

Nitrogen and phosphorus co-doped carbon dots as a “turn-off-on” fluorescence probe for the detection of Hg²⁺ and GSH and cell imaging

Xuefang Yang,^a Mengting Zhang,^b Yulu Zhang,^b Ning Wang^b and Wei Bian,^{*b} and Martin M.F. Choi^c

^a College of Pharmacy, Shanxi Medical University, 030001, Taiyua, China.

^b School of Basic Medical Science, Shanxi Medical University, 030001, Taiyuan, China.

^c Bristol Chinese Christian Church, c/o Tyndale Baptist Church, 137-139 Whiteladies Road, Bristol, BS8 2QG, United Kingdom

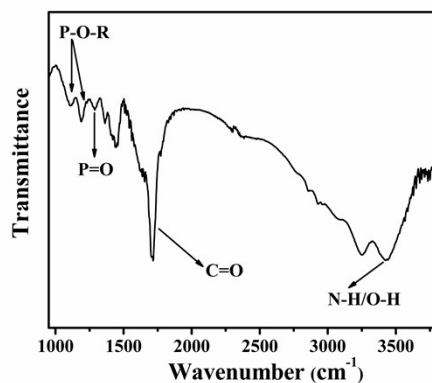


Fig. S1. FT-IR spectrum of NPCDs.

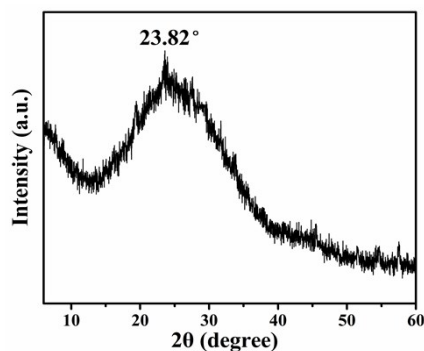


Fig. S2. XRD spectrum of NPCDs.

* Corresponding author.

E-mail address: sxykdx_bianwei@163.com.

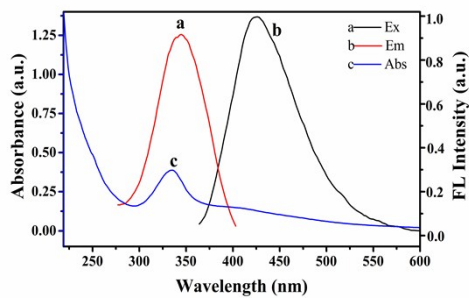


Fig. S3. The fluorescence excitation spectrum (a), The fluorescence emission spectrum of NPCDs (b), UV-Vis absorption spectrum (c).

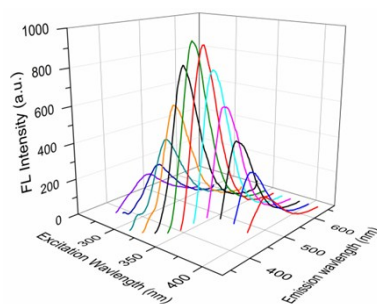


Fig. S4. 3D excitation-dependent fluorescence spectrum of NPCDs.

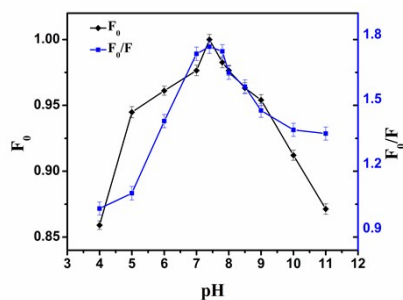


Fig. S5. The fluorescence intensity of NPCDs-Hg²⁺ system and NPCDs-Hg²⁺-GSH system at different pH.

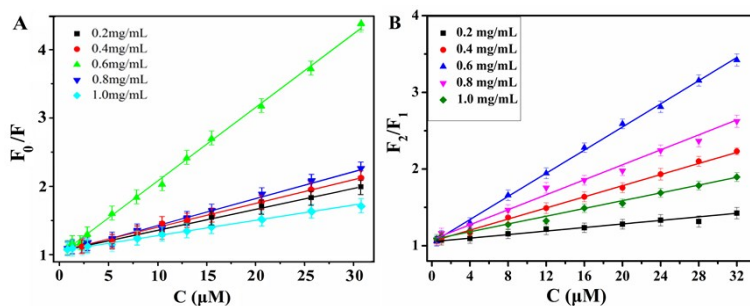


Fig. S6. Effect of the fluorescence intensity of NPCDs-Hg²⁺ (A) and NPCDs-Hg²⁺-GSH (B) at 0.20-1.0 mg/mL NPCDs

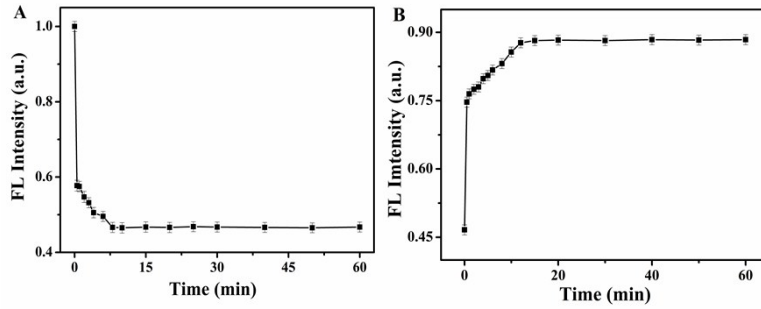


Fig. S7. The effect of the reaction time on the fluorescence intensity of NPCDs-Hg²⁺ system (A), NPCDs-Hg²⁺-GSH system (B).

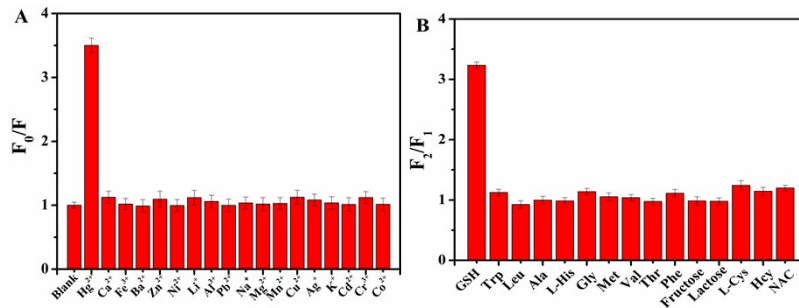


Fig. S8. The effect of different metal ions on the fluorescence intensity of NPCDs (A); The relative fluorescence intensity ratio (F_2/F_1) of NPCDs-Hg²⁺ system in the presence of GSH and other amino acids (B).

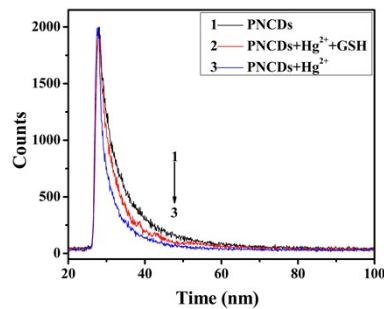


Fig. S9. The fluorescence lifetime in the presence of (1) NPCDs; (2) NPCDs- Hg²⁺-GSH system; (3) NPCDs- Hg²⁺ system.

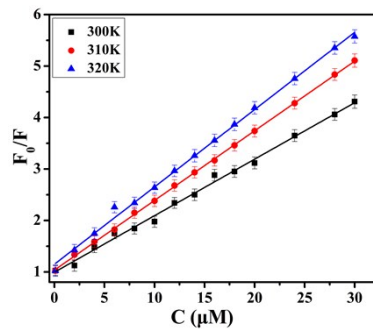


Fig. S10. Stern-Volmer curves of NPCDs-Hg²⁺ system at different temperatures.

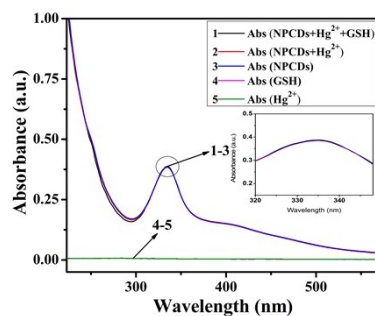


Fig. S11. UV-vis absorption spectra of (1) NPCDs- Hg^{2+} -GSH system, (2) NPCDs- Hg^{2+} system, (3) NPCDs, (4) GSH, and (5) Hg^{2+} .

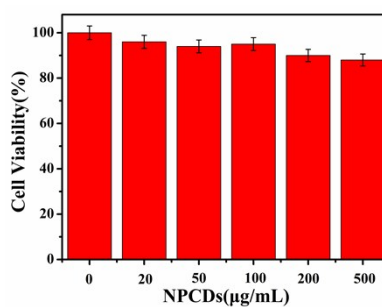


Fig. S12. Cells viability of at different NPCDs concentrations.

Table S1 The fluorescence intensity of NPCDs in the presence of Hg^{2+} with 40-fold interfering substances

Interferents	Concentration of interferent (μM)	Change of fluorescence intensity (%)	Interferents	Concentration of interferent (μM)	Change of fluorescence intensity (%)
Na^+	600	1.36	Trp	600	-0.72
K^+	600	0.57	Leu	600	3.54
Ca^{2+}	600	-2.69	Ala	600	1.39
Ba^{2+}	600	1.13	L-His	600	2.84
Mg^{2+}	600	0.50	Gly	600	-0.76
Zn^{2+}	600	3.03	Met	600	1.50
Fe^{3+}	600	-1.43	Val	600	-0.65
Cu^{2+}	600	-0.99	Thr	600	2.14
Ag^+	600	1.22	Phe	600	1.37
Al^{3+}	600	0.97	L-Cys	600	2.44
Co^{2+}	600	-2.98	Hcy	600	-1.59
Cd^{2+}	600	1.05	<i>N</i> -acetyl-L-cysteine	600	-0.72
Li^+	600	-0.75	Fructose	600	2.31
Mn^{2+}	600	-2.05	Lactose	600	0.65
Pb^{2+}	600	2.61			

Table S2 The fluorescence intensity of NPCDs- Hg²⁺ system in the presence of GSH with 40-fold interfering substances

Interferents	Concentration of interferent (μM)	Change of fluorescence intensity (%)	Interferents	Concentration of interferent (μM)	Change of fluorescence intensity (%)
Na ⁺	640	0.36	Trp	640	1.72
K ⁺	640	1.41	Leu	640	2.50
Ca ²⁺	640	1.68	Ala	640	-1.16
Ba ²⁺	640	-2.53	L-His	640	1.39
Mg ²⁺	640	0.57	Gly	640	0.53
Zn ²⁺	640	-2.14	Met	640	-0.87
Fe ³⁺	640	-1.43	Val	640	1.98
Cu ²⁺	640	-3.29	Thr	640	3.04
Ag ⁺	640	2.22	Phe	640	0.76
Al ³⁺	640	-1.87	L-Cys	640	-1.53
Co ²⁺	640	1.35	Hcy	640	0.63
Cd ²⁺	640	-2.13	N-acetyl-L-cysteine	640	2.14
Li ⁺	640	0.69	Fructose	640	-2.01
Mn ²⁺	640	-1.05	Lactose	640	1.73
Pb ²⁺	640	3.11			

Table S3 Average fluorescence lifetime (τ) of NPCDs, NPCDs+Hg²⁺ and NPCDs+Hg²⁺+GSH Hg²⁺ and the fitting parameters of the biexponential fitting curves

Sample	B ₁	B ₂	τ_1	τ_2	τ (ns)
NPCDs	1082.58	731.85	3.12	10.62	6.15
NPCDs+Hg ²⁺	1064.25	786.08	2.78	9.56	5.69
NPCDs+Hg ²⁺ +GSH	1055.24	805.10	2.99	9.88	5.97

Table S4 Determination of Hg²⁺ in biological samples

Samples	Added (μM)	Found (μM)	Recovery (%)	RSD (%)
Urine	6.00	5.80	96.70	2.3
	12.00	12.31	102.50	1.1
	18.00	18.10	100.60	3.1
Serum	6.00	6.20	103.30	2.5
	12.00	11.83	98.30	1.6
	18.00	18.32	101.71	2.1

Table S5 Determination of GSH in biological samples

Samples	Concentration of GSH		Recovery (%)	RSD (n=3) (%)
	Added (μM)	Found (μM)		
Urine sample	6.00	6.17	102.83	2.8
	12.00	12.25	102.08	1.4
	18.00	17.54	97.44	3.2
Serum sample	6.00	9.46	101.28	2.6
	12.00	15.06	99.41	3.0
	18.00	21.02	98.50	3.1