Experimental section

Reagents and materials

Rhodamine B (RhB) was bought from Dengke chemical reagent Co. LTD(Tianjin, China). NaOH (≥96.0%), HCl (36–38%) and boric acid (BA) were purchased from Damao Chemical Corp (Tianjin, China). NaH_2PO_4, Na_2HPO_4 and H_3BO_3 were obtained from Aladin Ltd. (Shanghai, China). All chemicals were used without any further purification. The ultrapure water used throughout all the experiments was purified through Water Purifier Nanopure water system (18.3M.cm).

Synthesis of G-CDs: In this work, green emissive carbon dots (G-CDs) with ultra-high quantum yield were synthesized by hydrothermal pyrolysis of RhB at 180 °C for 8 h in NaOH aqueous solution. In brief, 96 mg of Rhodamine B (RhB) was dissolved in 15 mL NaOH aqueous solution (0.67 M), and then the solution was transferred into poly(tetrafluoroethylene) lined autoclaves and heated at 180 ºC in an oven for 8 h. After cooling down to room temperature naturally, the resultant mixture was precipitated by acid. Then the solid G-CDs were obtained by drying at 60 °C.

Synthesis of the G-CDs/B_2O_3 composite: Firstly, 2 mg of G-CDs and 3 g of boric acid (BA) were dissolved with 40 mL DI water in a beaker by ultrasonic. The beaker was covered with foil to keep the water evaporating slowly. And then, the beaker was heated in an oven at 180 °C for 5 h, after cooling down to room temperature naturally. The final products were obtained by grinding.

Synthesis of the G-CDs/B_2O_3 composite at different temperatures: 2 mg of G-CDs and 3 g of boric acid (BA) were dissolved with 40 mL DI water in a beaker by ultrasonic.The beaker was covered with tin foil and reacted at 150 °C, 180 °C, 210 °C and 240 °C in an oven for 5 h, after cooling down to room temperature naturally. The final products were obtained by grinding.

Synthesis of the G-CDs/ B_2O_3 composite at different reaction time: 2 mg of G-CDs and 3 g of boric acid (BA) were dissolved with 40 mL DI water in a beaker by ultrasonic. The beaker was covered with tin foil and reacted at 180 °C in an oven for 3h, 5 h, 4h, 6h and 7h, respectively and cooling down to room temperature naturally. The final products were obtained by grinding.

Synthesis of the G-CDsx/ B_2O_3 composite at different ratios of G-CDs to BA: 0, 1, 2, 3 mg of G-CDs and 3 g of boric acid (BA) were dissolved with 40 mL DI water in a

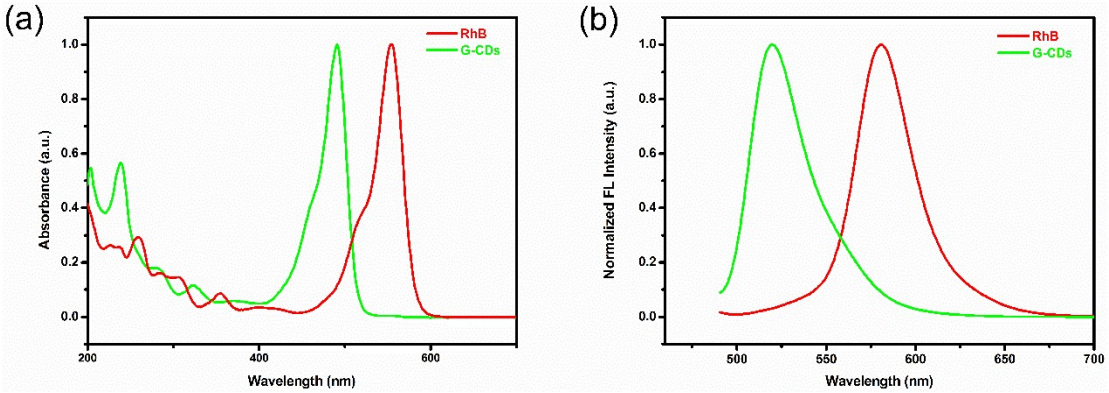
beaker by ultrasonic. The beaker was covered with tin foil and reacted at 180 °C in an oven for 5 h and cooling down to room temperature naturally. The final products were ground into powder.

Synthesis of the G-CDs/starch composite: 3g starch and 2 mg G-CDs were added into 10 ml DI water. The mixture was sitrred well at room temperature in a beaker. The beaker was dried in an oven at 60 °C. The final products were ground into powder.

Coating the G-CDs/B_2O_3 composite on glass: BA (90 g) and G-CDs (60 mg) were dissolved in 1200 mL DI water by ultrasonic. And then, the above solution was poured into a glass culture dish (d=25cm). The glass culture dish was covered with tin foil and heated in an oven at 180 °C for 8 h. Finally, the G-CDs/B_2O_3 composite was coated on the bottom of the dish as a smooth platform.

Characterization

The morphology and the size of nanoparticles were analyzed using the transmission electron microscopy (TEM, Hitachi H-7000, operated at 80 kV). The collection of phosphorescence spectra and fluorescent spectra were performed by a fluorescence spectrometer F-7000 (Hitachi, Japan). UV–vis absorption spectra were scanned by using of a U-3900 UV–vis spectrophotometer (Hitachi, Japan). The X-ray diffraction (XRD) patterns were collected using a D8 ADVANCE X-ray diffractometer (Bruker AXS,German) with Cu-Kα radiation (40 kV, 40mA, λ =1.5418 Å) at a scanning rate of 1° min^{-1} in the range from 5° to 80°. The Fourier transform infrared spectroscopy (FTIR) spectrum of CDs were recorded using a FT-IR200 spectrometer (Thermo, America) with KBr pellets technique, over the range 400 – 4000 cm^{-1}. Photographs were taken using a Canon camera (EOS 550) under excitation by a hand-hold UV lamp (254 nm, 365 nm) and cellphoe LED . The absolute quantum yields (QYs) lifetime and the time-resolved decay curve was performed by a fluorescence spectrometer FLS-1000 (Edinburgh).



FigureS1. (a) UV-vis absorption spectrum of G-CDs and RhB in aqueous solution. (b) Fluorescence emission spectra of G-CDs and RhB in aqueous solution.

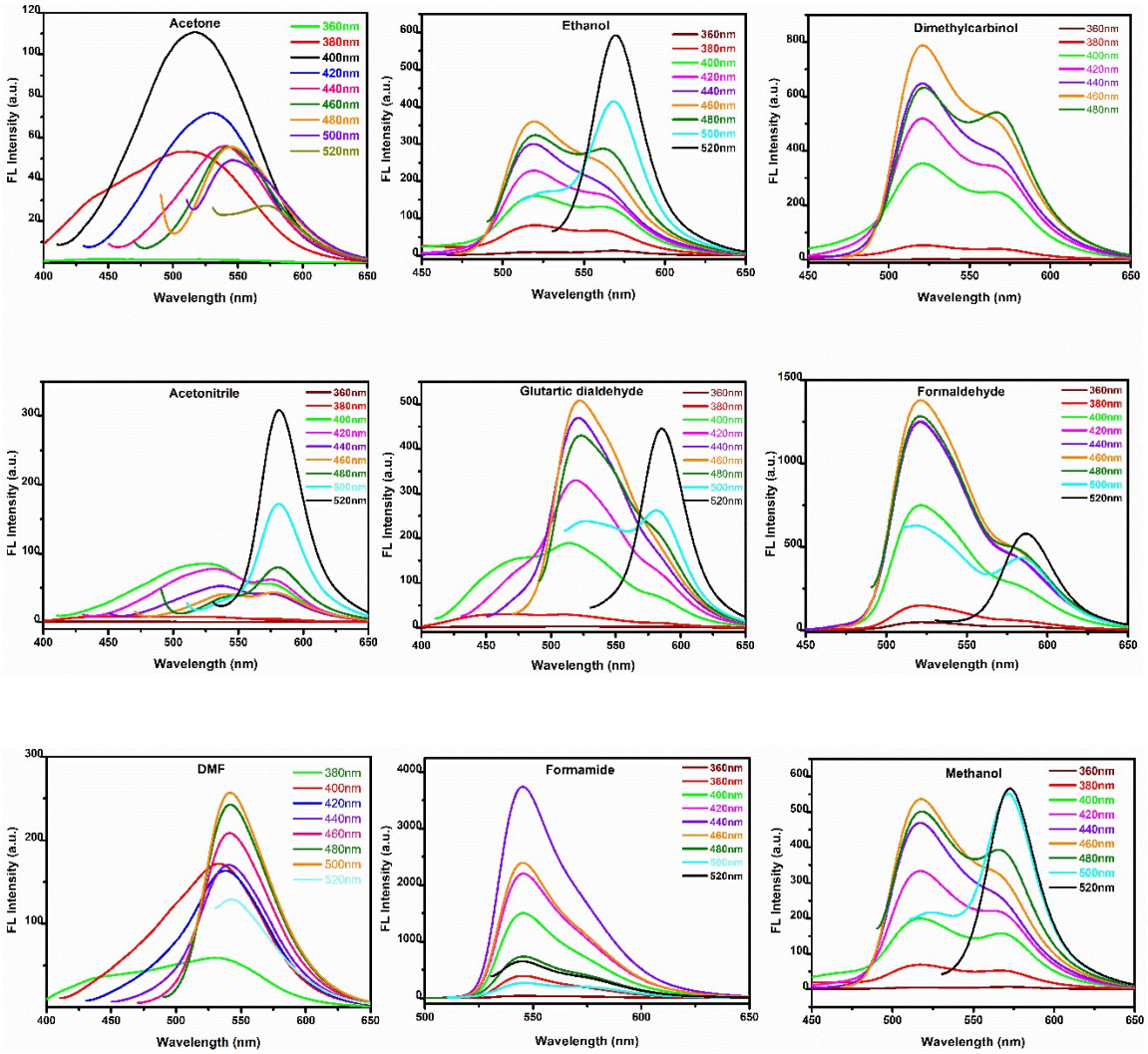


Figure S2. Fluorescence emission spectra of G-CDs dispersed in different organic solvents.

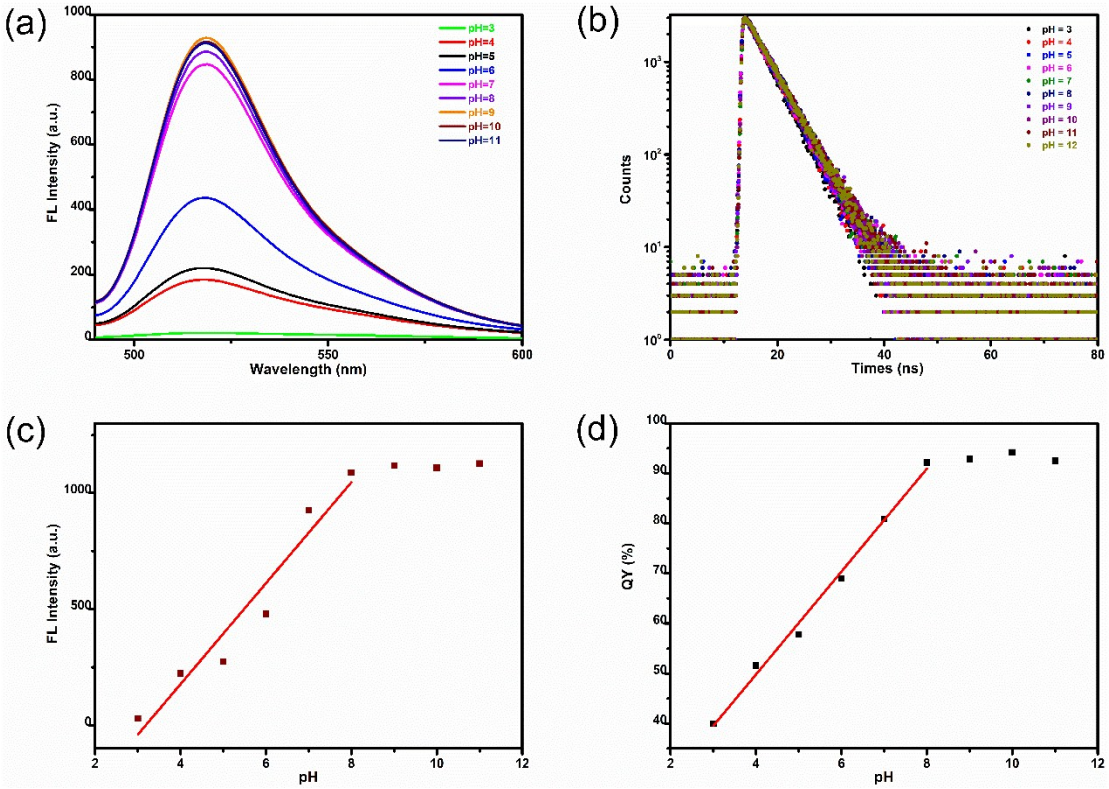


Figure S3. (a) Fluorescence emission spectra of G-CDs in aqueous solution at different pH values under excitation at 480 nm. (b) The time-resolved decay curves of G-CDs in aqueous solution at different pH values monitored at 520 nm with 480 nm excitation. (c) The linear relationship between fluorescence intensity and pH. (d) The linear relationship between the absolute quantum yield and pH.

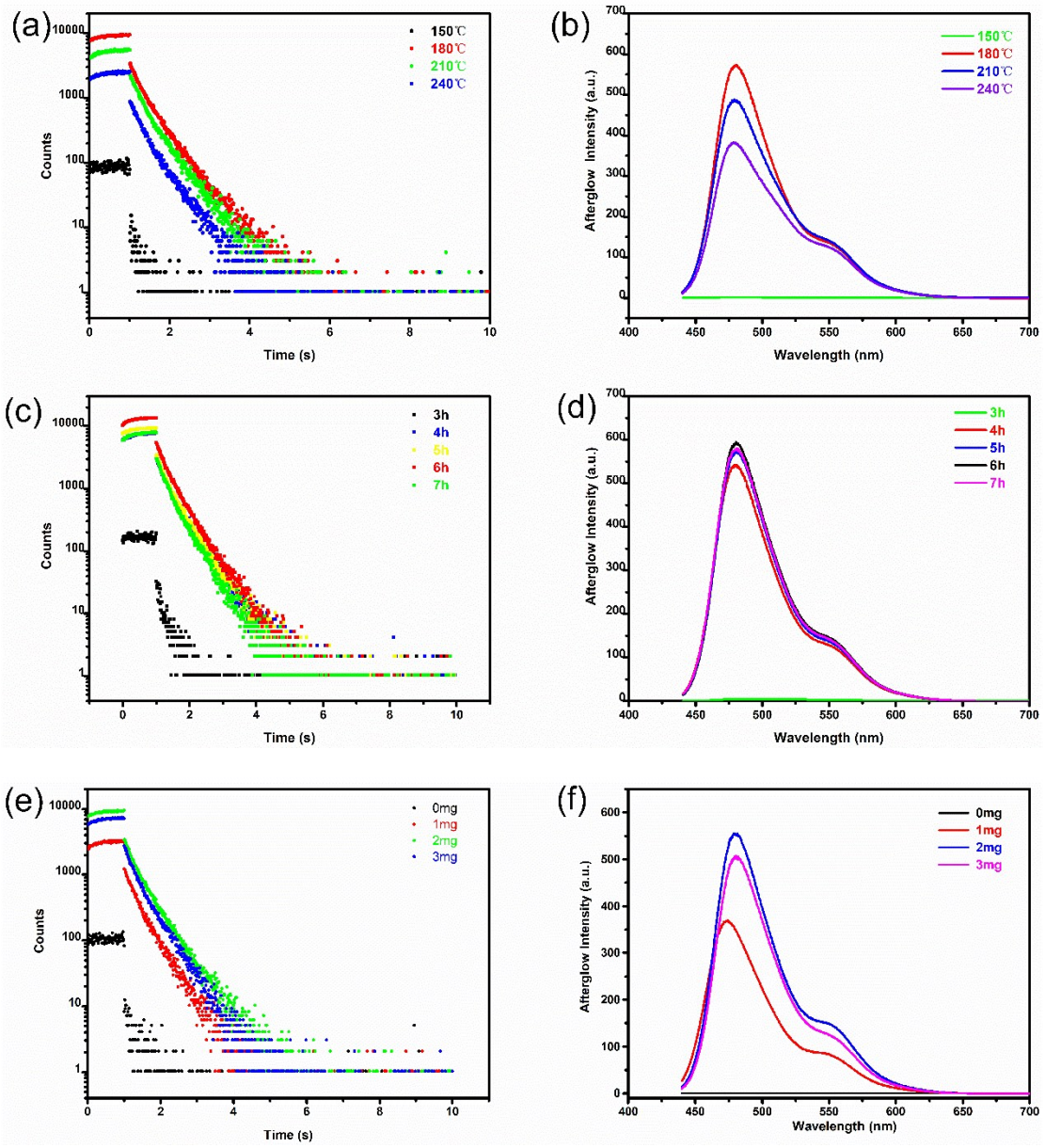


Figure S4. (a) The time-resolved decay curves of the G-CDs/B_2O_3 composite prepared at different temperatures, monitored at 480 nm with 420 nm excitation. (b) Afterglow emission spectra of the G-CDs/B_2O_3 composite prepared at different temperatures excited at 420 nm. (c) The time resolved decay curves of the G-CDs/B_2O_3 composite prepared at different time, monitored at 480 nm with 420 nm excitation. (d) Afterglow emission spectra of the G-CDs/B_2O_3 composite prepared at different time excited at 420 nm. (e) The time resolved decay curves of the G-CDs/B_2O_3 composite prepared at different ratios of G-CDs to BA (0, 1, 2, 3 mg/3 g) monitored at 480 nm with 420 nm excitation. (f) Afterglow emission spectra of the G-CDs/B_2O_3 composite prepared at different ratios of G-CDs to BA (0, 1, 2, 3 mg/3 g) excited at 420 nm.

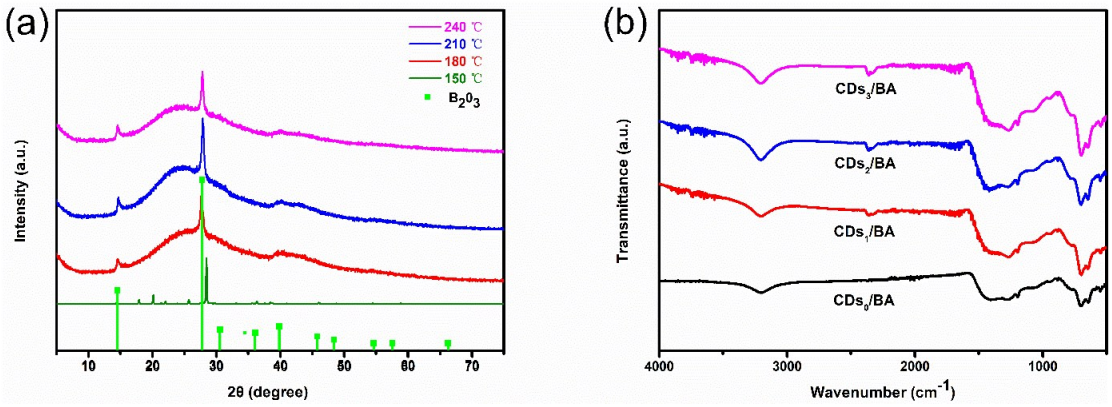


Figure S5. (a) XRD patterns of the G-CDs/B_2O_3 composite prepared at different temperatures. (b) FT-IR spectra of the G-CDs/B_2O_3 composite prepared at different ratio of G-CDs to BA (0, 1, 2, 3 mg/3 g).

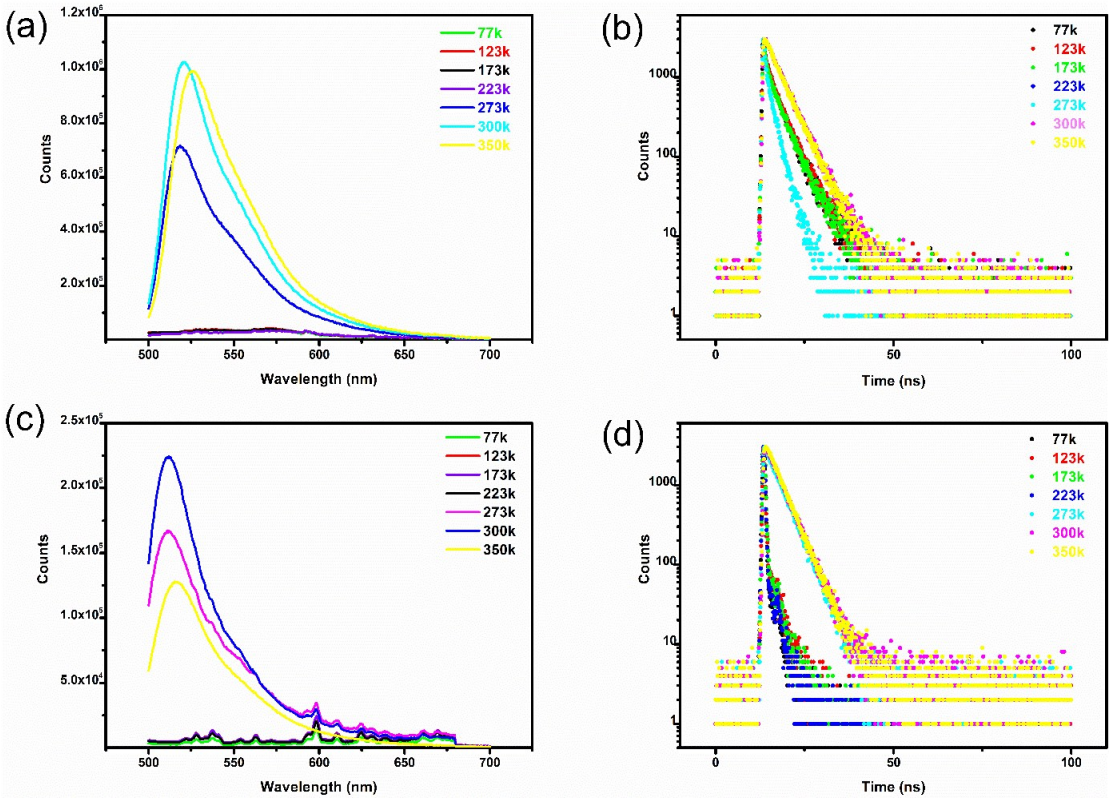


Figure S6. (a) Emission spectra and (b) the time-resolved decay curves (monitored at 518 nm under 480 nm excitation) of G-CDs in aqueous solution collected at different temperatures. (c) Emission spectra and (d) the time-resolved decay curves (monitored at 518 nm under 480 nm excitation) of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution collected at different temperatures.

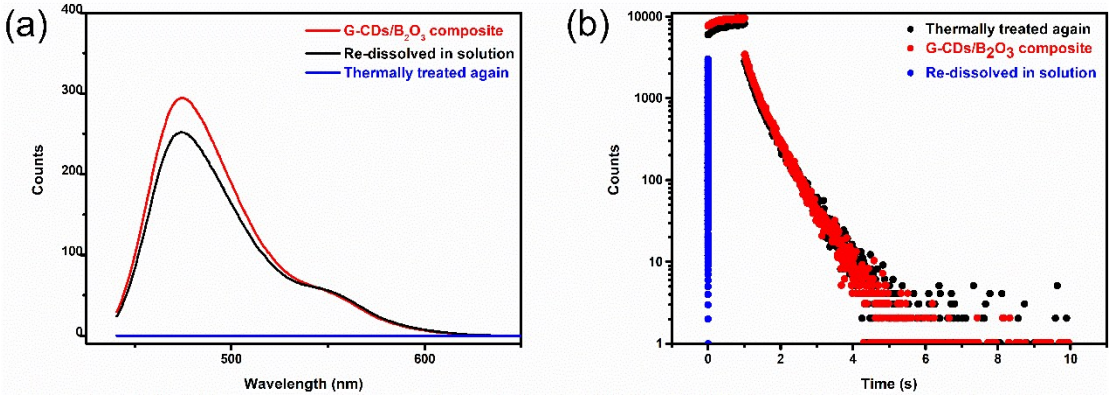


Figure S7. (a) Afterglow emission spectra and (b) the time-resolved afterglow decay curves of the G-CDs/B_2O_3 composite, re-dissolved in aqueous solution and then thermally treated again at 180 °C for 5 h.

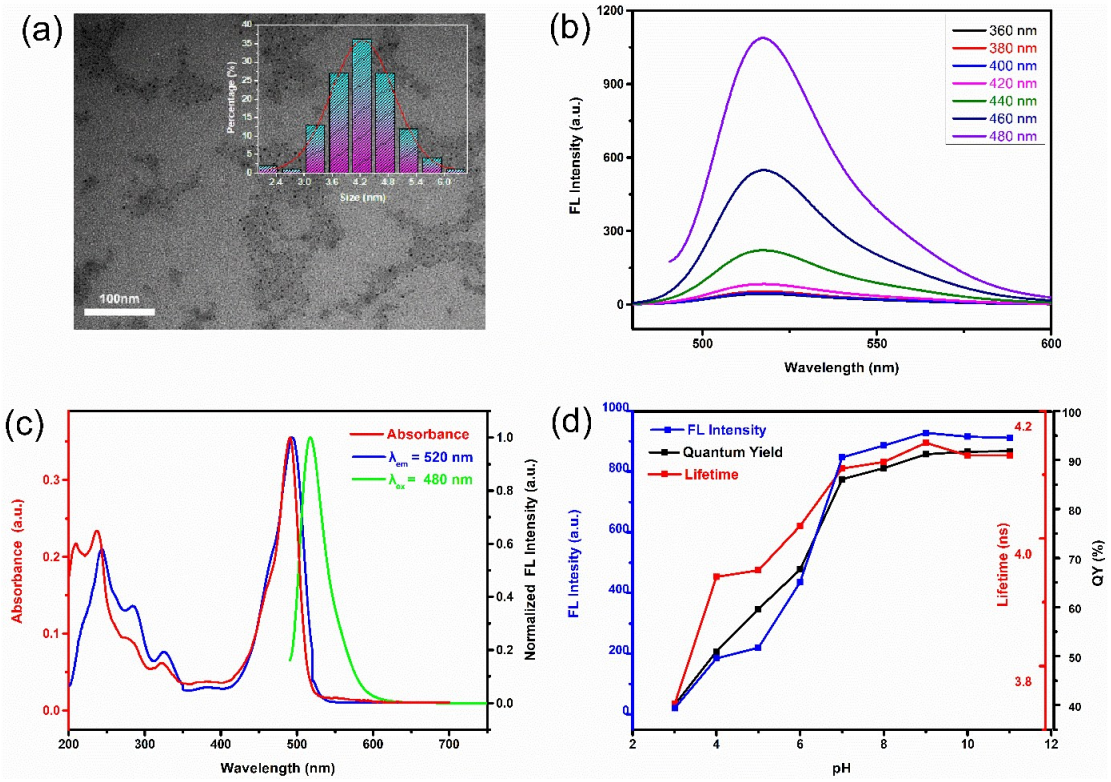


Figure S8. (a) TEM image of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution, inset: the size distribution of the particles in aqueous solution of the G-CDs/B_2O_3 composite. (b) Fluorescence spectra of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution. (c) Absorption, excitation and emission spectra of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution. (d) Fluorescence intensity, absolute quantum yield and fluorescence lifetime of the G-CDs/B_2O_3 composite re-

dissolved in aqueous solution monitored at 518 nm under excitation at 480 nm as functions of pH.

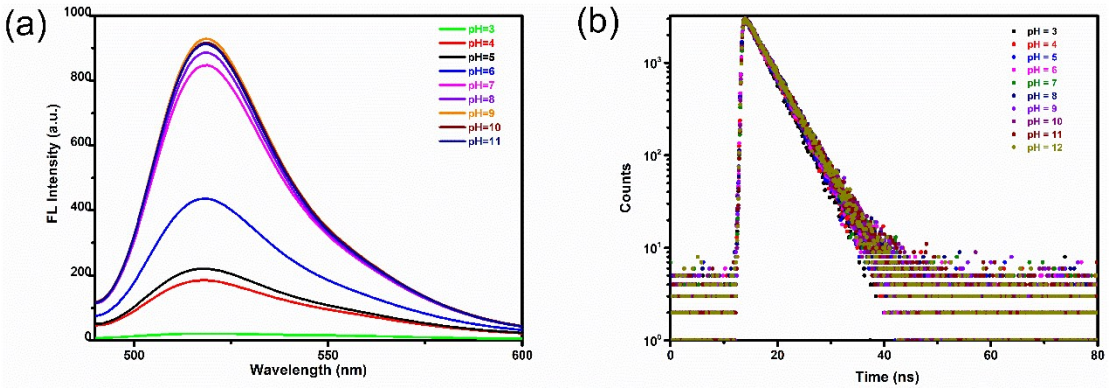


Figure S9. (a) Fluorescence emission spectra (b) the time-resolved decay spectra (monitored at 518 nm with 480 nm excitation) of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution at different pH values.

Table S1. The lifetimes and absolute quantum yields of G-CDs in aqueous solution at different pH values monitored at 518 nm emission with 480 nm excitation.

pH	τ_1[ns]	B_1[%]	T_{avg} [ns]	$\chi 2$	QY[%]
3	3.73	100	3.73	1.276	39.96
4	3.92	100	3.92	1.135	51.59
5	3.96	100	3.96	1.012	57.84
6	4.04	100	4.04	1.043	68.95
7	4.12	100	4.12	1.092	80.88
8	4.15	100	4.15	1.022	92.15
9	4.13	100	4.13	1.001	92.88
10	4.15	100	4.15	1.008	94.24
11	4.15	100	4.15	1.056	92.47

Table S2. A comparison between the decay time to naked eyes and the lifetime of afterglow for the G-CDs/B_2O_3 composite with those of afterglow materials.

Afterglow materials	Emission wavelength (nm)	Lifetime (ms)	Decay time to naked eyes (s)	Reference
CDs–APS	500	655	1.5	1
CQDs/PU	500	8.7	/	2
m-CDs@nSiO 2	470	703	/	3
CDs@Zn-CHA	500	22.32	/	4
CDs@Mn-LEV	620	18.14	/	4
CDs@MS	566	886	/	5
CDs @aluminum sulfate	500	876	/	6
m-CDs-PVA	506	456	/	7
CDs@MnAPO-CJ50	620	10.94	0.119	8
CDs@SiO2	455	1210	3	9
a-CDs/BA	530	1600	8	10
N-CDs/BA	532	2260	4	10
EDA-CDs/filter paper	502	693.67	7	11
CDs	420	1800	/	12
TA-CDs	560	183.6	2.5	13
P-CDs	518	822.69	7	14
$PCDs_{I-1}$	494	658.11	7	15
URTP CDs	535	1460	10	16
NCDs	515	747	2	17
G-CDs/B_2O_3	480	477.96	13	This work

Table S3. Afterglow lifetimes of the G-CDs/B_2O_3 composite prepared at different temperatures monitored at 480 nm emission with 420 nm excitation.

T[℃]	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	τ_{avg}[ms]	χ2
150	**34.81**	**74.07**	**399.53**	**25.93**	**129.39**	**1.342**
180	**251.10**	**25.73**	**556.56**	**74.27**	**477.96**	**0.990**
210	**201.73**	**25.57**	**540.97**	**72.43**	**447.44**	**1.105**
240	**194.06**	**23.61**	**501.88**	**76.39**	**429.20**	**1.019**

Table S4. Afterglow lifetimes of the G-CDs/B_2O_3 composite prepared at different reaction times monitored at 480 nm with 420 nm excitation.

T[h]	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	T_{avg}[ms]	χ2
3	**3.37**	**60.83**	**220.98**	**39.17**	**88.61**	**0.997**
4	**199.87**	**22.82**	**540.25**	**77.18**	**462.57**	**1.054**
5	**251.10**	**25.73**	**556.56**	**74.27**	**477.96**	**0.990**
6	**195.73**	**22.22**	**521.85**	**77.78**	**449.86**	**1.175**
7	**496.80**	**71.41**	**211.05**	**28.59**	**415.11**	**1.127**

Table S5. Afterglow lifetimes of the G-CDs/B_2O_3 composite prepared at different ratios of G-CDs to BA (0, 1, 2, 3 mg/3 g) excited at 420 nm monitored at 480 nm with 420 nm excitation.

M_{CDs}[mg]	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	τ_{avg}[ms]	χ2
0	**8.29**	**59.90**	**212.50**	**40.10**	**90.18**	**0.918**
1	**216.54**	**28.13**	**498.85**	**71.87**	**419.44**	**1.107**
2	**251.10**	**25.73**	**556.56**	**74.27**	**477.96**	**0.990**
3	**196.67**	**21.36**	**511.29**	**78.61**	**440.00**	**1.058**

Table S6. Afterglow lifetimes and absolute quantum yields of the G-CDs/B_2O_3 composite prepared at different pH monitored at 480 nm with 420 nm excitation.

pH	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	τ_{avg}[ms]	χ2	QY[%]
BA	**251.10**	**25.73**	**556.56**	**74.27**	**477.96**	**0.990**	**33.03**
3	**230.74**	**24.18**	**543.70**	**75.82**	**468.03**	**1.062**	**35.36**
4	**169.05**	**17.41**	**459.22**	**83.59**	**414.72**	**1.193**	**33.17**
5	**215.94**	**28.59**	**486.47**	**71.41**	**353.66**	**1.106**	**35.09**
6	**151.67**	**17.33**	**456.56**	**82.67**	**403.72**	**1.051**	**36.90**
7	**147.70**	**23.59**	**454.58**	**76.42**	**382.23**	**1.172**	**38.06**
8	**100.38**	**18.44**	**234.65**	**81.56**	**209.90**	**1.055**	**12.31**

Table S7. Afterglow lifetimes of the G-CDs/B_2O_3 composite monitored at 480 nm with 420 nm excitation at different temperatures.

T[k]	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	τ_{avg}[ms]	χ2
77	/	/	/	/	/	/
123	/	/	/	/	/	/
173	/	/	/	/	/	/
223	**718.60**	**100**	**0**	**0**	**718.60**	**0.850**
273	**275.58**	**12.52**	**881.84**	**87.48**	**805.94**	**1.263**
300	**251.10**	**25.73**	**556.56**	**74.27**	**477.96**	**0.990**
350	**68.83**	**66.71**	**125.39**	**33,29**	**87.88**	**1.332**

Table S8. The lifetimes of G-CDs in aqueous solution at different temperatures monitored at 518 nm emission with 480nm excitation.

T[k]	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	τ_{avg}[ns]	χ2
77	**0.52**	**13.47**	**4.16**	**86.53**	**3.67**	**1.113**
123	**0.78**	**16.43**	**4.32**	**83.57**	**3.74**	**1.094**
173	**0.61**	**15.27**	**4.16**	**84.73**	**3.62**	**1.095**
223	**0.55**	**24.57**	**3.58**	**75.43**	**2.84**	**0.939**
273	**0.38**	**20.08**	**2.24**	**79.92**	**1.87**	**1.327**
300	**4.44**	**100**	**0**	**0**	**4.44**	**0.961**
350	**4.34**	**100**	**0**	**0**	**4.34**	**1.064**

Table S9. The lifetimes of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution measured at different temperatures monitored at 518 nm emission with 480 nm excitation.

T[k]	τ_1[ms]	B_1[%]	τ_2[ms]	B_2[%]	τ_{avg}[ns]	χ2
77	**0.29**	**87.99**	**3.12**	**12.01**	**0.63**	**0.956**
123	**0.28**	**77.05**	**3.29**	**22.95**	**0.98**	**0.738**
173	**0.29**	**78.97**	**3.15**	**21.03**	**0.89**	**0.741**
223	**0.29**	**88.01**	**2.97**	**11.99**	**0.61**	**1.041**
273	**4.10**	**100**	**0**	**0**	**4.10**	**0.947**
300	**4.13**	**100**	**0**	**0**	**4.13**	**1.090**
350	**4.06**	**100**	**0**	**0**	**4.06**	**1.071**

Table S10. The lifetimes of the G-CDs/B_2O_3 composite re-dissolved in aqueous solution measured at different pH monitored at 518 nm emission with 480 nm excitation.

pH	τ_1[ns]	B_1[%]	T_{avg} [ns]	χ2	QY[%]
3	**3.74**	**100**	**3.74**	**1.085**	**40.05**
4	**3.94**	**100**	**3.94**	**1.027**	**50.97**
5	**3.95**	**100**	**3.95**	**1.208**	**59.64**
6	**4.02**	**100**	**4.02**	**1.192**	**67.62**
7	**4.11**	**100**	**4.11**	**1.134**	**86.12**
8	**4.12**	**100**	**4.12**	**1.111**	**88.34**
9	**4.15**	**100**	**4.15**	**1.184**	**91.20**
10	**4.13**	**100**	**4.13**	**1.082**	**91.69**
11	**4.13**	**100**	**4.13**	**1.109**	**91.77**

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