Electronic Supplementary Information

Low temperature synthesis of phosphorous and nitrogen co-doped yellow fluorescent carbon dots for sensors and bioimaging

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Measurement of quantum yield (Φ_s)

The Φ_s of the P,N-CD were determined by a comparative method as follows:

$$\Phi_s = \Phi_R(\mathrm{Grad_S}/\mathrm{Grad_R})\ (\eta^2_S/\eta^2_R) \qquad (1)$$

where Grad is the gradient from the plot of integrated fluorescence intensity against absorbance and η(1.333) is the refractive index of the solvent. The subscripts S and R represent P,N-CD and the reference (quinine sulfate in 0.10 M H_2SO_4). To prevent the re-absorption effect, the absorbances of P,N-CD and quinine sulfate solutions in the 10-mm fluorescence cuvette were adjusted to less than 0.10 at the excitation wavelength (λ_{ex}) of 380 nm (*i.e.*, the moderate excitation wavelength of P,N-CD and quinine sulfate). The integrated fluorescence intensity was the area under the PL curve in the wavelength range 460–720 nm. The Φ_R was taken as 0.54 since it is almost independent (within 5%) with λ_{ex} at 200–400 nm.[1,2]

Reference

[1] X. Wang, K. Qu, B. Xu, J. Ren and X. Qu, *J. Mater. Chem.*, 2011, **21**, 2445.
[2]Y. Fang, S. Guo, D. Li, C. Zhu, W. Ren, S. Dong and E. Wang, *ACS Nano*, 2012, **6**, 400.

Table S1. Elemental analysis of the as-synthesised P,N-CD: (A) elemental content and (B) relative number of atom in P,N-CD.

(A)

Sample name	Elemental content (%)				
	C	H	N	P	O (Calculated)
P,N-CD	8.62	2.72	1.56	21.60	65.50

(B)

Sample name	Relative number of atom					Empirical formula
	C	H	N	P	O	
P,N-CD	13	49	2	13	74	$C_{13}H_{49}N_2P_{13}O_{74}$

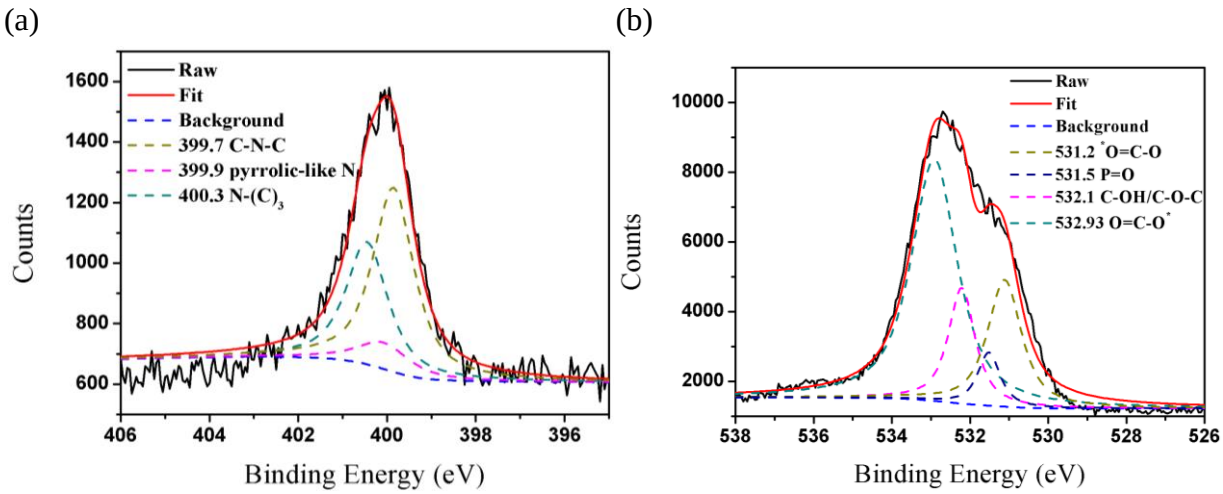

Fig. S1. (a) N1s XPS and (b) O1s XPS of P,N-CD.

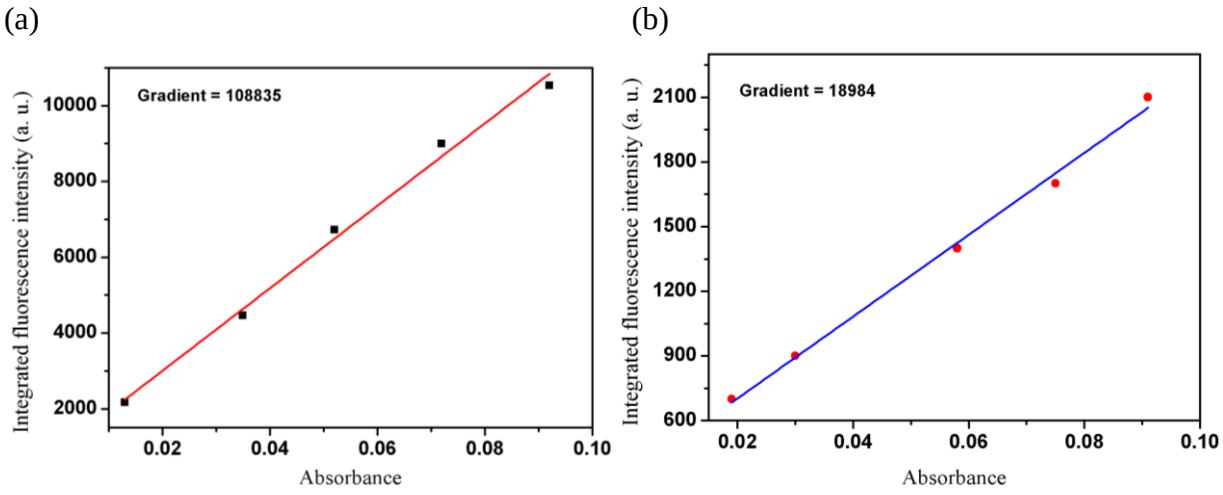

Fig. S2. Plots of integrated PL intensity against absorbance of (a) quinine sulfate and (b) P,N-CD at λ_{ex} of 380 nm.

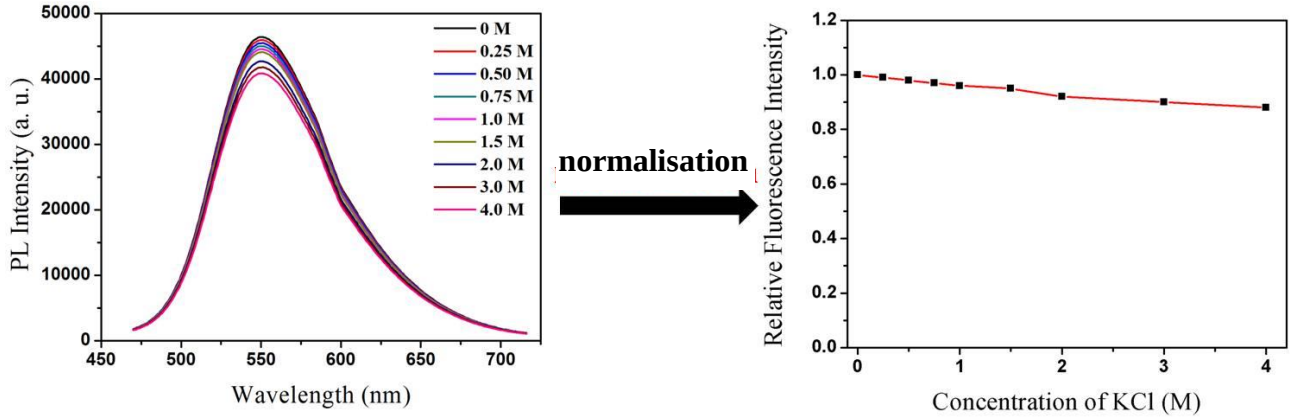

Fig. S3. Effect of ionic strength on fluorescence intensity of P,N-CD. The ionic strength is controlled by KCl.

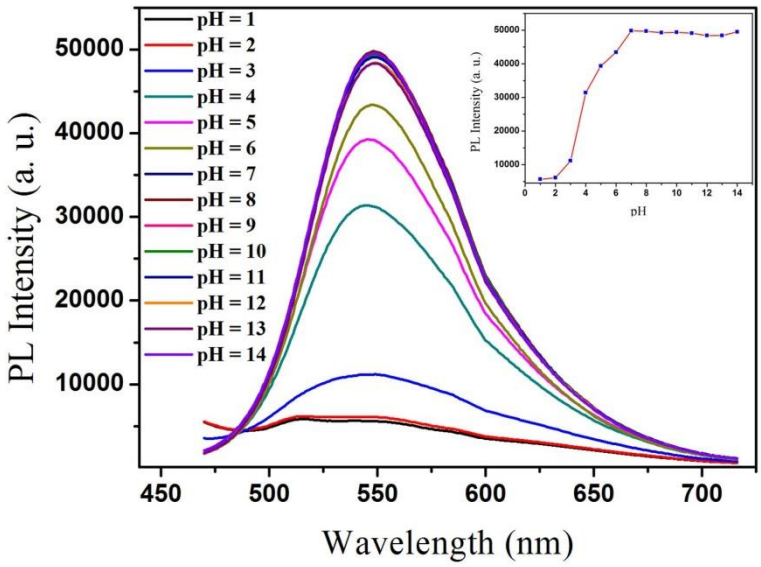

Fig. S4. The PL spectra of P,N-CD at different pHs (1.0–14). The inset displays the PL intensity of P,N-CD against pH at $\lambda_{ex}/\lambda_{em}$ of 425/550 nm.

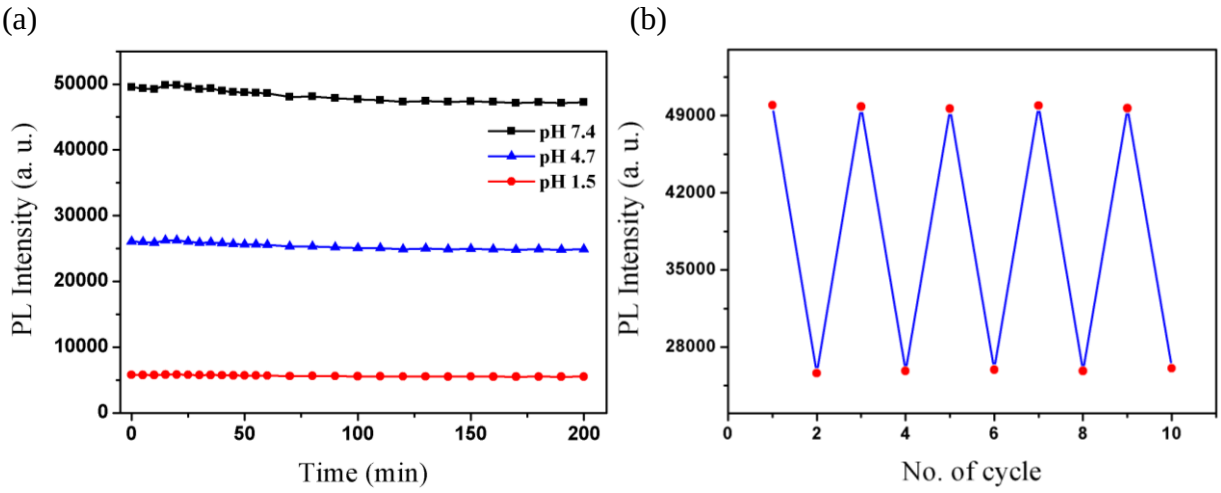

Fig. S5. (a) Changes in fluorescence intensity of P,N-CD with time at pH 7.4, 4.7 and 1.5. Excitation and emission bandwidths are both set at 2 nm. (b) Changes in the PL intensity of P,N-CD cycled between pH 7.4 and 4.7. $\lambda_{ex}/\lambda_{em}$ are 425/550 nm.

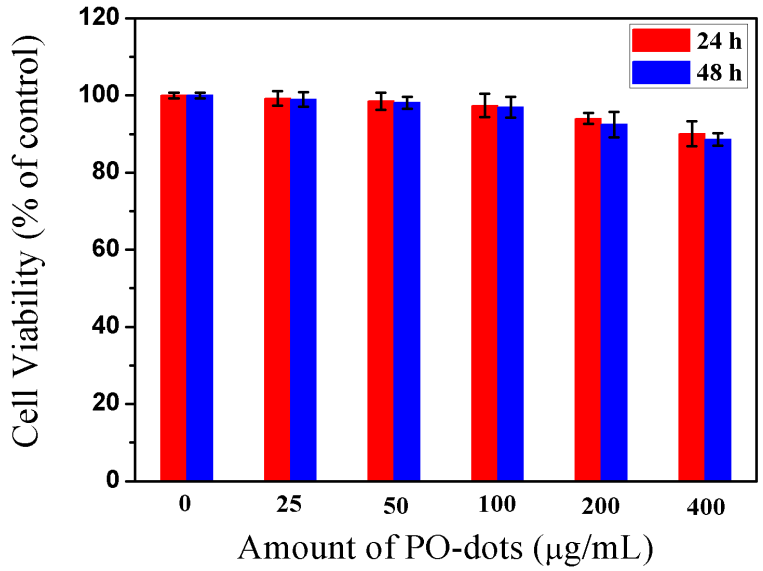

Fig. S6. Cytotoxicity test of P,N-CD on MCF-7 cells viability. The values represent percentage cell viability (mean% ± SD, *n*=6).

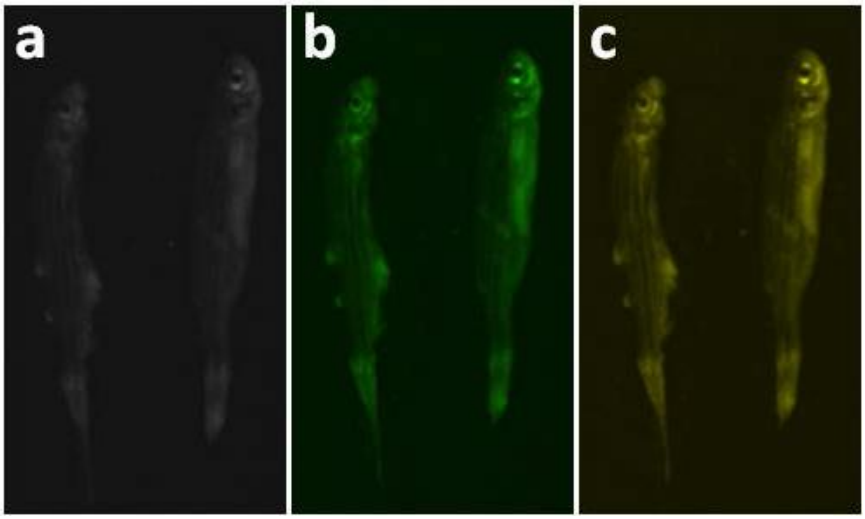

Fig. S7. *In vivo* zebrafish imaging of P,N-CD under (a) bright field, (b) $\lambda_{ex}/\lambda_{em}$ of 435/525 nm, and (c) 470/570 nm for 60 min (left) and 120 min (right).

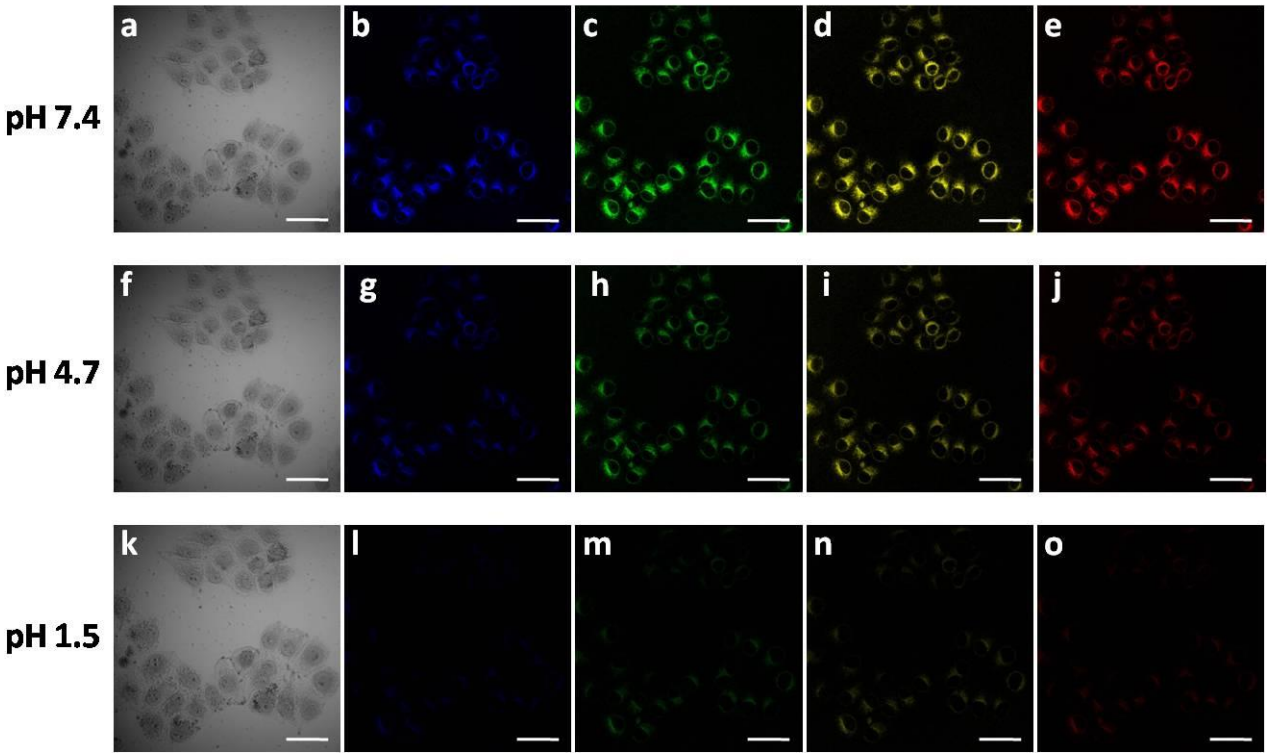

Fig. S8. Confocal fluorescence imaging of MCF-7 cells incubated with 0.40 mg/mL P,N-CD for 60 min at pH 7.4, 4.7 and 1.5. (a), (f) and (k) show the bright field images of MCF-7 cells. (b), (g) and (i), (c), (h) and (m), (d), (i) and (n), and (e), (j) and (o) are cell images taken at $\lambda_{ex}/\lambda_{em}$ of 405/422 ± 25, 488/500 ± 25, 515/570 ± 25 and 543/650 ± 25 nm, respectively. Scale bar, 50 μm.