

Supporting Information

RGB-multicolor fluorescent carbon dots by changing the reaction solvent type for white light-emitting diodes

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Experimental Section

Materials. All chemicals used were purchased from commercial sources and used without further purification. O-Phenylenediamine and formamide were purchased from Aladdin Chemicals Co. Ltd (Shanghai, China). L-Phenylalanine were purchased from Sangon Biotechnology Co., Ltd. (Shanghai, China). N,N-Dimethylacetamide were purchased from Damao Chemical Reagent Co., Ltd. (Tianjin, China). Sulfuric acid (H₂SO₄, 98%) were purchased from Tianli Chemical Reagent Co., Ltd (Tianjin, China). Deionized water was used for all of the experiments.

Instrumentation. Transmission electron microscopy (TEM) was performed on FEI Tecnai G2 F20. Raman scattering spectra were obtained using RENISHAW inVia spectrometer with 532 nm laser. The X-ray powder diffraction (XRD) patterns were recorded using a Lab XRD-7000s X-ray diffractometer in the range of 5–80 degree at room temperature. The Fourier transform infrared (FT-IR) experiment was carried out on a Nicolet iN10 MX & Is10 Fourier transform infrared spectrometer and used a wavenumber range of 400–4000 cm⁻¹. X-ray photoelectron spectroscopy (XPS) measurements were carried out on an ESCALAB 250 Xi (Thermo Scientific, MA, USA) using non-monochromatized Mg-K α X-ray as the excitation source. The binding energies for the samples were calibrated by setting the measured binding energy of C 1s to 284.60 eV. Ultraviolet Photoelectron Spectroscopy (UPS) measurement was performed with an $h\nu = 21.22$ eV, He I source (AXIS ULTRA DLD, Kratos). The expression of work function is

$$\Phi = h\nu - (E_{\text{cutoff}} - E_{\text{Fermi}})$$

UV-vis spectra were acquired from a Hitachi UH5300 UV-vis absorption spectrophotometer (Hitachi, UH5300, Japan). The photoluminescence spectroscopy (PL) was recorded using a Hitachi F7000 Fluorescence spectrophotometer. The time-resolved fluorescence spectra were collected with Edinburgh FLS1000 steady state/transient fluorescence spectrometer. The 2D EEM spectra of CDs were measured by using a spectrofluorometer (Hitachi, F7000, Japan).

Synthesis of multicolor CDs. Using o-phenylenediamine and phenylalanine as raw materials, multicolor fluorescent CDs were obtained by solvothermal method with different solvents. For blue carbon dots, 0.1g o-phenylenediamine and 0.1g phenylalanine were dissolved in 12ml formamide; for green carbon dots, 0.1g o-phenylenediamine and 0.1g phenylalanine were dissolved in 12ml N,N-Dimethylacetamide; For the red carbon dots, 0.1g o-phenylenediamine and 0.1g phenylalanine were dissolved in 7ml water and 5ml sulfuric acid. Then ultrasonic for 30min, transfer to Teflon-lined stainless-steel autoclaves and heated at 200 °C for 6 h. After the reactor was cooled to room temperature, the aqueous solution was centrifuged at 10 000 rpm for 10 min to remove insoluble large particles. Subsequently, the supernatant was filtered with a 0.22 μm filter membrane and finally dialyzed with membrane (1000 Da) for 24 h to remove the salt and acid.

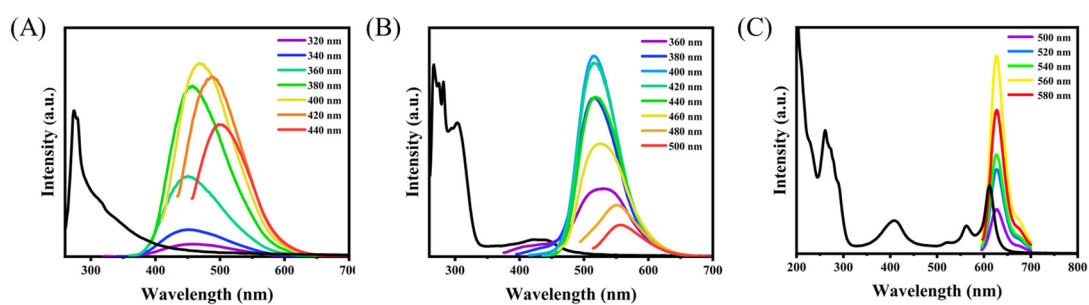


Figure S1. Absorption spectra and PL emission spectra of (A) B-CDs, (B) G-CDs, and (C) R-CDs under excitation of different wavelengths of light.

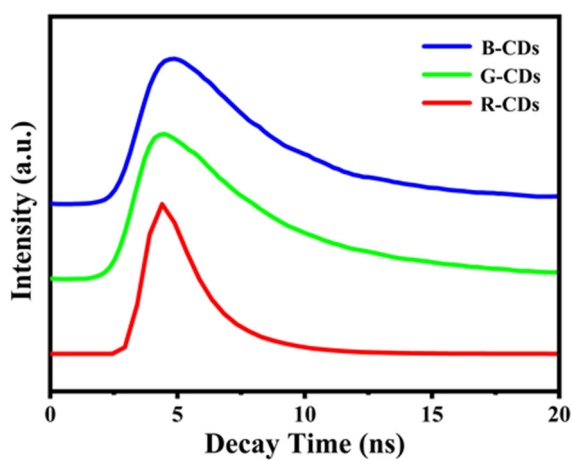


Figure S2. Time-resolved PL spectra of B-CDs, G-CDs, and R-CDs.

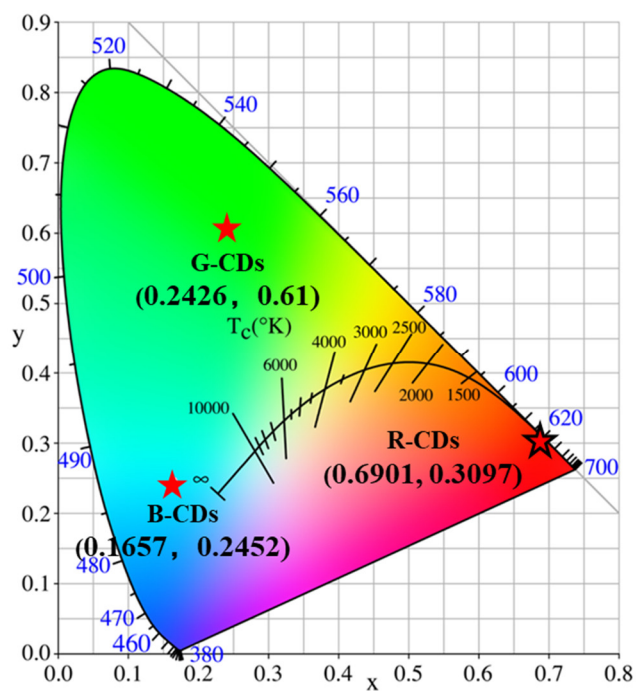


Figure S3. B-CDs, G-CDs, and R-CDs chromaticity diagram (Red Pentagram).

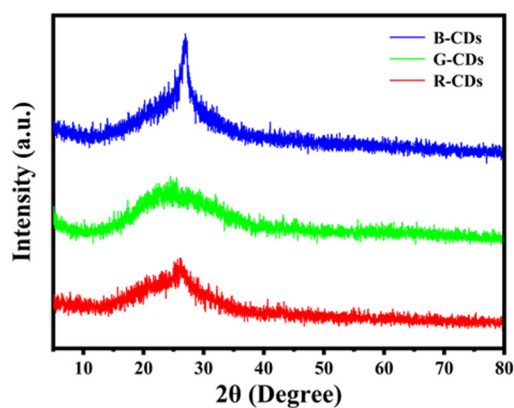


Figure S4. Powered XRD patterns of B-CDs, G-CDs, R-CDs.

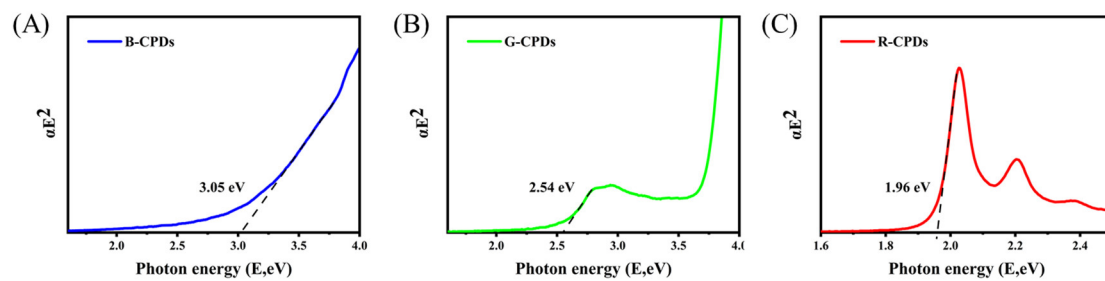


Figure S5. The calculation results of energy gaps of (A) B-CPDs, (B) G-CPDs, and (C) R-CPDs according to UV-vis spectra.

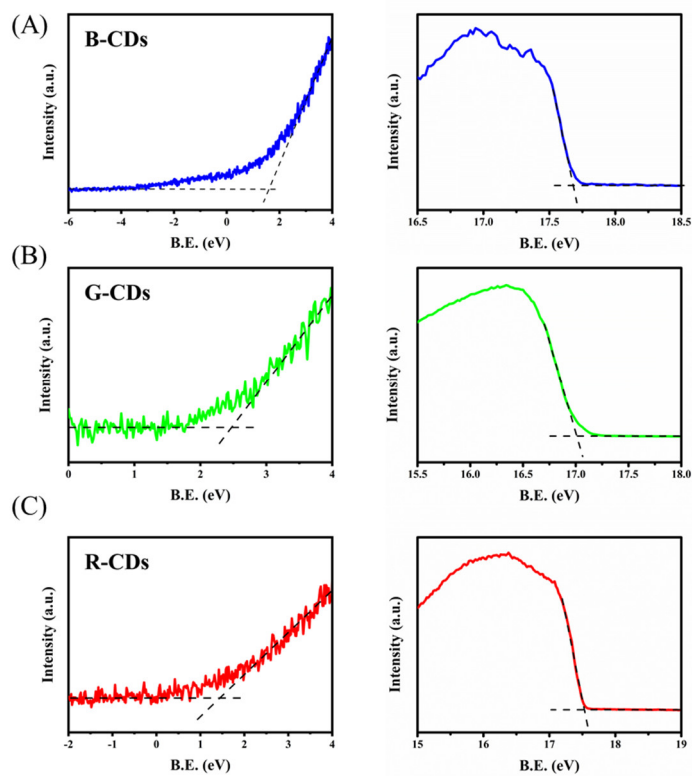


Figure S6. UPS spectra of (A) B-CDs, (B) G-CDs, and (C) R-CDs.

Table S1. The C, N, O element contents of B-CDs, G-CDs, and R-CDs determined by XPS results.

Sample	C %	N %	O %
B-CDs	61.04	32.13	6.82
G-CDs	70.07	6.94	22.90
R-CDs	81.59	11.09	7.32

Table S2. XPS data analyses of the C 1s, N 1s and O 1s spectra of B-CDs, G-CDs, and R-CDs.

Sample	Carbon %			Nitrogen %		Oxygen %	
	C=C/C-C	C-N/C-O	C=O	Pyridinic N	Pyrrolic N	C-O	C=O
B-CDs	36.37	54.09	9.53	53.70	46.30	70.66	29.34
G-CDs	75.93	17.84	6.23	82.04	17.96	94.00	6.00
R-CDs	68.48	24.83	6.69	58.26	41.74	92.37	7.63

Table S3. The calculation results of energy level of B-CDs, G-CDs, and R-CDs according to UV-vis spectra and UPS spectra.

Sample	HOMO (eV)	LUMO (eV)	λ_{edge} (nm)	E_{gopt} (eV)
B-CDs	-5.15	-2.1	407	3.05
G-CDs	-6.68	-4.14	488	2.54
R-CDs	-5.15	-3.19	633	1.96

Table S4. Comparison of WLED based on CDs

Precursor	Method	CIE	Ra	CCT (K)	Ref
P-aminosalicylic + Citric acid	Hydrothermal	(0.29, 0.30)	83	8526	[1]
C60 + Oxon	Solvothermal	(0.34, 0.40)	77.3	5290	[2]
Phosphoric acid +Urea	Hydrothermal	(0.27, 0.35)	85.3	8756	[3]
Citric acid + Urea	Solvothermal	(0.34,0.31)	82.4	5048	[4]
Citric acid +Urea	Microwave	(0.31, 0.34)	82	-	[5]
Phloroglucinol + Ethylenediamine + Boric acid	Microwave	(0.34, 0.37)	84	5194	[6]
PAA + Glycerol	Hydrothermal	(0.27, 0.32)	78.2	-	[7]
Triammonium citrate + Urea	Solvothermal	(0.36, 0.35)	83.4	4412	[8]
Citric acid + Urea	Hydrothermal	(0.34, 0.32)	85	5092	[9]
P-phenylenediamine Phenylalanine	Solvothermal	(0.29, 0.35)	86	7127	This Work

Reference

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