

Supporting Information

Solution-processed orange and white OLEDs sensitized by an electroactive pure organic room-temperature phosphorescence polymer

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1. Experimental Section

1.1. General Information. PEDOT: PSS (Clevios P CH 8000) was purchased from Heraeus Precious Metals GmbH Co. KG. PFI (Nafion, ≥ 1.00 meq/g exchange capacity) was purchased from Alfa-Aesar. P(DMPAc-O-TPTrz) was synthesized in our laboratory according to previously reported methods. TBRb 2,8-Di-tert-butyl-5,11-bis(4-tert-butylphenyl)-6,12-diphenyltetracene, TSPO1 (diphenyl-4-triphenylsilylphenyl-phosphine oxide), TmPyPB (Tri(m-pyridin-3-ylphenyl)benzene, 1,3,5-Tris(3-pyridyl-3-phenyl)benzene), mCP (1,3-bis(carbazol-9-yl)benzene), and LiF was bought from Luminescence Technology Corp.

1.2. Measurements and characteristics. Cyclic voltammetry (CV) measurements were recorded on an EG&G 283 potentiostat/galvanostat system from Princeton Applied Research. The UV–Vis absorption spectra were recorded by using a PerkinElmer Lambda 35 UV-vis spectrometer. The photoluminescence (PL) spectra and low-temperature phosphorescence spectra were measured by using a Horiba Instruments Inc. FL3C-111 fluorescence spectrometer. And the film samples were prepared by spin-coating the mCP, sensitizer, and dyes mixed solutions on the quartz substrate. The low-temperature phosphorescence spectra were obtained at 77 K under vacuum with a delay time of 0.01 ms to remove the fluorescent component. Transient PL spectra decay characteristics were recorded using a DeltaFlex™ Modular Fluorescence Lifetime System (Horiba Scientific) with an excitation wavelength of 300 nm in N₂.

1.3. Device fabrication and testing. The solution-processed devices were fabricated with a

configuration is ITO/PEDOT:PSS (Al 8000) (40 nm)/EML (30 nm)/TSPO1(8 nm) /TmPyPB (42 nm)/LiF (1 nm)/Al (150 nm). First, the cleaned ITO-coated substrates (15 Ω per square) were treated with Ultraviolet-ozone (UVO) for 1.5 hours. Secondly, the PEDOT: PSS (Clevios CH 8000) was spin-coated on the substrate in the air at a speed of 7000 rpm, annealed at 120°C for 1 hour, and then transferred into a nitrogen-filled glove box. Subsequently, the 30 nm EML was spin-coated onto the PEDOT: PSS layer from its chlorobenzene solution at a speed of 1800 rpm, then annealed at 100 °C for 10 minutes. After being transferred into a vacuum chamber, other functional layers including 8 nm TSPO1, 42 nm TmPyPB, 1 nm LiF, and 150 nm Al were thermally deposited layer-by-layer in sequence at a pressure under 3×10^{-4} Pa. The current density–voltage–luminance (J-V-L) characteristics of all fabricated devices were measured using Keithley 2000 and Keithley 2400 (fitted with calibrated silicon photodiode) systems. The EL spectra and CIE coordinates were measured using a CS2000 spectrometer. EQE was calculated from the EL spectrum, luminance, and current density assuming a Lambertian emission distribution. All the measurements were performed at room temperature and air atmosphere.

1.4. Calculation of Förster Energy Transfer. The Förster energy transfer process from P(DMPAc-O-TPTrz) to TBRb was quantitatively evaluated. Firstly, we calculated the molar extinction coefficient of TBRb by UV-Vis absorption spectroscopy using the Lambert-Bier law.

$$A = \varepsilon CL\#(S - 1)$$

In equation (**S-1**), A is the absorbance at the peak position of the first exciton absorption

peak. C is the molar concentration of dyes (mol/L). L is the optical path length of about 1 cm. ε is the molar extinction coefficient (L/(mol·cm)).

Secondly, the Förster energy transfer radius (R_0) is calculated by the expression:

$$R_0^6 = \frac{9000(\ln 10)k^2\phi_{PL}}{128\pi^5N_A n^4} \int_0^\infty Fh(\lambda)\varepsilon g(\lambda)\lambda^4 d\lambda \#(S-2)$$

In equation (S-2), Φ_{PL} is PLQY of sensitizer host, κ^2 is the transition dipole orientation factor with the value of 2/3, n is the refractive index with the value of 1.7, N_A is Avogadro's

number, $\int_0^\infty Fh(\lambda)\varepsilon g(\lambda)\lambda^4 d\lambda$ is the overlap integral between the PL of sensitizer and the absorption of the guest. In the overlap integral, $Fh(\lambda)$ stands for the normalized donor emission spectrum, and $\varepsilon g(\lambda)$ is the molar absorption coefficient of the acceptor.

Thirdly, the average distance between sensitizer and dopant (R_{DA}) was calculated following the expression:

$$R_{DA} = \left(\frac{4\pi}{3}N_G\right)^{-\frac{1}{3}} N_G = \beta\rho N_A M_C \#(S-3)$$

In equation (S-3), Where NG is the quantity of guest material in a unit volume, which is in direct proportion to the guest doping concentration. β is the fraction of the guest material, ρ is the density of the film assumed to be 1 g cm⁻³, N_A is the Avogadro's number and M_C is the molecular weight of the guest material.

2. Supplementary figures and tables

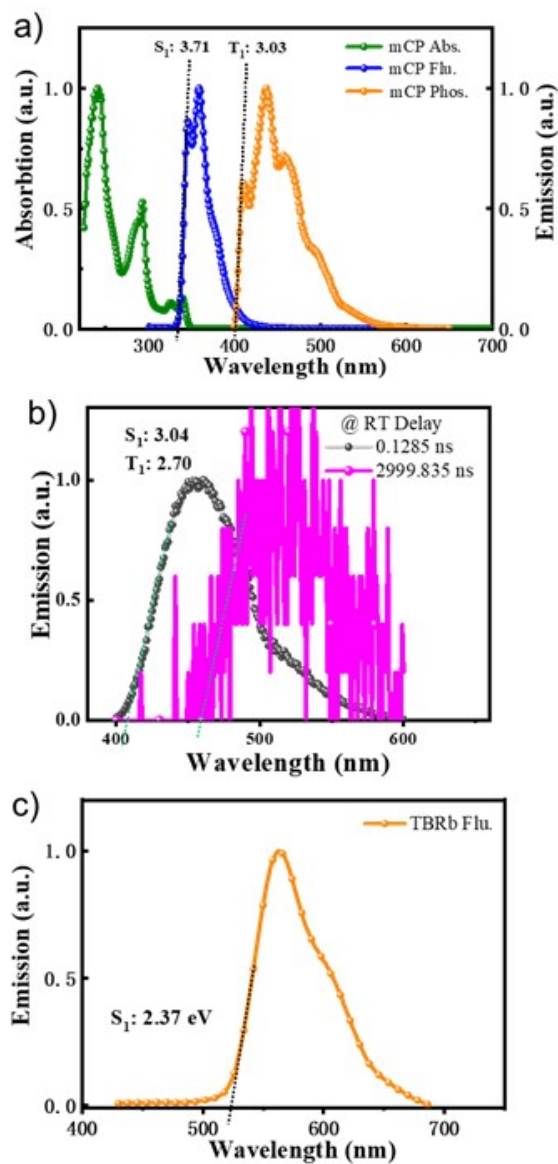


Figure S1. (a) UV-vis absorption, fluorescence and phosphorescence spectra at 77 K for mCP; (b) Time resolved PL spectra for P(DMPAc-O-TPTrz). The curves at 0.1285 and 2999.835 ns are taken as the fluorescence and phosphorescence spectra, respectively; (c) PL spectra of TBRb.

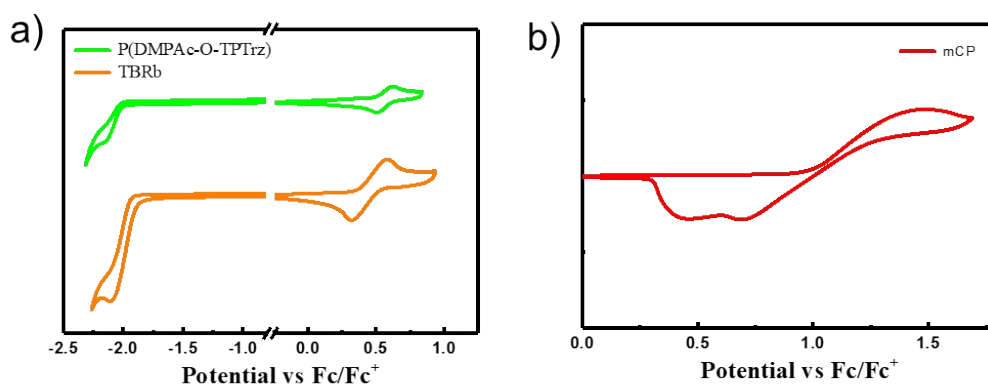


Figure S2. Cyclic voltammogram traces for P(DMPAc-O-TPTrz) and TBRb (a), and mCP (b) in dichloromethane solution using 0.1 M $n\text{-Bu}_4\text{NClO}_4$ as supporting electrolyte at a scan rate of 50 mV/s.

Table S1. Summary of photophysical and electrochemistry properties for used materials in solution-processed PSF.

Used materials	E_{S1}^a [eV]	E_{T1}^b [eV]	ΔE_{ST}^c [eV]	HOMO ^d [eV]	LUMO ^d [eV]
mCP	3.71	3.09	0.56	-5.73	-2.40 ^e
P(DMPAc-O-TPTrz)	3.04	2.70	0.34	-5.31	-2.84
TBRb	2.50	n. d.	-	-5.18	-2.90

^aSinglet energy estimated from the onset of the fluorescence spectrum (298 K); ^bTriplet energy estimated from the onset of the phosphorescence spectrum (77 K); ^c $\Delta E_{ST} = E_{S1} - E_{T1}$; ^dDetermined from cyclic voltammetry by the formula: $E_{HOMO} = -(E_{ox} + 4.8)$ eV, $E_{LUMO} = -(E_{re} + 4.8)$ eV, where E_{ox} and E_{re} are the onset values of the first oxidation and reduction waves, respectively; ^eTaken from the literature.

Table S2. Summary of photophysical parameters for doped films based on mCP: 15 wt.% P(DMPAc-O-TPTrz): x wt.% TBRb.

TBRb content (x wt.%)	τ_F^a (ns)	τ_P^a (ns)	R_{DA}^b (nm)	R_0^c (nm)
x = 0	13.57	1501.43	-	-
x = 0.2	4.70	1273.81	5.32	
x = 0.3	4.21	1135.64	4.64	
x = 0.4	3.88	1074.32	4.22	
x = 1.0	3.63	990.60	3.11	2.11
x = 3.0	3.20	901.24	2.16	
x = 5.0	2.91	892.77	1.82	

^aFluorescence and room-temperature phosphorescence lifetimes estimated from the transient PL spectra; ^bIntermolecular distance between P(DMPAc-O-TPTrz) and TBRb; ^c Förster energy transfer radius from P(DMPAc-O-TPTrz) to TBRb.

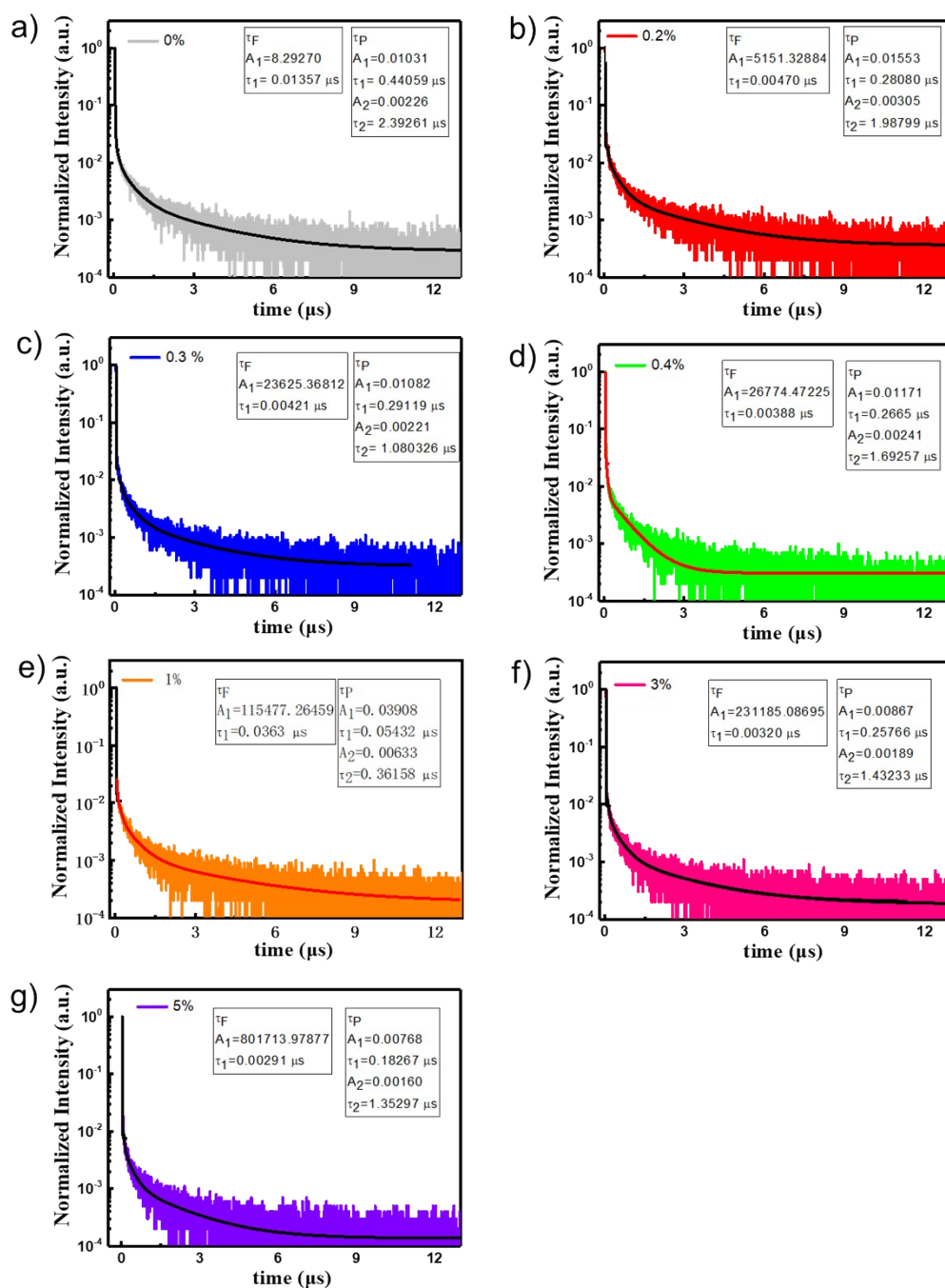


Figure S3. Transient PL spectra together with triexponential fittings for doped films based on mCP: 15 wt.% P(DMPAc-O-TPrz): x wt.% TBRb films, where x is 0 (a), 0.2 (b), 0.3 (c), 0.4 (d), 1.0 (e), 3.0 (f) and 5.0 (g).

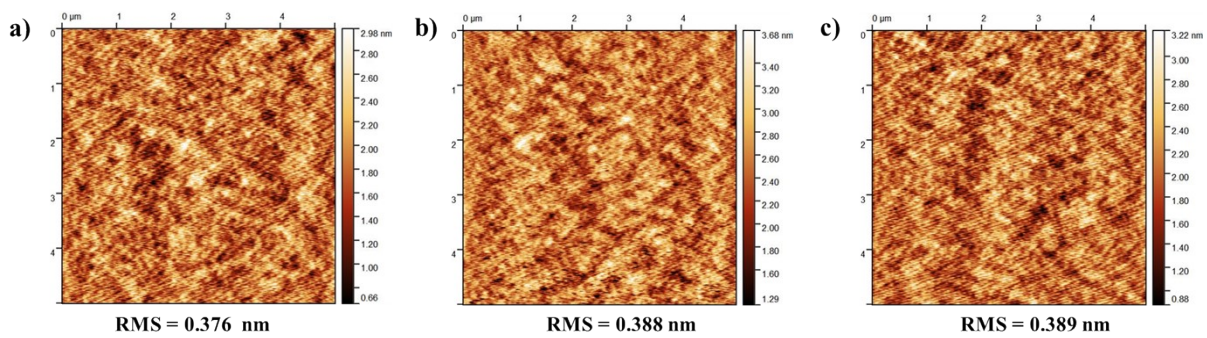


Figure S4. AFM morphology images on ITO/PEDOT: PSS substrate for (a) mCP: 15 wt.% P(DMPAc-O-TPTrz); (b) mCP: 15 wt.% P(DMPAc-O-TPTrz): 0.2 wt.% TBRb; (c) mCP: 15 wt.% P(DMPAc-O-TPTrz): 1.0 wt.% TBRb.

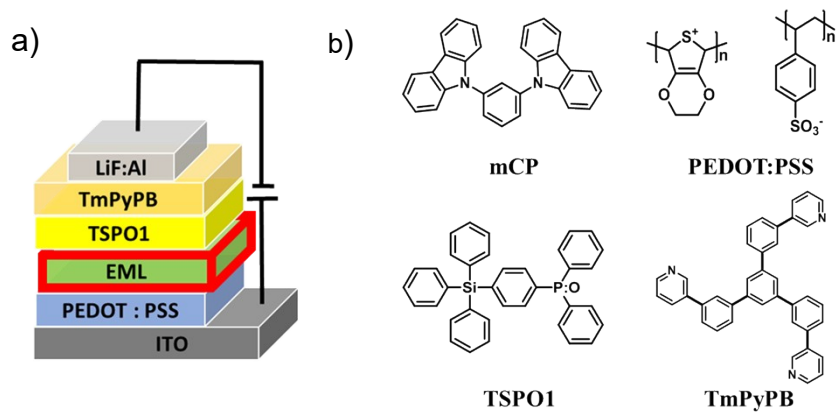


Figure S5. Device configuration (a) and molecular structures of used materials.

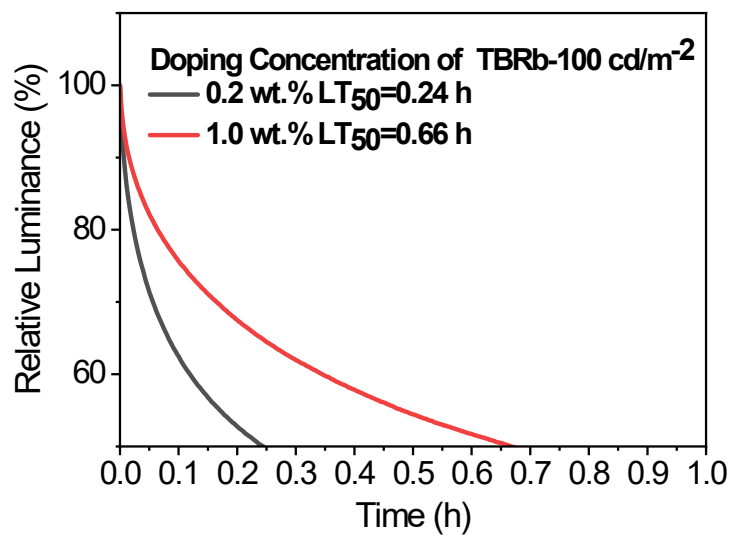


Figure S6. The operational lifetimes of the devices based on the structure of mCP: 15 wt.% P(DMPAc-O-TPTrz): x wt.% TBRb with initial luminance at 100 cd/m².

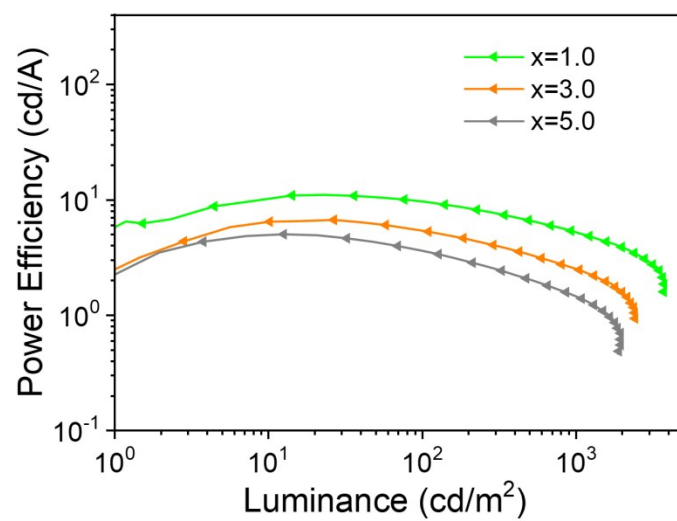


Figure S7. Power efficiency as a function of luminance for solution-processed orange OLEDs.

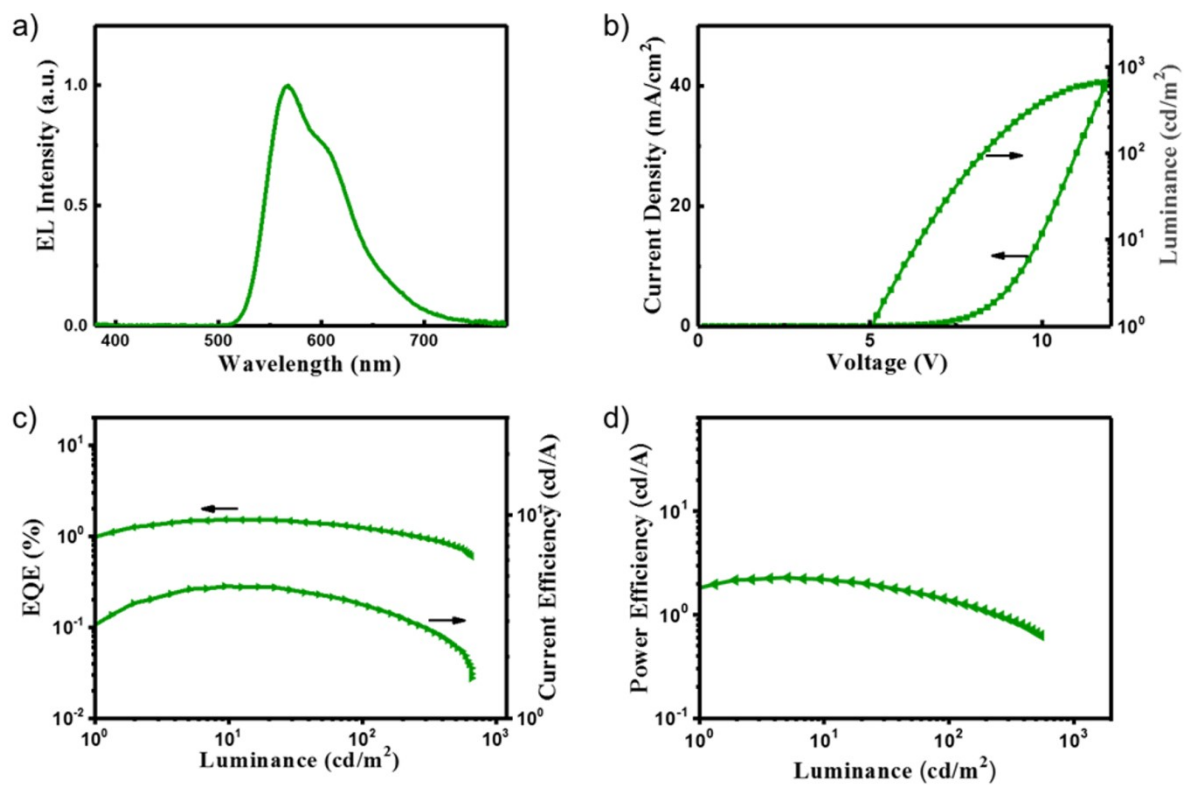


Figure S8. Control device performance for mCP: 5 wt.%TBRb: (a) EL spectra at 1000 cd/m²; (b) current density-voltage-luminance characteristics; (c) EQE and current efficiency as a function of luminance; (d) Power efficiency as a function of luminance.

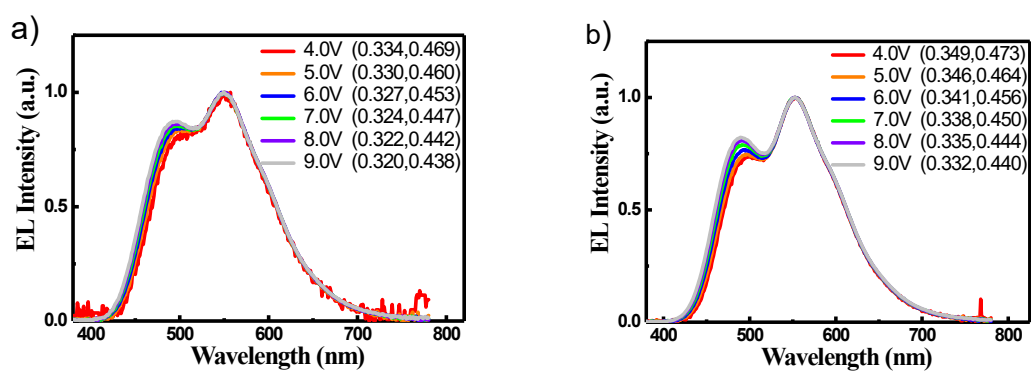


Figure S9. Driving voltage dependence on EL spectra for solution-processed white OLEDs based on mCP: 15 wt% of P(DMPAc-O-TPrz): x wt% TBRb, where x is 0.3 (a), and 0.4 (b).

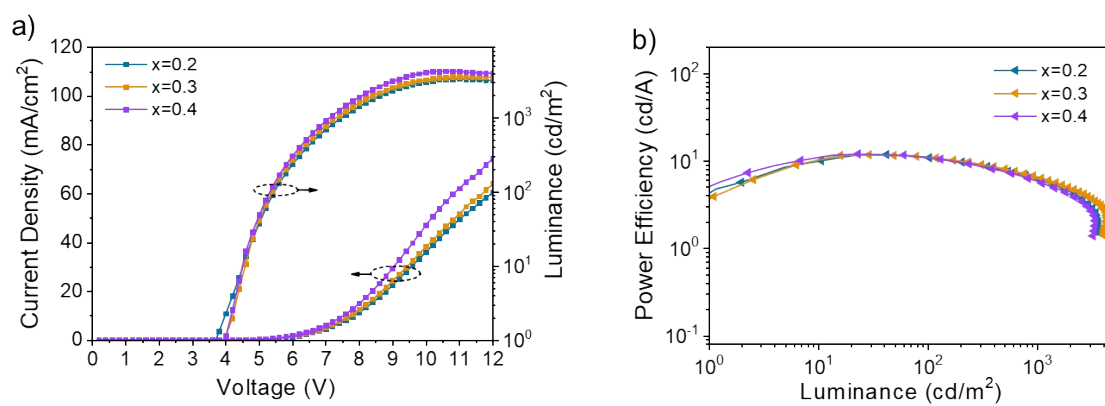


Figure S10. Current density-voltage-luminance characteristics (a), and power efficiency as a function of luminance (b) for solution-processed white OLEDs.