## **Electronic Supporting Information**

# High Efficiency Red Emission Carbon Dots Based on Phenylene Diisocyanate for Trichromatic White and Red LEDs

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#### **Preparation of carbon dots**

*Red emission carbon dots (R-CDs)*: 0.1g 1,4-phenylene diisocyanate (PDI) and 0.02g NaOH was dissolved into 20 mL anhydrous DMF. The transparent solution was translated into a teflon vessel (80 mL) and sealed. The teflon vessel was put in the oven and heated from room temperature to 180 °C then kept for 12 h. After cooling to room temperature naturally, the palm red product was vacuum distilled to remove the solvent. Subsequently, the solid was ultrasonically treated to dissolve in 5 mL ethanol. The product was purified by a centrifugation and silica column chromatography. The eluant was dichloromethane and methanol whose volume ratio was 20:1. The R-CDs were reserved in ethanol solution.

*Green emission carbon dots* (*G*-*CDs*): 0.5g citric acid was dissolved in 10 ml ethanol. The solution was added into 30 ml N-(2-aminoethyl)-3-aminopropyl-trimethoxysilane and adequately stirred. At last, the solution was transferred into a teflon vessel and heated from the room temperature to 160 °C then kept for 12 h. The purification process is similar to R-CDs. *Red emission carbon dots from p-phenylenediamine (R-CDs-pPD)*: Preparation was by referring to a previous report.<sup>1</sup> 0.1 g p-phenylenediamine was dissolved into 20 mL ethanol. The solution was translated into a teflon vessel (80 mL) and sealed. The teflon vessel was put in the oven and heated from room temperature to 180 °C then kept for 12 h. After cooling to room temperature naturally, the palm red product was obtained. The other purification process is similar to R-CDs.

#### **Fabrication of LEDs**

*Red LEDs*: The R-CDs (2 mg/mL) were evenly mixed with 0.1 mL N-(2-aminoethyl) -3-aminopropyl-trimethoxysilane and the mixture was dropped onto the blue light chips. After heating at 60 °C for 10 min, the red LEDs were papered.

*White LEDs*: The G-CDs (3 mg/mL) and R-CDs (2 mg/mL) were evenly mixed in different volume ratio of 5:1, 7.5:1 and 10:1. After the same process, the white LEDs were prepared.

#### Measurements

The properties of the red LEDs and white LEDs were measured by Everfine HASS-1200 LED measurement. The high resolution transmission electron microscope (HRTEM) images were obtained by JEOL JEM-2100F under an acceleration voltage of 200 kV. Atomic force microscope (AFM) measurements were carried out with Veeco Dimension 3100V. The Fourier transform infrared (FT-IR) spectra was recorded by Varian Excalibur HE 3100 through dropping the solution sample onto the KBr pellets. The UV-Vis absorption spectrum was measured by Hitachi U-3000 and the fluorescence spectra was obtained by Hitachi F-4500. The relative QY was measured by both of UV-Vis absorption spectra and fluorescence spectra mentioned above at room temperature. X-ray photoelectron spectroscopy (XPS) was carried out using Kratos Axis Ultra DLD spectrometer with monochromatic Al K $\alpha$  as the excitation source.



Fig S1. PL spectra R-CDs prepared with different mass of NaOH excited at 460 nm.

**Table S1**. The quantum yield (QY) and maximum emission wavelength (Em) of theR-CDs in different reaction temperature.

T (°C)	160	180	200	240
QY (%)	32.4	33.7	32.5	31.6
Em (nm)	604	604	602	602



Fig S2. PL spectra of R-CDs excited at 460 nm in different pH.



Fig S3. PL spectra of R-CDs in different solvent.



Fig S4. FT-IR spectra of R-CDs prepared by PDI and R-CDs-pPD prepared by

p-phenylenediamine.



Fig S5. XPS surveys of R-CDs and R-CDs-pPD and relative high-resolution XPS C 1s, N 1s, and O 1s spectra.

according to XPS spectra.					
	C 70	7.00	15.01		
R-CDs	77.11	7.88	15.01		
R-CDs-pPD	71.89	4.03	24.08		

Table S2. The relative content of C, N, O atoms for R-CDs and R-CDs-pPD

Table S3. The XPS data analyses result of C 1s, N 1s and O 1s.

	Sample	R-CDs	R-CDs-pPD	
C 1s	C-C/C=C %	73.60	62.06	
	C-N %	20.12	28.58	
	C-O %	4.48	7.64	
	COOH %	1.81	1.73	
N 1s	Amion N %	22.85	69.21	
	Pyridinic N %	3.57	9.07	
	Pyrrolic N %	73.58	21.72	
O 1s	C=0 %	70.22	78.14	
	C-O %	29.78	21.86	

Table S4. The performance of white LEDs in different volume ratios of G-CDs and

R-CDs	under	20	mA	driven	current.

Volume Ratio	Luminous Efficacy		CRI	Tc (K)
(G-CDs : R-CDs)	(lm/W)	$\operatorname{CHL}(\mathbf{x},\mathbf{y})$		
5:1	44.15	0.33, 0.33	83	5746
7.5:1	50.73	0.30, 0.32	79	7250
10:1	57.23	0.29, 0.34	71	7938

### References

1. K. Jiang, S. Sun, L. Zhang, Y. Lu, A. Wu, C. Cai and H. Lin, *Angew. Chem. Int. Ed.*, 2015, **54**, 5360.