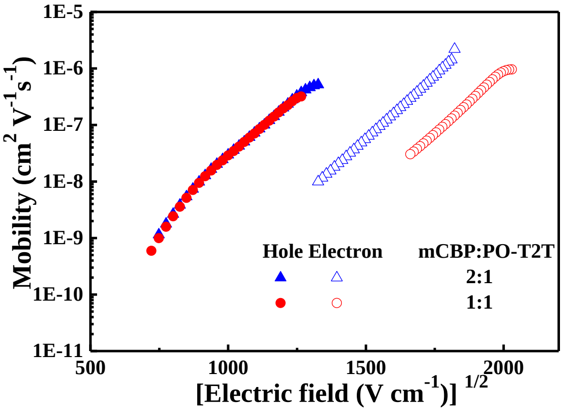

Fig. S4. Mobilities as electric field function of mCBP: PO-T2T films with different ratios. The hole-only and electron-only devices were fabricated with structures of ITO/ HAT-CN (15 nm)/ mCBP: PO-T2T (2:1 or 1:1, 50 nm)/ HAT-CN (15 nm)/ Al (150 nm) and ITO/ LiF (10 nm)/ mCBP: PO-T2T (2:1 or 1:1, 50 nm)/ LiF (1 nm)/ Al (150 nm).

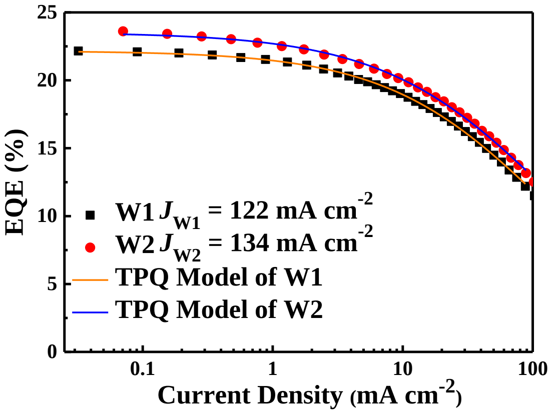

Fig. S5. External quantum efficiency vs current density characteristics of devices W1 and W2. The corresponding fitting curves are based on TPQ model (Correlation coefficient R^2=0.999 for W1 and W2).

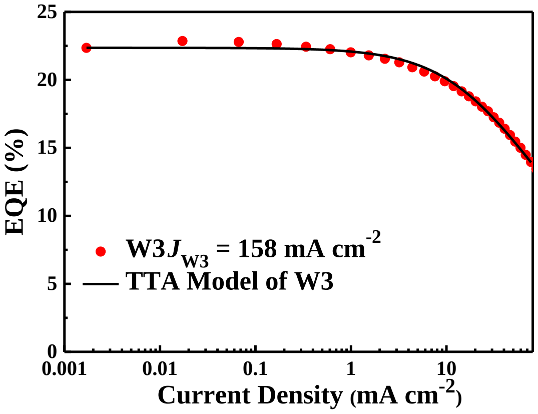

Fig. S6. External quantum efficiency vs current density characteristic of device W3. The corresponding fitting curves are based on TTA model (Correlation coefficient R^2=0.994).

The quenching processes and the equation of TTA model and TPQ model have been analysed in detail:

For TTA, the annihilation of two triplet states leads to an intermediate state X, which can be transferred, according to spin statistics, into one singlet, three triplet, or five quintet states.[1] The quintet states are usually higher in energy than the two initial triplet states and can thus be neglected. Possible pathways are as follows:

$$\mathrm{T_1} + \mathrm{T_1} \xrightarrow{\mathrm{k_{TT}}} \mathrm{X} \begin{cases} \xrightarrow{75\%} \mathrm{T_1} + \mathrm{S_0} \\ \xrightarrow{25\%} \mathrm{S_1} + \mathrm{S_0} \end{cases} \qquad (1)$$

Where T_1 is the triplet state, S_1 is the singlet state, S_0 is the molecular ground state.

TTA model follows the established biexcitonic quenching mechanism proposed by Baldo et al.[2, 3] The current density (J) dependence of EQE in TTA model can be expressed as:

$$\frac{\eta_{TT}}{\eta_0} = \frac{J_0}{4J}\left(\sqrt{1+\frac{8J}{J_0}} - 1\right) \qquad (2)$$

Where J_0 is the critical current density for TTA where $\eta = \eta_0/2$, η_0 is the EQE without the triplet exciton quenching, and η_{TT} is the EQE in the presence of TTA. Additionally, TPQ can be expressed by Equation (3) and (4):

$$T_1 + M^+ \overset{k_h}{\rightarrow} S_0 + M^+ \qquad (3)$$

$$T_1 + M^- \overset{k_e}{\rightarrow} S_0 + M^- \qquad (4)$$

Where M^+ and M^- are the trapped charge carriers assumed to annihilate the triplet excitons, and k_h and k_e are the TPQ rate parameters. We then modeled the roll-off characteristics by using the TPQ model by Equation (5):[4]

$$\frac{\eta_{TP}}{\eta_0} = \frac{1}{1+\left(\frac{J}{J_e}\right)^{1/(1+m)}} \qquad (5)$$

Where η_0 is the EQE in absence of TPQ, η_{TP} is the EQE in the presence of

TPQ, j_e is the critical current density and m is the fitting parameter.

Then, Eqs. (2) and (5) can be applied to fit the normalized EQEs versus current density characteristics of our white devices.

References

[1] A. Köhler, H. Bässler, *Mater. Sci. Eng. R*, 2009, **66**, 71.

[2] M. A. Baldo and S. R. Forrest, *Phys. Rev. B,* 2000, **62**, 10958.

[3] M. A. Baldo, C. Adachi and S. R. Forrest, *Phys. Rev. B,* 2000, **62**, 10967.

[4] S. Reineke, K. Walzer and K. Leo, *Phys. Rev. B,* 2007, **75**, 125328.