

Supporting information

Green synthesis of phosphorescent carbon dots for anti-counterfeiting and information encryption

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Chemicals and materials

Thiamine hydrochloride (Vitamin B1), ethylenediamine (EDA), and boric acid (BA) were purchased from Titan Scientific (Shanghai, China). Ultrapure water was used throughout the whole experiment.

Instrumentation

High-resolution transmission electron microscopy (HR-TEM) pictures were collected at 100 kV using a TECNAI G2 microscope (FEI, USA). The image of scanning electron micrographs (SEM) was measured by XL-30ESEM FEG scanning electron microscope (FEI, USA). FTIR spectra were conducted with a VERTEX 70 FT-IR spectrometer (Bruker, Germany). The X-ray photoelectron spectroscopy (XPS) spectra were acquired using an ESCALAB 250Xi spectrometer (ThermoFisher, USA). A Rigaku Minister apparatus was used to generate the X-ray diffraction (XRD) patterns (Tokyo, Japan). The UV absorption spectra were performed via a Hitachi UV2450 spectrophotometer (Tokyo, Japan). The fluorescence spectra were obtained using an F97Pro FL spectrophotometer coupled with a 1.0 cm quartz cell (Lengguang Technology, Shanghai). Also, the fluorescent and phosphorescent lifetime were analyzed at room temperature using an FLS-1000 fluorescence spectrophotometer (Edinburgh, UK).

Experimental Section

Synthesis of VB1-CDs

In general, 0.5 g of vitamin B1 was dissolved in 10 ml of ultrapure water initially, and then 150 μ l of EDA was dropped into the solution and ultrasonically dispersed well. Subsequently, the solution was transferred to a 50 ml poly(tetrafluoroethylene) lined autoclave and reacted at 180°C for 8 hours in a drying oven. After the reaction, the centrifuge (8000 rpm, 10 min) removes the pellets and prepares them for usage.

Synthesis of PCDs

Basically, aspirate 50 μ l, 100 μ l, 500 μ l, 1000 μ l of VB1-CDs solution into a small beaker, add 20 ml of ultrapure water, stir evenly, then add 3 g of boric acid, cover with tin foil, and place in a drying oven to react at 180°C for 5 hours, grinding the material into a powder.

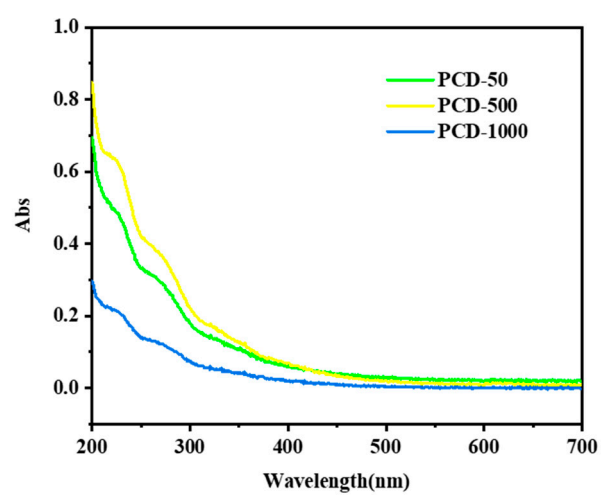


Figure S1 UV–Vis absorption of PCD50, PCD500 and PCD1000, respectively.

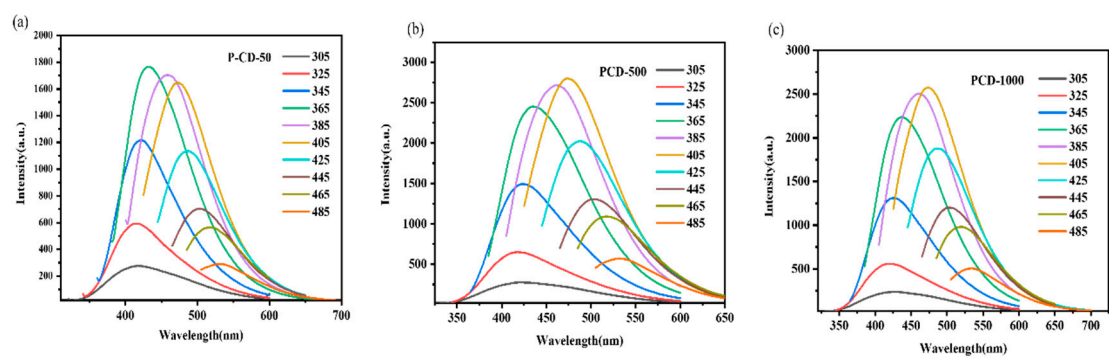


Figure S2 PL emission spectra of (a) PCD50, (b) PCD500 and (c) PCD1000 aqueous solution, respectively.

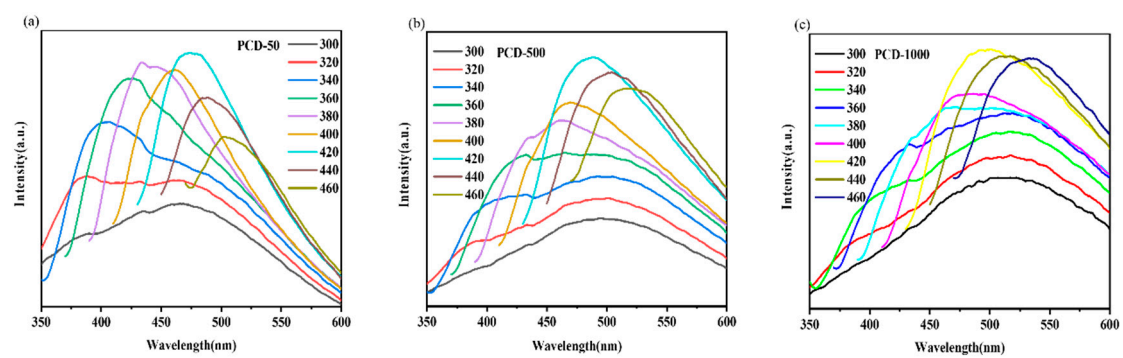


Figure S3 PL emission spectra of (a) PCD50, (b) PCD500 and (c) PCD1000 solid, respectively.

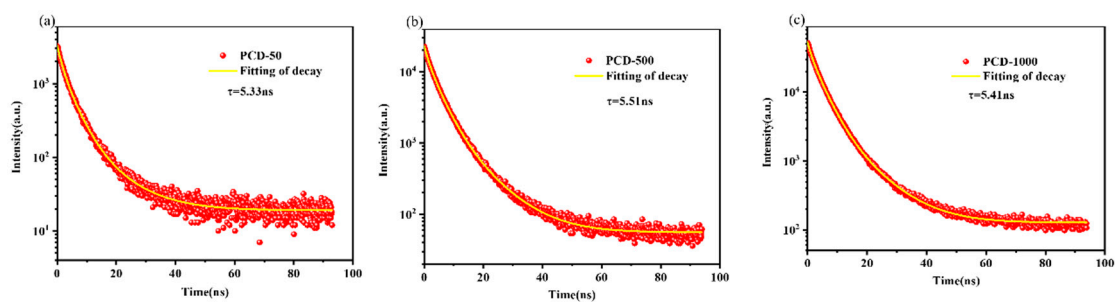


Figure S4 Fluorescence lifetime decay of (a) PCD50, (b) PCD500 and (c) PCD1000 aqueous solution respectively.

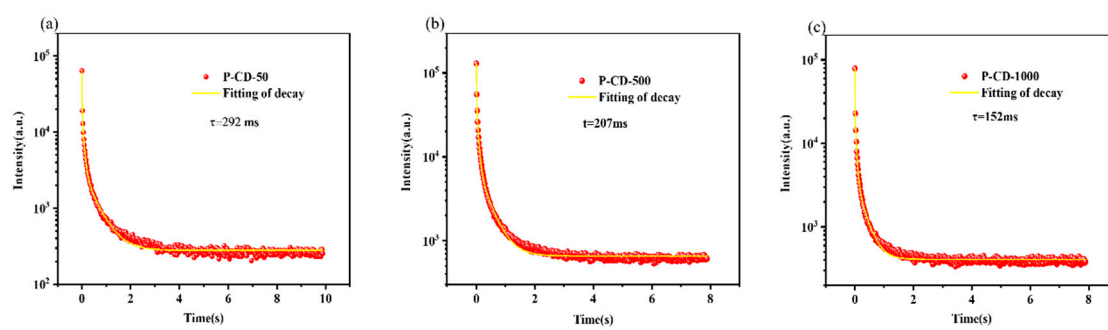


Figure S5 RTP lifetime decay of (a) PCD50, (b) PCD500 and (c) PCD1000 under the excitation of 365 nm, respectively.

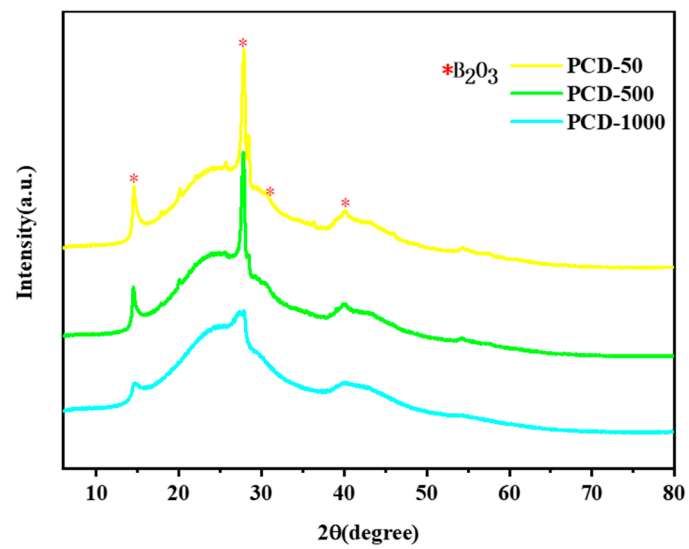


Figure S6 XRD patterns of PCD50, PCD500 and PCD1000, respectively.

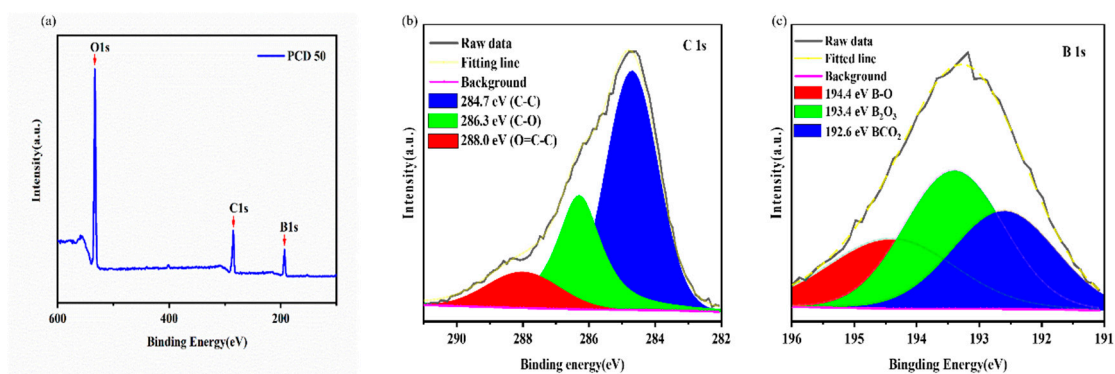


Figure S7 (a) Full scan XPS spectrum of PCD50. HR XPS C 1s (b) and B 1s (c) spectra of PCD50.

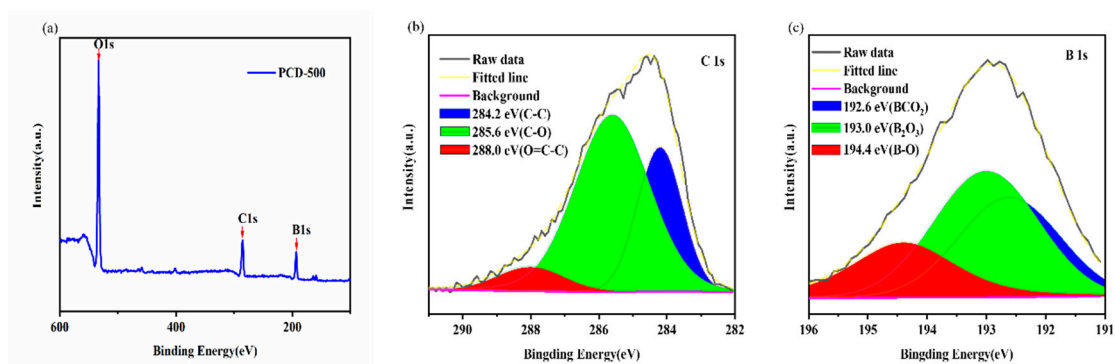


Figure S8 (a) Full scan XPS spectrum of PCD500. HR XPS C 1s (b) and B 1s (c) spectra of PCD500.

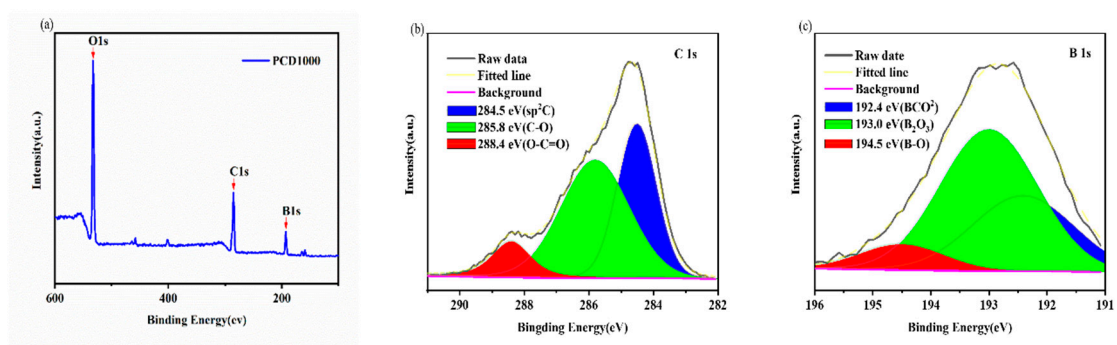


Figure S9 (a) Full scan XPS spectrum of PCD1000. HR XPS C 1s (b) and B 1s (c) spectra of PCD1000.

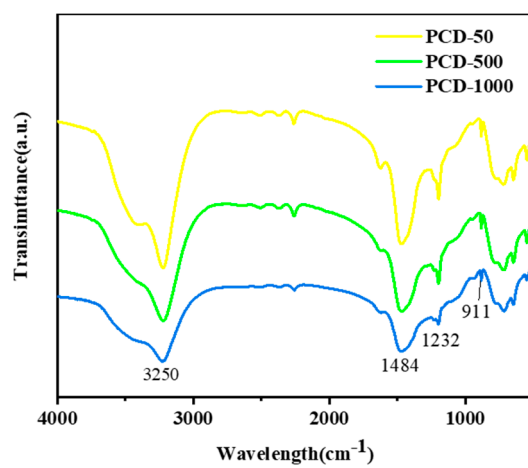


Figure S10 FTIR patterns of PCD50, PCD500 and PCD1000, respectively.

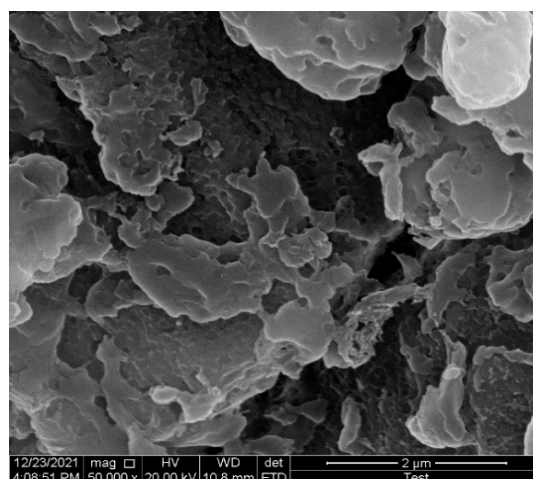


Figure S11 SEM image of PCD100

Table S1. Fluorescence lifetime of PCDs under 365 nm.

| PCDs | A1 | T1(ns) | A2 | T2(ns) | A3 | T3(ns) | T _{ave} (ns) |
|---------|----------|---------|----------|---------|----------|----------|-----------------------|
| PCD50 | 1314.064 | 1.53111 | 1706.274 | 4.08068 | 248.5376 | 11.19366 | 5.33 |
| PCD100 | 3676.45 | 1.85854 | 2989.83 | 4.94927 | 248.9425 | 14.6089 | 5.50 |
| PCD500 | 5792.112 | 1.35522 | 14605.4 | 3.9698 | 2578.231 | 10.16136 | 5.51 |
| PCD1000 | 11604.89 | 1.2001 | 35590.82 | 3.88546 | 5481.684 | 10.22111 | 5.41 |

Table S2. Photophysical lifetime of PCDs under 365 nm.

| PCDs | A1 | T1(ns) | A2 | T2(ns) | A3 | T3(ns) | T _{ave} (ns) | T _{ave} (ms) |
|---------|----------|----------|----------|----------|----------|-----------|-----------------------|-----------------------|
| PCD50 | 44966.45 | 8277670 | 15390.29 | 75772500 | 3061.887 | 518374000 | 292492397.9 | 292 |
| PCD100 | 45058.51 | 8344550 | 15339.14 | 76037900 | 3049.998 | 519701000 | 292762537 | 293 |
| PCD500 | 82537.85 | 10418800 | 38853.63 | 62177400 | 7637.832 | 383133000 | 206436458.5 | 207 |
| PCD1000 | 54628.6 | 6565740 | 19818.77 | 45523300 | 3849.948 | 285742000 | 151533921.4 | 152 |

Table S3. The contents of C, O and B in PCDs determined by XPS.

| PCDs | C Content(%) | O Content(%) | B Content(%) |
|------|--------------|--------------|--------------|
| 50 | 22.46 | 42.75 | 32.93 |
| 100 | 32.18 | 38.3 | 27.45 |
| 500 | 19.55 | 43.9 | 34.52 |
| 1000 | 30.33 | 39.38 | 27.35 |

Table S4. The FL emission peaks, RTP emission peaks, and calculated ΔE_{ST} of PCD50 and PCD100 stimulated at 300nm.

| | FL peak (nm) | RTP peak (nm) | ΔE_{ST} (eV) |
|--------|--------------|---------------|----------------------|
| PCD50 | 467 | 558 | 0.43 |
| PCD100 | 470 | 560 | 0.42 |