Electronic Supplementary Information

Facile Synthesis of Magnetic Fluorescence Fe_3O_4-Carbon Dots for Detection and Removal of Hg^{2+}

*Mingyu Tang,[1] Guojuan Ren,[1] Fang Chai**

Key Laboratory of Photochemical Biomaterials and Energy Storage Materials, Heilongjiang Province; Key Laboratory for Photonic and Electronic Bandgap Materials, Ministry of Education, Harbin Normal University, Harbin, 150025, Heilongjiang, China.

E-mails: fangchai@gmail.com

Determination of the fluorescence QY

The QY of the N/S CDs was determined by a widely recognized process. As a rule, quinine sulfate in 0.1 M H_2SO_4 aqueous solution was chosen to be the reference (QY: 54% at 340 nm). In order to abate the reabsorption effects, the solution of reference sample and the CDs were always further diluted to keep the absorbance under below 0.1, respectively. The QY of the CDs is calculated following the equation below:

$$Q_{CDs} = Q_R \left(\frac{Grad_{CDs}}{Grad_R} \right) \left(\frac{\eta_{CDs}^2}{\eta_R^2} \right)$$

where subscripts R refers to quinine sulfate and N/S co-doping CDs, Q refers to the QY, Grad represents the gradient from the plot of integrated FL intensity / absorbance, and η is the refractive index of the solvent (η_{water}: 1.33).[1, 2]

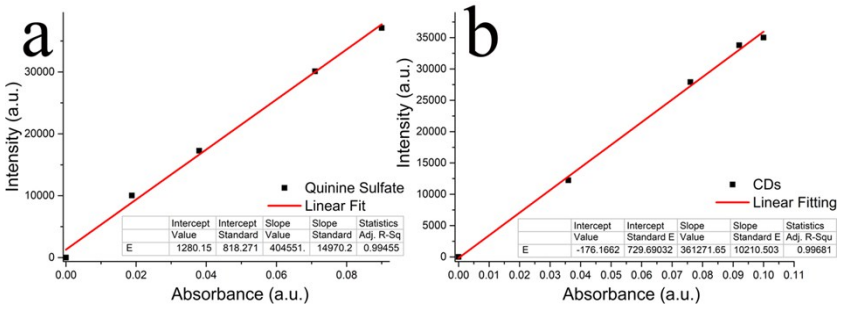

Fig. S1 Plots of integrated PL intensity of quinine sulfate and CDs as a function of optical absorbance at 340 nm.

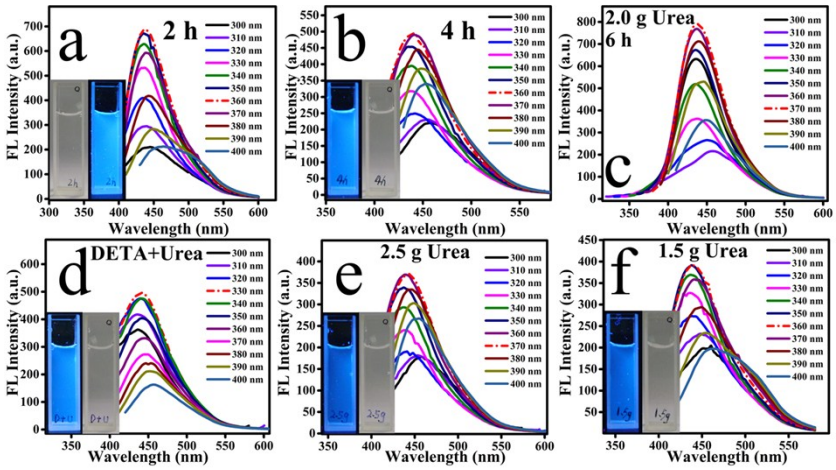

Fig. S2 Fluorescence spectra of the Fe_3O_4-CDs synthesized under (a) 2 h, (b) 4 h, (c) 6 h, (d) DETA+Urea, (e) 2.5 g Urea, (f) 1.5 g Urea.

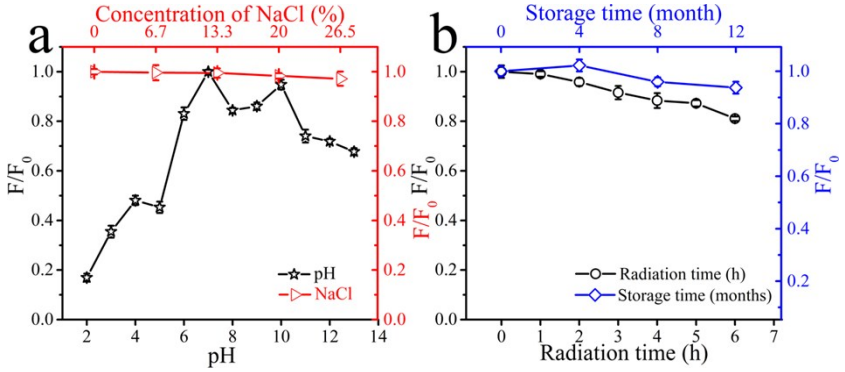

Fig. S3 (a) Fluorescence spectra stability under different salinity and pH (b) The fluorescence quenching ratio after UV radiation exposure and storage time.

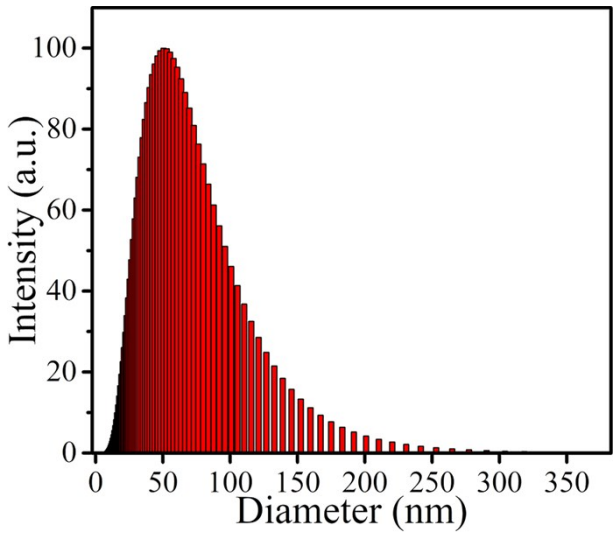

Fig. S4 DLS analysis of the Fe_3O_4-CDs

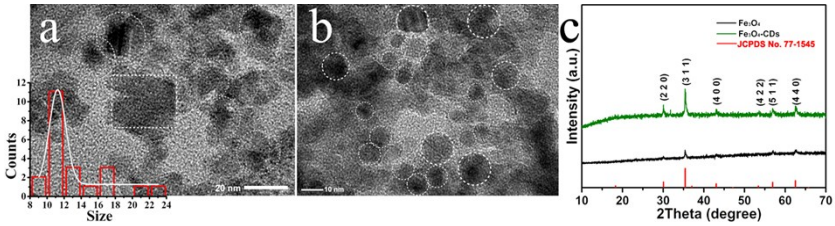

Fig. S5 (a) TEM of Fe_3O_4, (b) HRTEM of the Fe_3O_4-CDs image in scale of 10 nm, (c) XRD analysis of the Fe_3O_4-CDs.

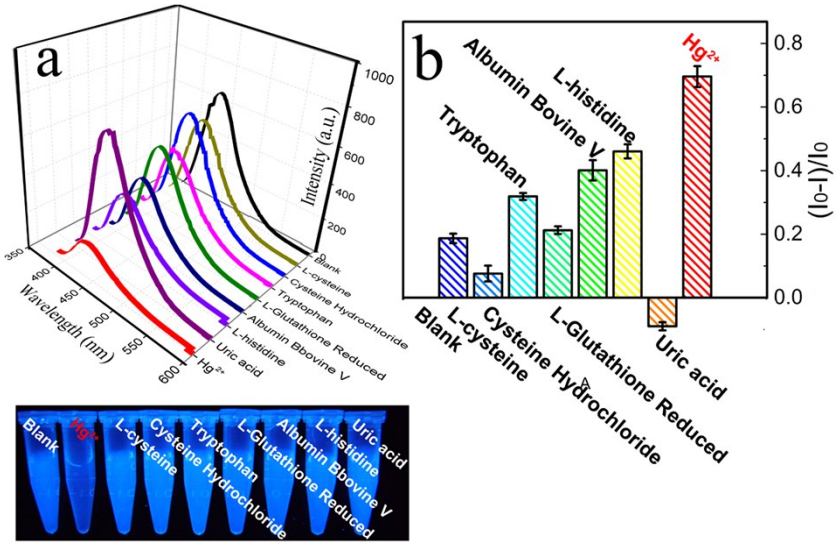

Fig. S6. (a) Fluorescence spectra and (b) bar diagram of different amino acids sensing. Insert: the corresponding image under UV lamp.

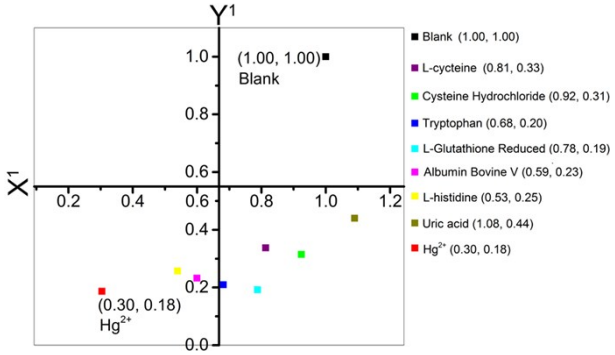

Fig. S7. The coordinate system in the anti-interference test, fluorescence intensity ratio value of X^1: (CDs+ biological substance) to (CDs+H_2O); Y^1: (CDs+ Amino Acid +Hg^{2+}) to (CDs+H_2O+H_2O).

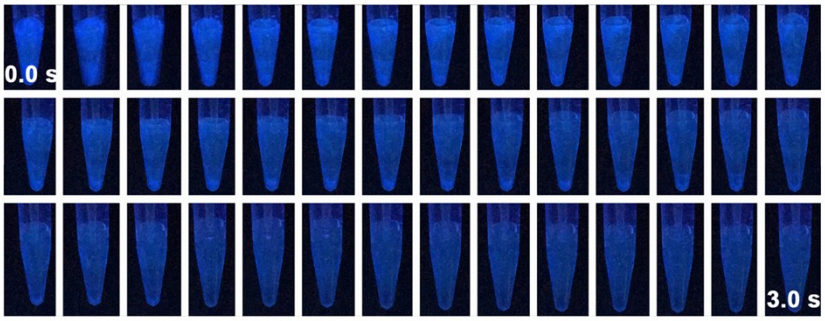

Fig. S8. The corresponding images of the CDs captured in 3.0 s when added with Hg^{2+}.

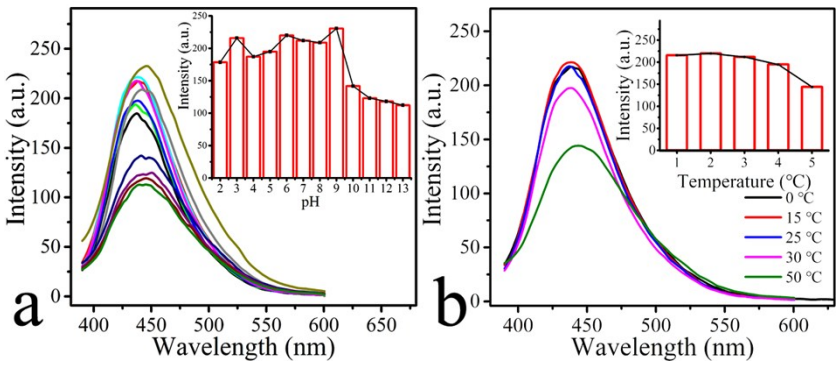

Fig. S9. The fluorescence intensity of the CDs based probe towards Hg^{2+} under different (a) pH and (b) temperature.

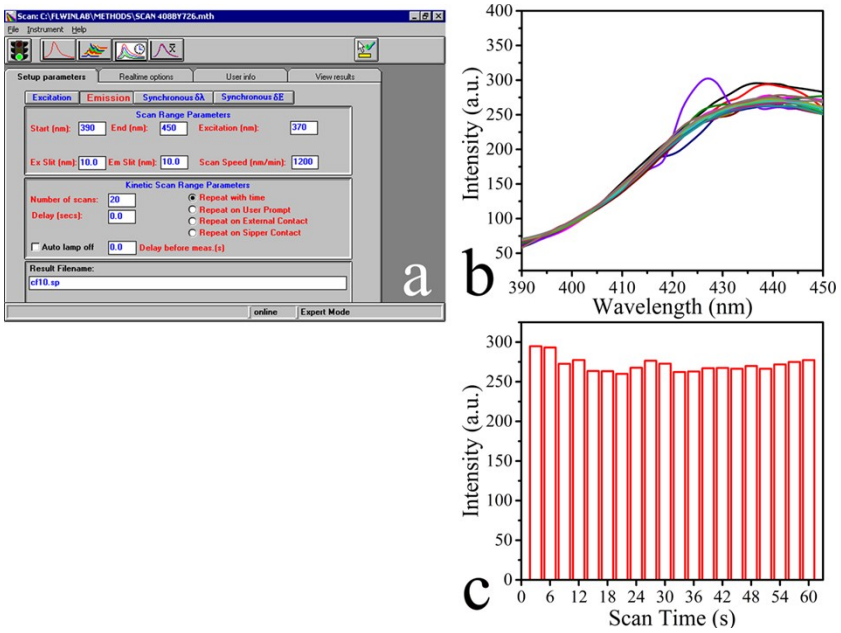

Fig. S10. (a) The instrument test condition, (b) Corresponding fluorescence spectra and (c) intensity bars.

Table S1 Comparison of several types of probe for the Hg^{2+} detection.

Methods	Probe type	LOD (M)	Ref.
Nitrogen-doped carbon dots	Fluorescence	2.00×10^{-8} M	[3]
Carbon dots	Fluorescence	6.20×10^{-8} M	[4]
Carbon dots	Fluorescence	38 ppb	[5]
Nitrogen- and Sulfur-Codoped Carbon Dots	Fluorescence	8.30×10^{-8} M	[6]
Carbon dots	Fluorescence	1.14×10^{-8} M	[7]
N-doped carbon dots	Fluorescence	2.30×10^{-8} M	[8]
Cinamaldehyde and pyrimidine	Colourmetric	3.90×10^{-7}	[9]
ZnO/rGO/PPy	Electrochemical	1.90×10^{-9}	[10]
Mn-doped ZnSe QDs	Fluorescence	7.00×10^{-9}	[11]
Naphthalimide–rhodamine	Colourmetric	6.69×10^{-7}	[12]
Gold nanoparticles	Colourmetric	3.80×10^{-8}	[13]
Thymine	Fluorescence	1.00×10^{-9}	[14]
Carbon dots	Fluorescence	1.26×10^{-8}	This work

Table S2 The ICP analysis of the removal test.

Mean Data: Sample 1

Analyte	CPS or Ratio	Conc.	RSD (%)	Time (sec)
Hg	7.281898E-4 P	<0.000 ppb	1.38	6.00

Mean Data: Sample 2

Analyte	CPS or Ratio	Conc.	RSD (%)	Time (sec)
Hg	0.05989022 P	44.17 ppb	2.9	6.00

Mean Data: Sample 3

Analyte	CPS or Ratio	Conc.	RSD (%)	Time (sec)
Hg	0.03961200 P	28.66 ppb	1.86	6.00

Table S3 Analytical results for Hg^{2+} detection in real samples.

Sample	Spiked (μM)	Found (μM)	Recovery (%)	RSD (%, n=5)
Tap Water	0.05	$0.05\pm2.57\times10^{-3}$	98.6-101.1	1.1
	0.20	$0.20\pm3.60\times10^{-3}$	98.3-102.8	1.8
	0.50	$0.49\pm5.39\times10^{-3}$	95.5-105.3	4.9
Sea Water	0.05	$0.05\pm3.01\times10^{-3}$	95.8-101.9	5.9
	0.20	$0.21\pm8.90\times10^{-3}$	95.8-106.8	4.3
	0.50	$0.50\pm1.22\times10^{-2}$	95.6-105.2	2.5
Human serum	0.05	$0.05\pm2.66\times10^{-3}$	96.7-102.9	5.4
	0.20	$0.21\pm5.85\times10^{-3}$	95.3-107.8	2.8
	0.50	$0.52\pm1.06\times10^{-2}$	95.8-103.1	2.0

Reference

1. E. Priyadarshini, K. Rawat, T. Prasad and H. B. Bohidar, *Colloids and surfaces. B, Biointerfaces*, 2018, **163**, 355-361.
2. B. Demir, M. M. Lemberger, M. Panagiotopoulou, P. X. Medina Rangel, S. Timur, T. Hirsch, B. Tse Sum Bui, J. Wegener and K. Haupt, *ACS applied materials & interfaces*, 2018, **10**, 3305-3313.
3. A. Iqbal, K. Iqbal, L. Xu, B. Li, D. Gong, X. Liu, Y. Guo, W. Liu, W. Qin and H. Guo, *Sensors and Actuators B: Chemical*, 2018, **255**, 1130-1138.
4. R. Tabaraki and N. Sadeghinejad, *Ecotoxicology and environmental safety*, 2018, **153**, 101-106.
5. E. Yahyazadeh and F. Shemirani, *Heliyon*, 2019, **5**, e01596.
6. H. Wu and C. Tong, *Journal of Agricultural and Food Chemistry*, 2019, **67**, 2794-2800.
7. L. Luo, P. Wang, Y. Wang and F. Wang, *Sensors and Actuators B: Chemical*, 2018, **273**, 1640-1647.
8. X. Sun, S. Yang, M. Guo, S. Ma, M. Zheng, J. He, *Analytical Sciences,* 2017, **33**, 761-767.
9. J. M. Jung, C. Kim and R. G. Harrison, *Sensors and Actuators B: Chemical*, 2018, **255**, 2756-2763.
10. Y. Zhuang, M. Zhao, Y. He, F. Cheng and S. Chen, *Journal of Electroanalytical Chemistry*, 2018, **826**, 90-95.
11. Z.-Q. Zhou, R. Yan, J. Zhao, L.-Y. Yang, J.-L. Chen, Y.-J. Hu, F.-L. Jiang and Y. Liu, *Sensors and Actuators B: Chemical*, 2018, **254**, 8-15.
12. Y. Wang, H. Ding, S. Wang, C. Fan, Y. Tu, G. Liu and S. Pu, *RSC Advances*, 2019, **9**, 11664-11669.
13. H. Chen, W. Hu and C. M. Li, *Sensors and Actuators B: Chemical*, 2015, **215**, 421-427.
14. Y. Shan, B. Wang, H. Huang, D. Jian, X. Wu, L. Xue, S. Wang and F. Liu, *Biosensors & bioelectronics*, 2019, **132**, 238-247.