Supporting Information

Combination of Carbon Dot and Polymer Dot Phosphors for White Light-Emitting Diodes

Chun Sun, Yu Zhang, Kai Sun, Claas Reckmeier, Tieqiang Zhang, Xiaoyu Zhang, Jun Zhao, Changfeng Wu, William W. Yu, and Andrey L. Rogach

Preparation of PFTBT

PFTBT was synthesized according to the previous report[1] by palladium-catalyzed Suzuki coupling. A certain amount of 2M Na_2CO_3 aqueous solution was added into toluene, then purified 2,7-dibromo-9,9-dioctylfluorene, 2,7-bis(4,4,5,5- tetramethyl-1,3,2-dioxaborolan-2-yl)-9,9-dioctylfluorene, 4,7-bis(5-bromo-4-hexyl-2- thienyl)-2,1,3-benzothiadiazole (DHTBT), and $(PPh_3)_4Pd(0)$ (0.5-1.5 mol %) and several drops of Aliquat336 were dissolved in the mixture under the argon atmosphere and refluxed for 48 h under vigorous stirring. The polymer chain was end-capped by adding the 2,7-dibromo-9,9-dioctylfluorene and 2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-9,9- dioctylfluorene. Finally, the whole mixture was poured into methanol. The resulted solid was filtered and washed with acetone to remove oligomers and catalyst residues.

Photoluminescence quantum yield (PL QY) measurement

An absolute method, using the fluorescence spectrometer equipped with a 120 mm integrating sphere with BENFLEC® coated inner face (Edinburgh Instruments FLS920P), was employed to determine the PL QY defined as the ratio between photons emitted and absorbed by the sample. Liquid samples were placed in a UV quarts cuvette with a light path of 10 mm (QS, Hellma) to measure their PL QY, while a solvent filled in the same cuvette was used as a blank sample for the reference measurement. The powder samples were measured in a PTFE powder sample holder. A non-fluorescent PVP powder sample having the same morphological characteristics was used as a blank sample for a reference measurement. The spectral correction curve which relates to the sensitivity of the monochromator, detector, sphere coating and optics to wavelength was provided by Edinburgh Instruments. The reference dyes with known quantum yield were used to test the accuracy of the integrating sphere apparatus. For Rhodamine B in water (reference QY of 31%, Exciton) the PL QY was measured as 31%, and for Rhodamine 101 in ethanol (reference QY of 100%, Exciton) the PL QY obtained was 99%.

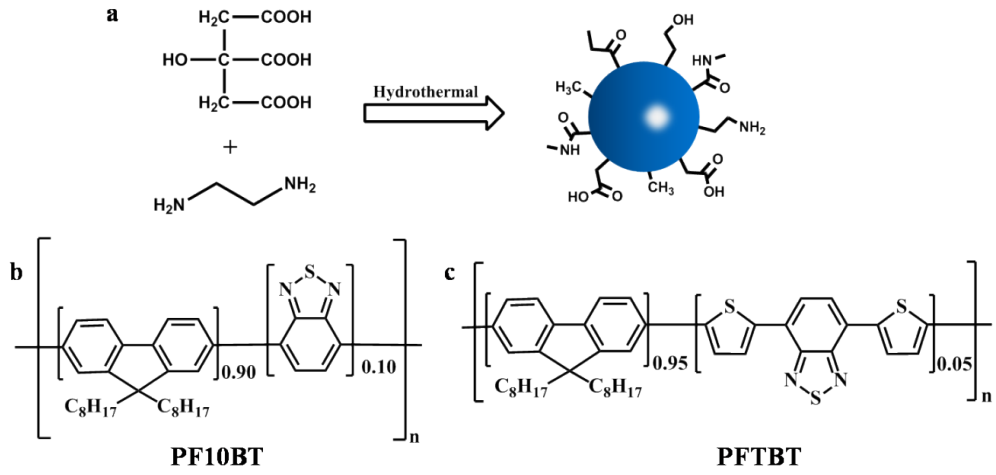

Figure S1. (a) Synthesis of CDs using citric acid and ethylenediamine and chemical structures of PF10BT **(b)** and PFTBT **(c)**.

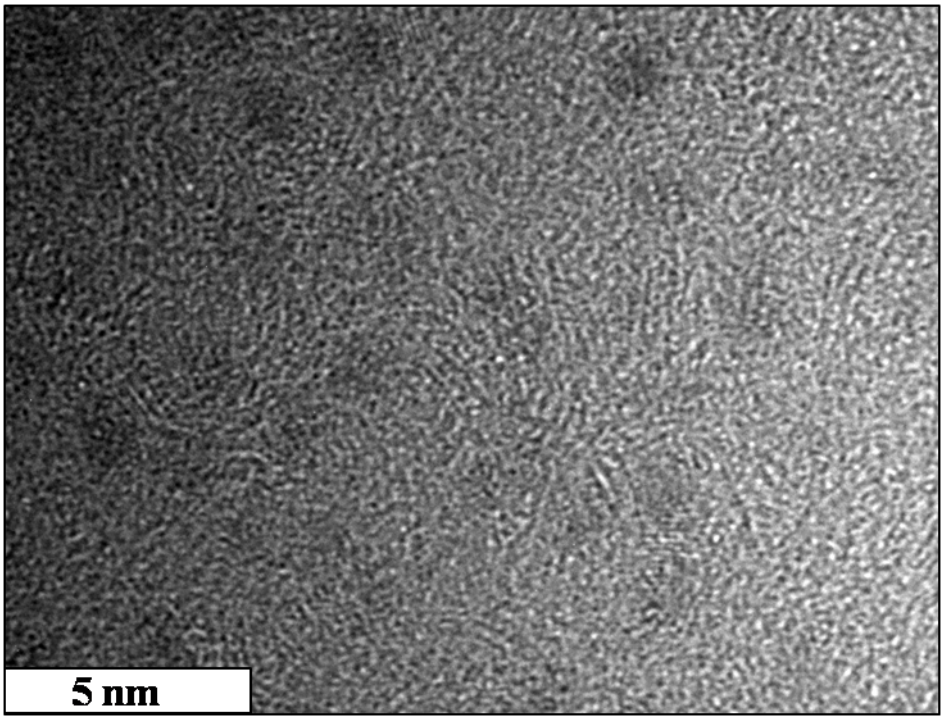

Figure S2. HRTEM image of CDs

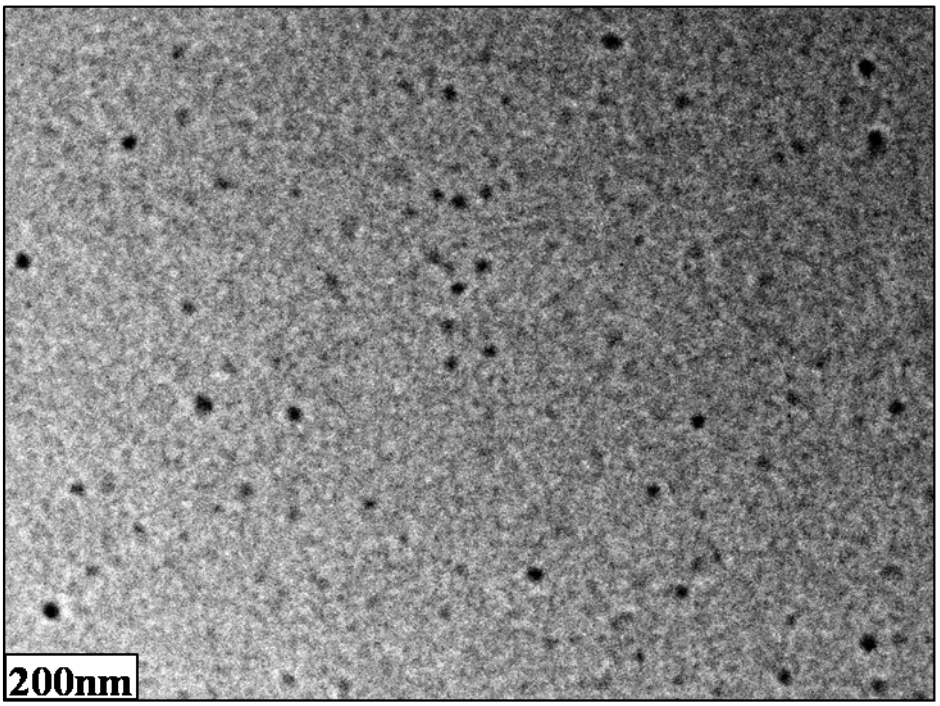

Figure S3. TEM image of PF10BT PDs.

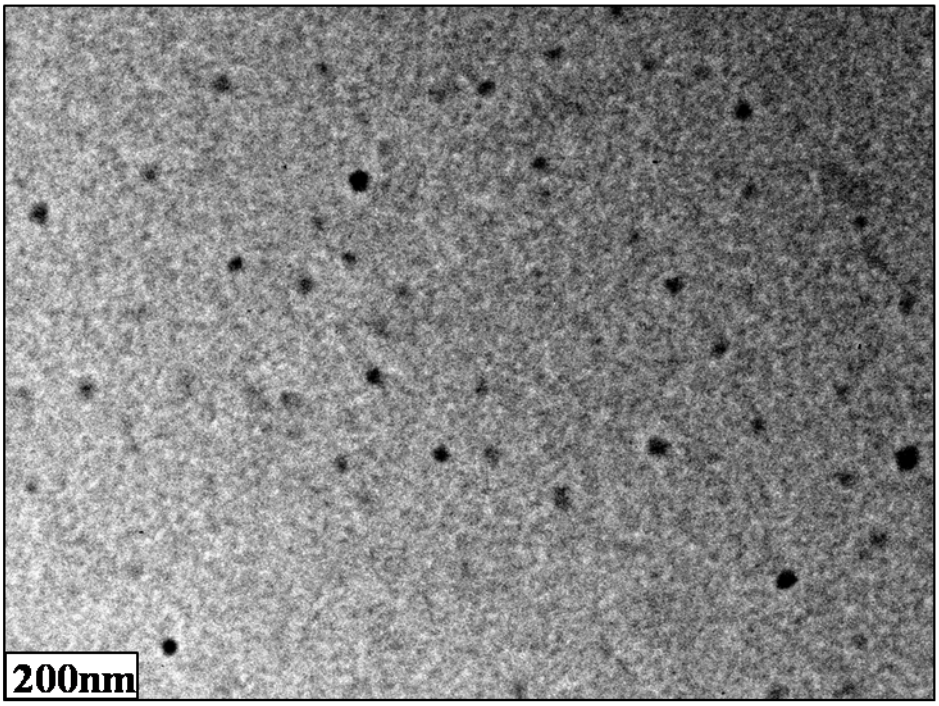

Figure S4. TEM image of PFTBT PDs.

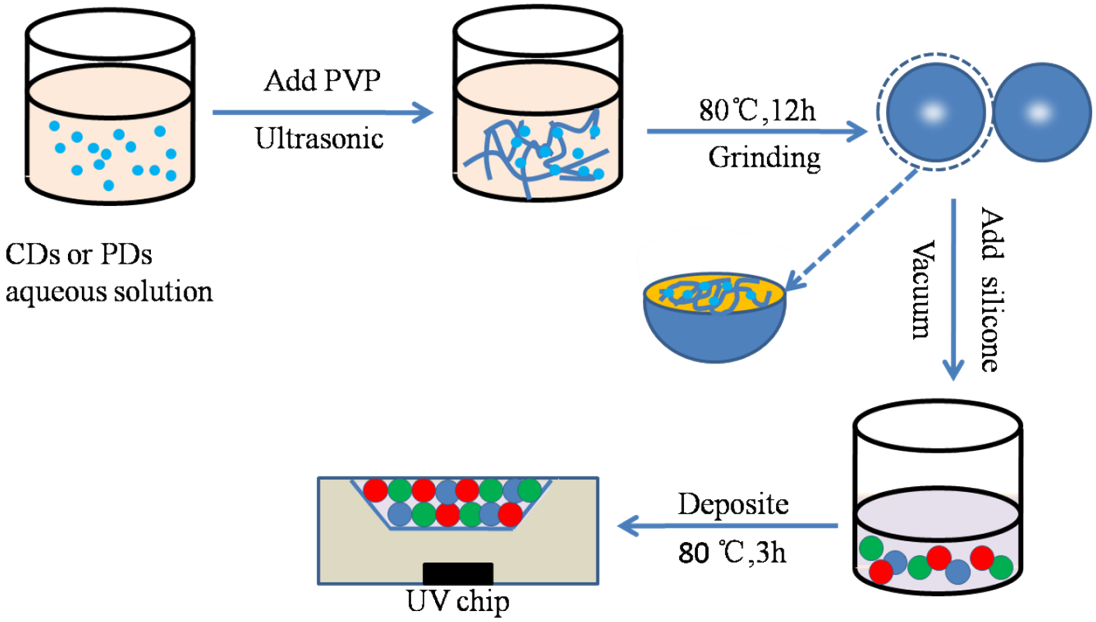

Figure S5. Schematic illustration of fabrication of CD/PVP and PD/PVP phosphors and their processing into WLEDs.

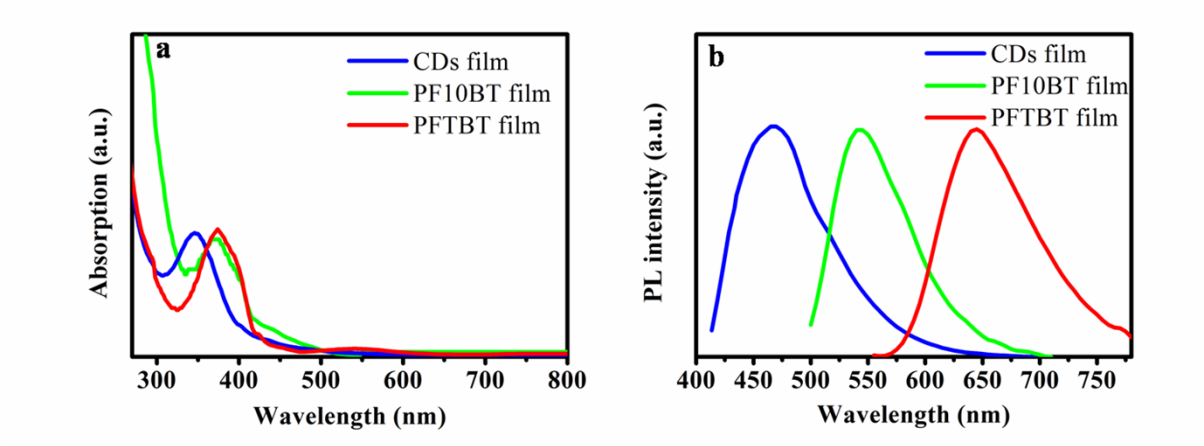

Figure S6. (a) UV–Vis absorption spectra of CD/PVP and PD/PVP films; **(b)** PL spectra of CD/PVP and PD/PVP films.

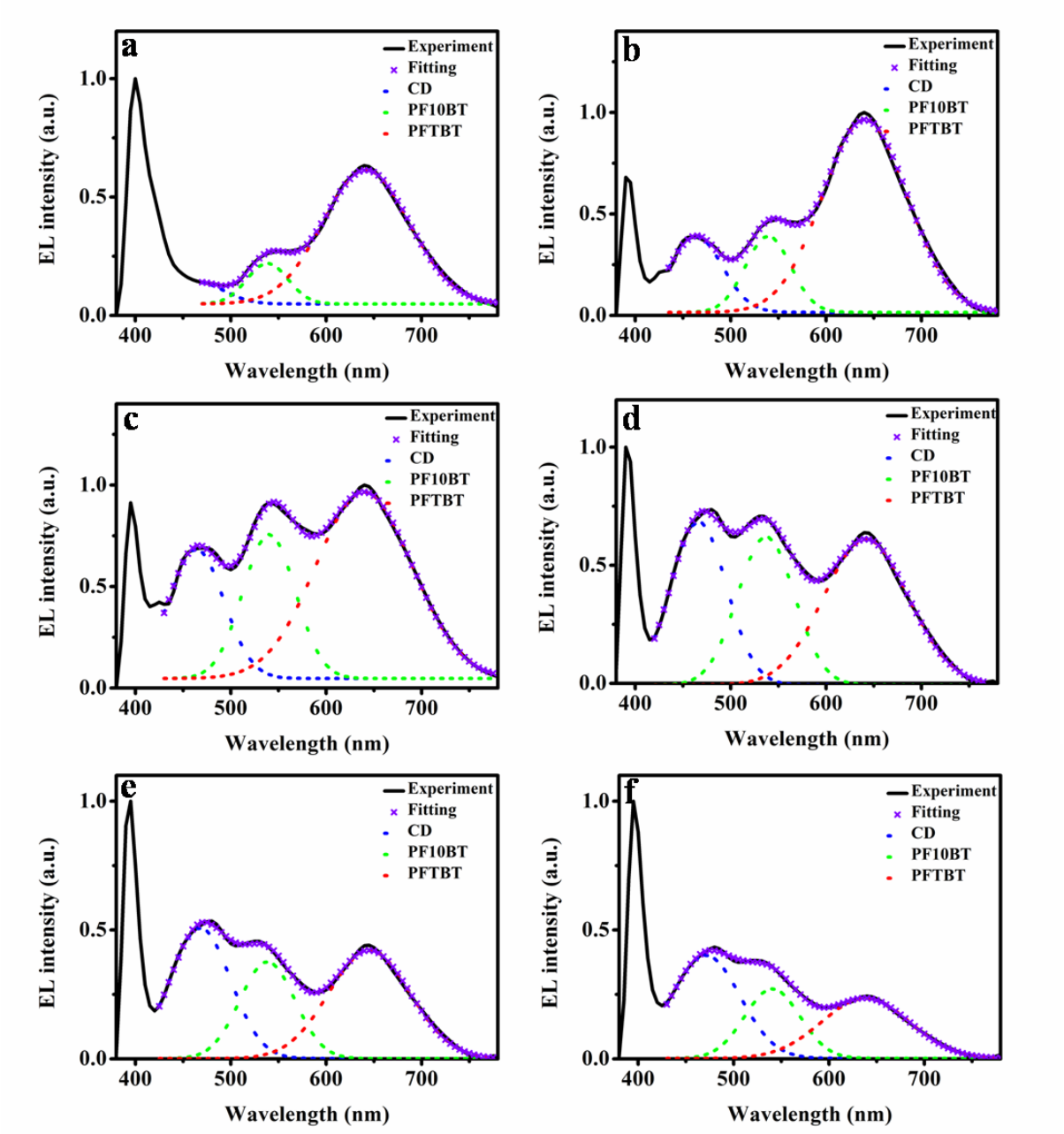

Figure S7. Emission spectra of WLED devices A-F (**a-f**). The cross symbols indicate the estimated spectra of total Gaussian fitting (purple) and the corresponding Gaussian fitting of CD (blue), PF10BT (green), and PFTBT (red), respectively.

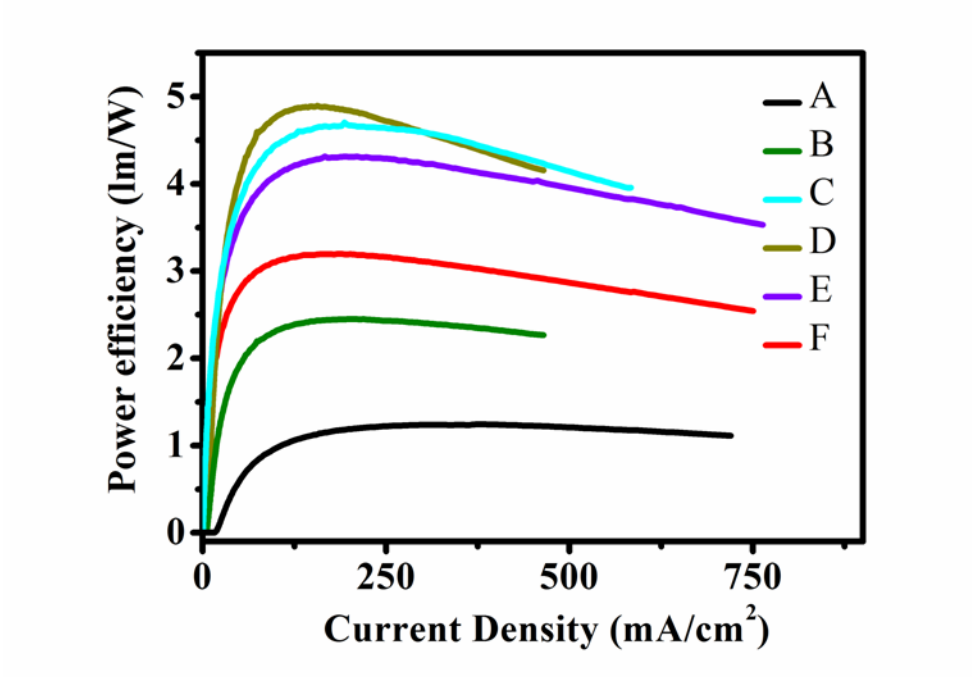

Figure S8. The luminous efficiencies of WLED devices A-F.

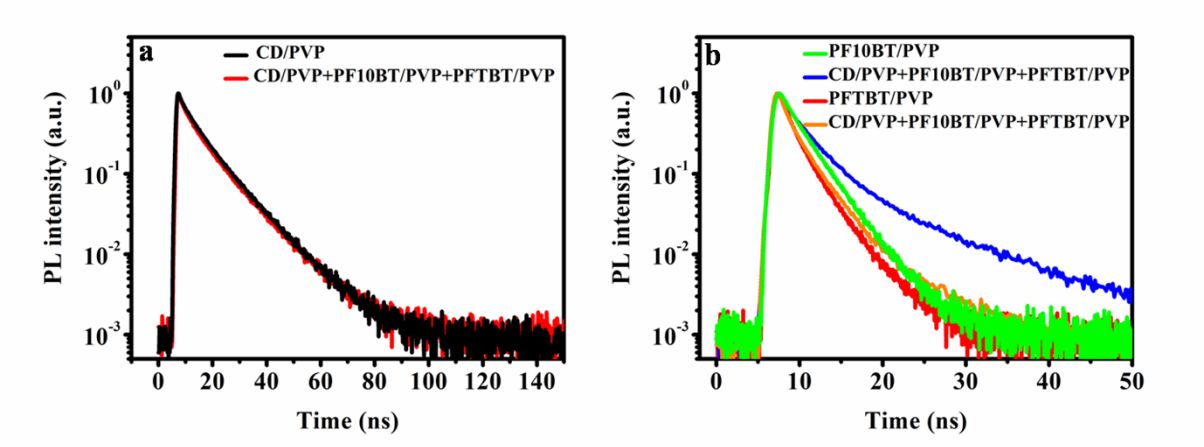

Figure S9. PL decay curves at 405 nm excitation for (a) CD/PVP powder and the mixed tri-phosphor powder probed at 475 nm, and (b) PF10BT/PVP powder, PFTBT/PVP powder and the mixed tri-phosphor powder probed at 540 nm and 660 nm, respectively.

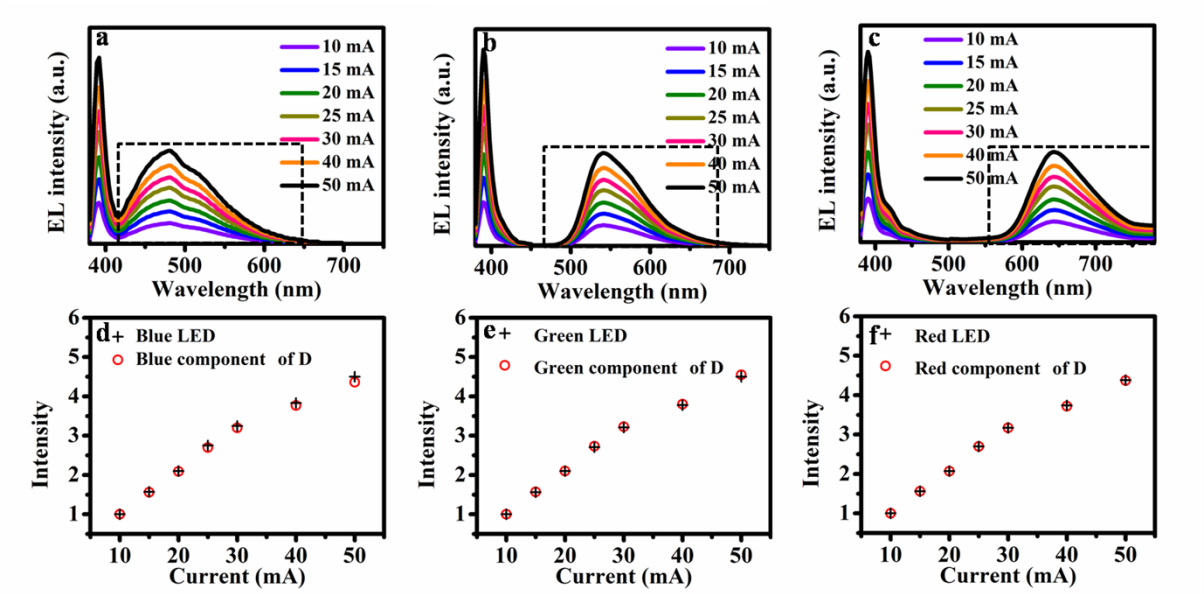

Figure S10. The EL spectra of blue **(a)**, green **(b)** and red **(c)** LEDs as a function of current (all the spectra within the dotted frame are multiplied by a factor of three); **(d)** the emission intensities of the blue component in the blue LED and the WLED device D; **(e)** the emission intensities of the green component in the green LED and the WLED device D; **(f)** the emission intensities of the red component in the red LED and the WLED device D.

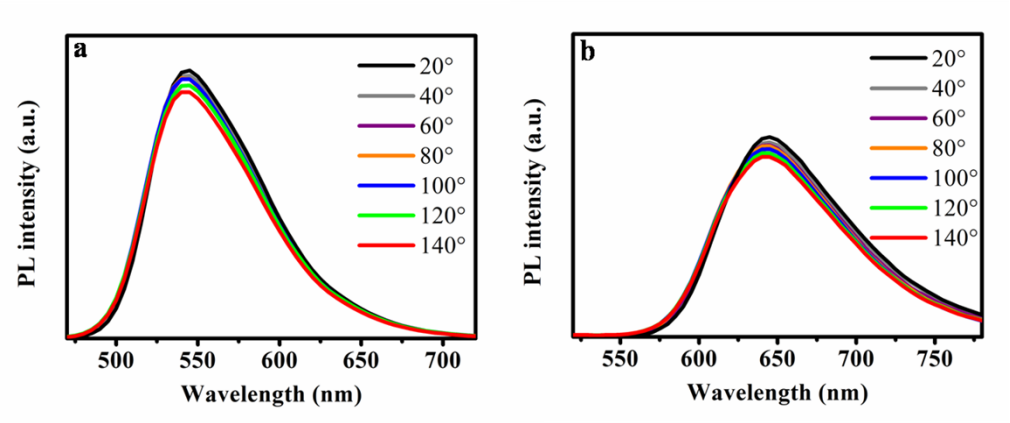

Figure S11. PL spectra of PF10BT/PVP film (a) and PFTBT/PVP film (b) measured in the temperature range 20-140°C.

Data notes: PL spectra of PD/PVP films have been measured at the temperature ranging from 20 to 140°C. As shown in Figure S11, no obvious shift can be observed in the PD/PVP films which are the same as for the PDs solution (Fig. 1e). The PL intensities of PF10BT and PFTBT decreased slightly in this temperature range (not more than by 10%). Because PDs are dispersed in the PVP network, the PVP is able to protect the PDs, so that the PDs/PVP composite is relatively stable at this range of temperatures.

Supporting References

1. Q. Hou, Q. Zhou, Y. Zhang, W. Yang, R. Yang and Y. Cao, *Macromolecules*, 2004, **37**, 6299-6305.