

## Supplementary information

**Preparation of carbon quantum dots-embedded silica  
microspheres/terbium composite for dual-ratiometric fluorescence  
detection of  $\text{MnO}_4^-$  ions**

Bo Duan,<sup>a</sup> Shuting Guo,<sup>a</sup> Qingzhong Guo,<sup>a,\*</sup> Jiangyu Wu<sup>a</sup> and Junfang Guo<sup>a,\*\*</sup>

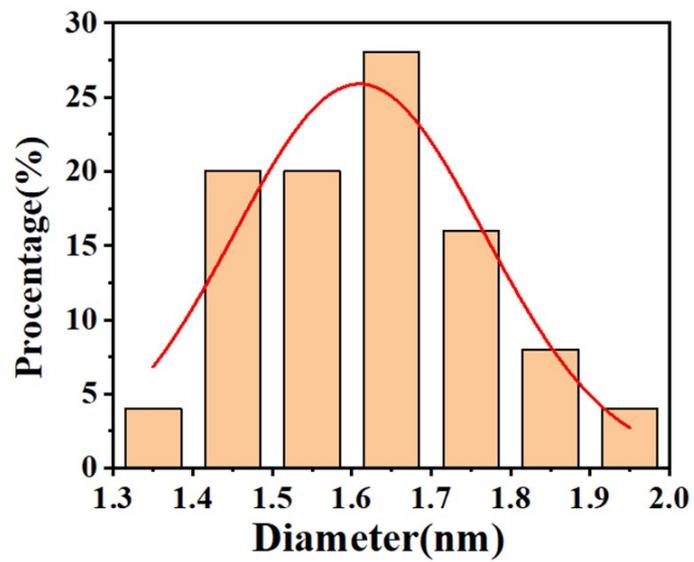
a. Hubei Key Laboratory of Plasma Chemistry and Advanced Materials, School of  
Materials Science and Engineering, Wuhan Institute of Technology, Wuhan 430205,  
China.

\* Corresponding author: Qingzhong Guo

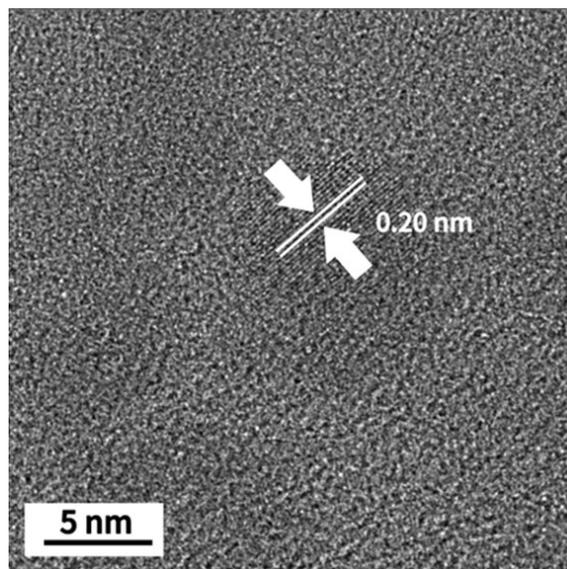
E-mail: ggg602@sina.com

\*\* Corresponding author: Junfang Guo

E-mail: junfangguo@aliyun.com



**Fig. S1** Size distribution histograms of N-CDs.



**Fig. S2** HRTEM images of N-CDs.

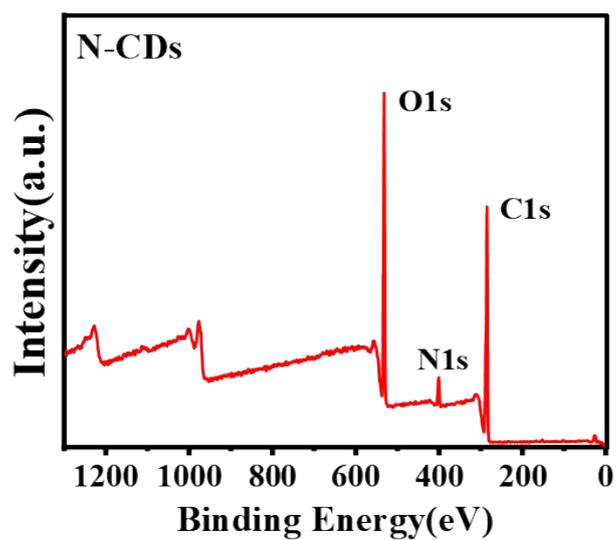


Fig. S3 XPS spectrum of N-CDs.

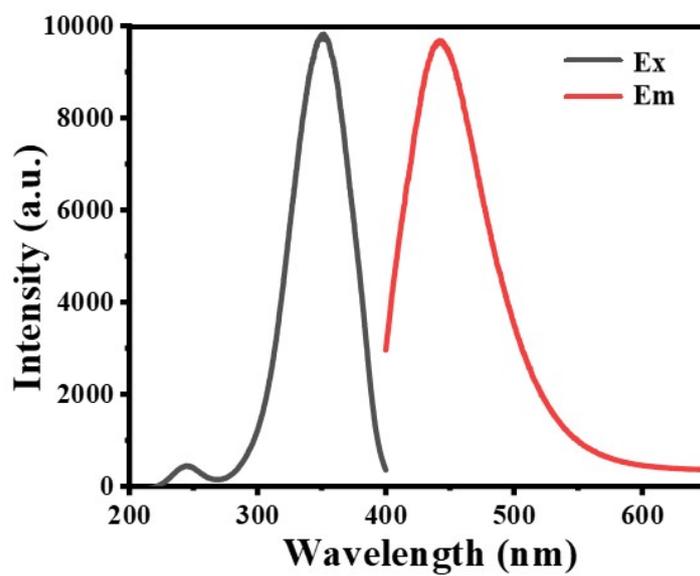
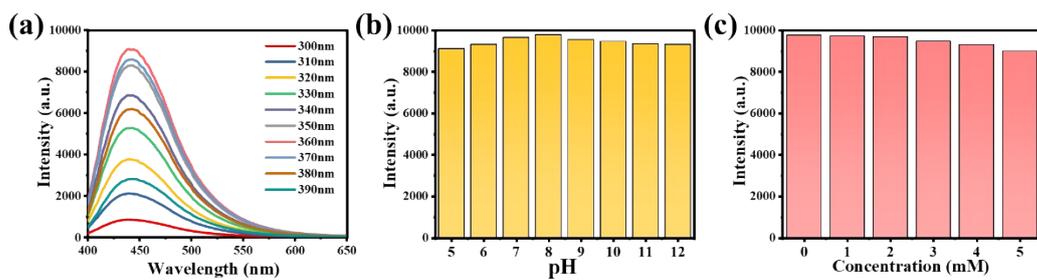
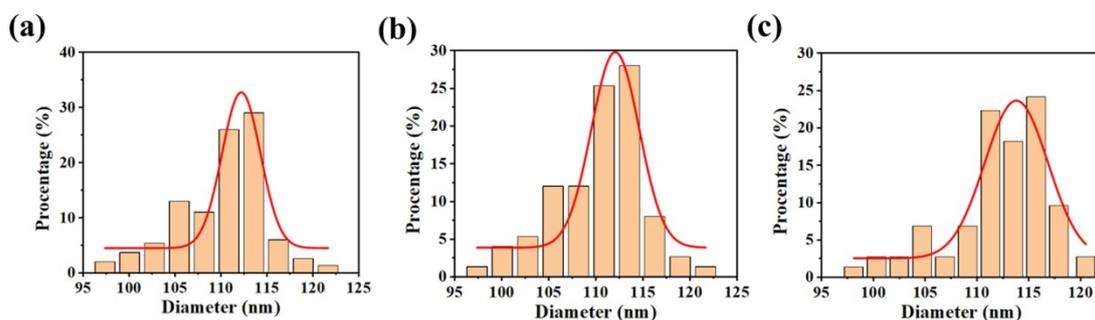


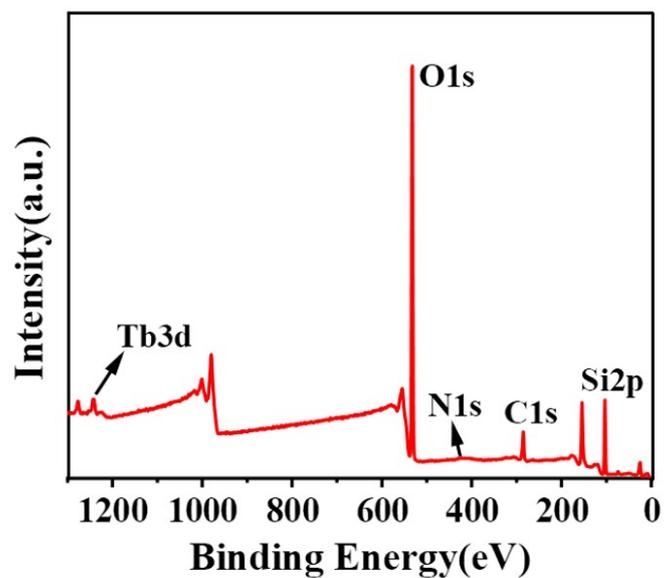
Fig. S4 The excitation and emission spectra of N-CDs.



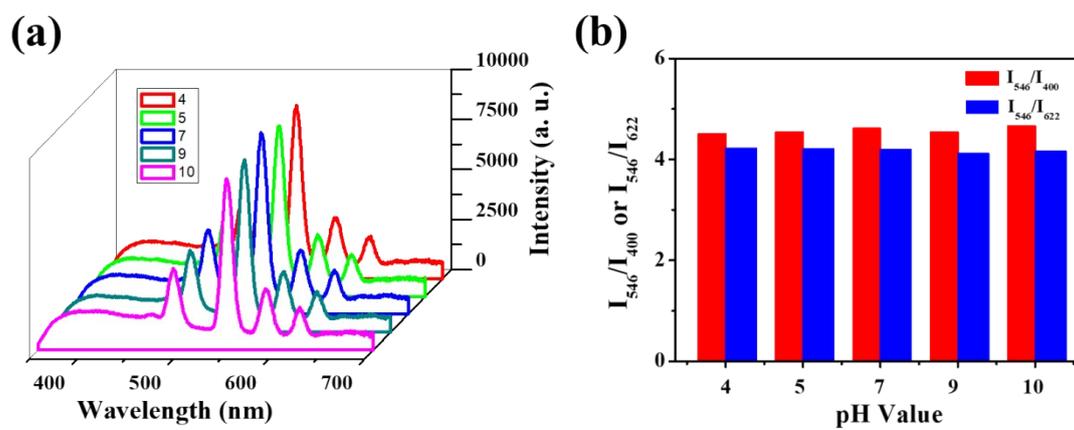
**Fig. S5** (a) Emission spectra of N-CDs with varying excitation wavelengths; Emission intensity of N-CDs at pH values ranging from 5-12 (b) and in NaCl solutions with concentrations ranging from 0-5 mM (c).



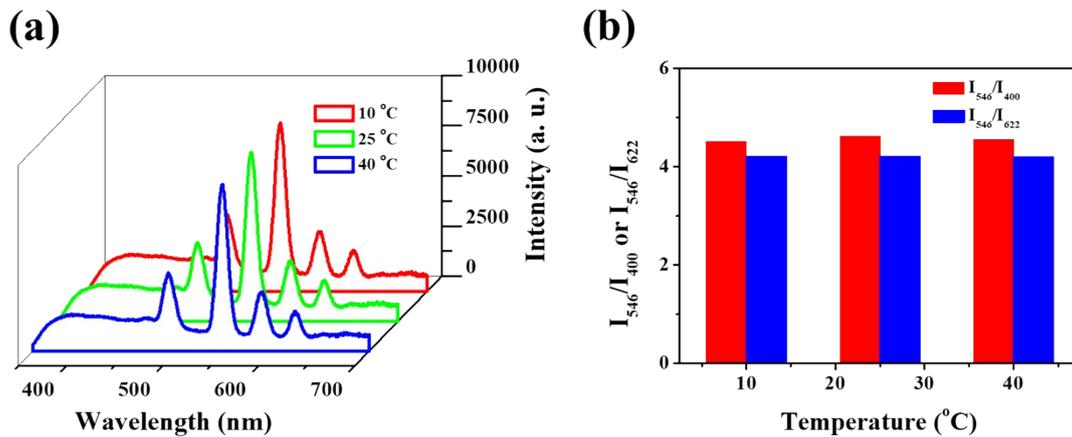
**Fig. S6** The respective size distribution histograms of (a) N-CDs@SiO<sub>2</sub>-NH<sub>2</sub>; (b) N-CDs@SiO<sub>2</sub>-COOH; (c) N-CDs@SiO<sub>2</sub>-Tb microspheres.



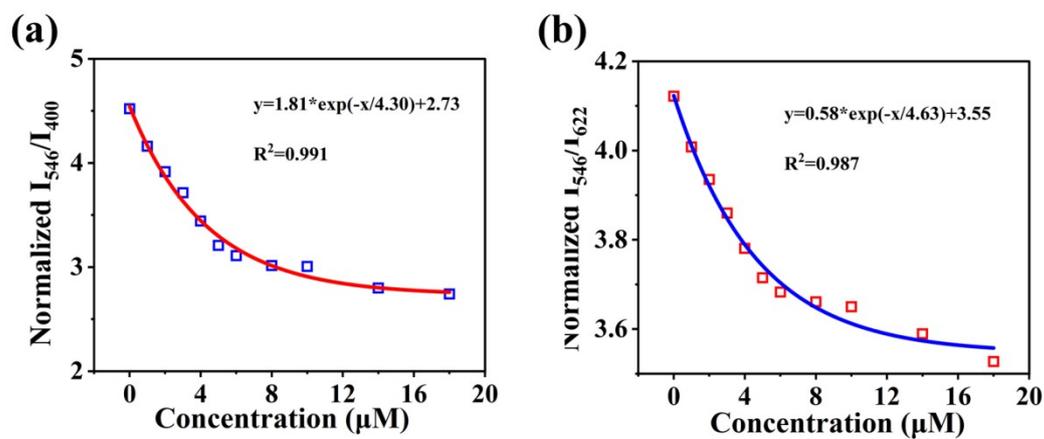
**Fig. S7** XPS spectrum of N-CDs@SiO<sub>2</sub>-Tb.



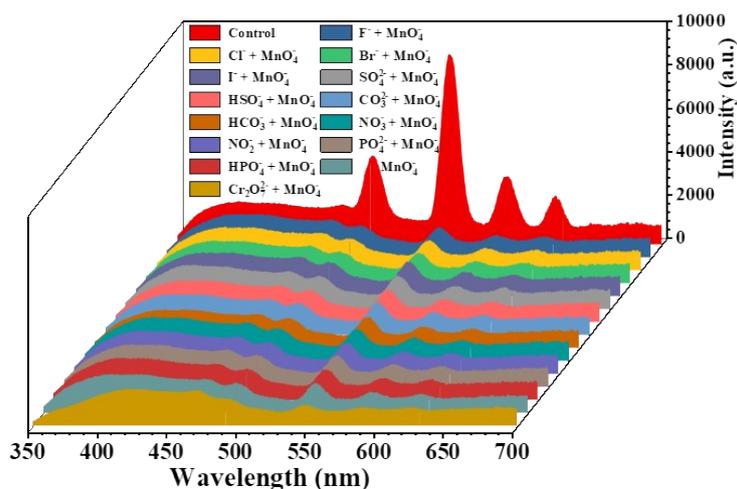
**Fig. S8** Emission spectra (a) and the corresponding intensity ratio of I<sub>546</sub>/I<sub>400</sub> or I<sub>546</sub>/I<sub>622</sub> (b) of N-CDs@SiO<sub>2</sub>-Tb suspensions ( $\lambda_{\text{ex}} = 235 \text{ nm}$ ) at different pH values.



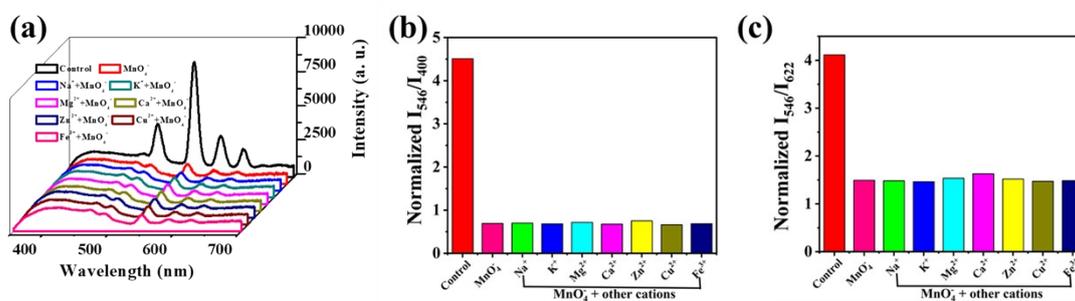
**Fig. S9** Emission spectra (a) and the corresponding intensity ratios of  $I_{546}/I_{400}$  or  $I_{546}/I_{622}$  (b) of N-CDs@SiO<sub>2</sub>-Tb suspensions ( $\lambda_{\text{ex}} = 235$  nm) at different temperature.



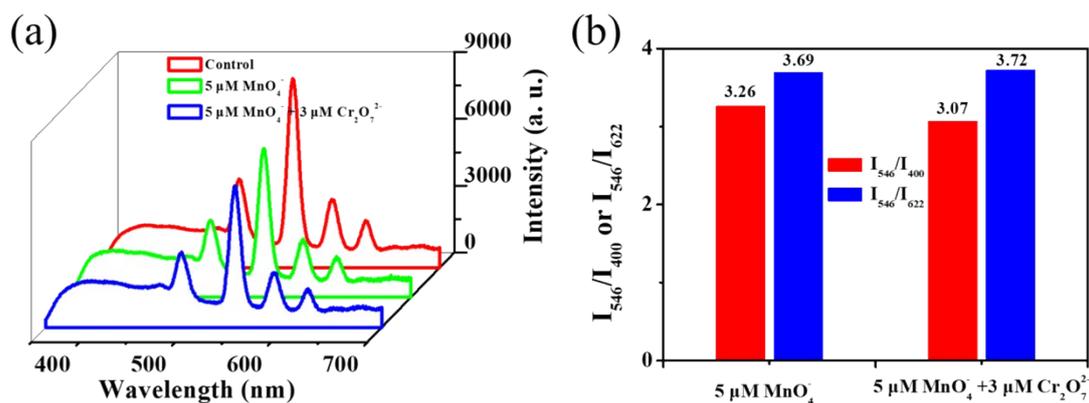
**Fig. S10** (a)  $I_{546}/I_{400}$  and (b)  $I_{546}/I_{622}$  ratios versus  $\text{MnO}_4^-$  concentration (0-18  $\mu\text{M}$ ).



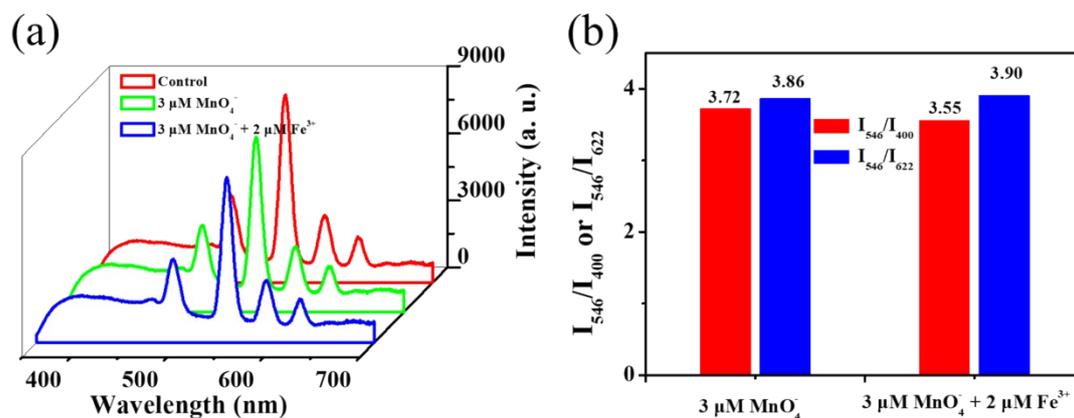
**Fig. S11** Anti-interference performance of the N-CDs@SiO<sub>2</sub>-Tb probe: Fluorescence emission spectra ( $\lambda_{\text{ex}} = 235$  nm) before and after adding MnO<sub>4</sub><sup>-</sup> (0.01 M) in the presence of different interfering anions (0.1 M).



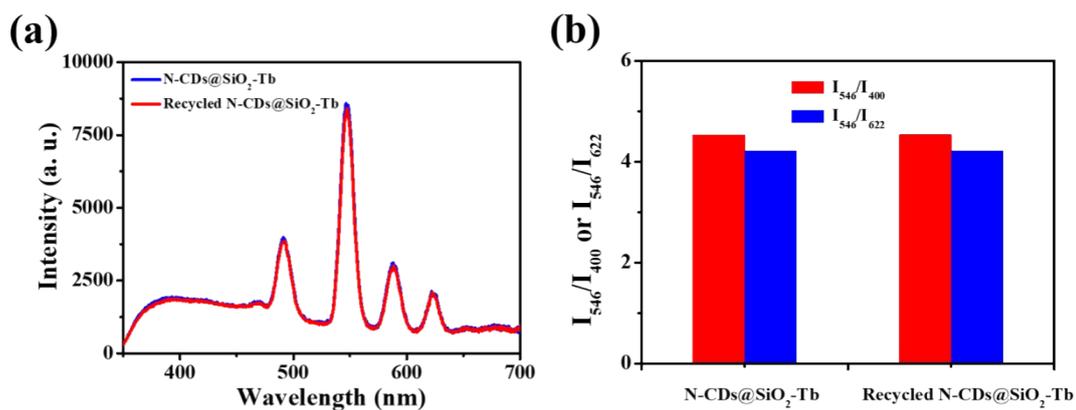
**Fig. S12** Anti-interference performance of the N-CDs@SiO<sub>2</sub>-Tb probe against common cations: (a) Fluorescence emission spectra ( $\lambda_{\text{ex}} = 235$  nm); (b)  $I_{546}/I_{400}$  and (c)  $I_{546}/I_{622}$  ratios before and after adding MnO<sub>4</sub><sup>-</sup> (0.01 M) to systems containing different interfering anions (1 mM).



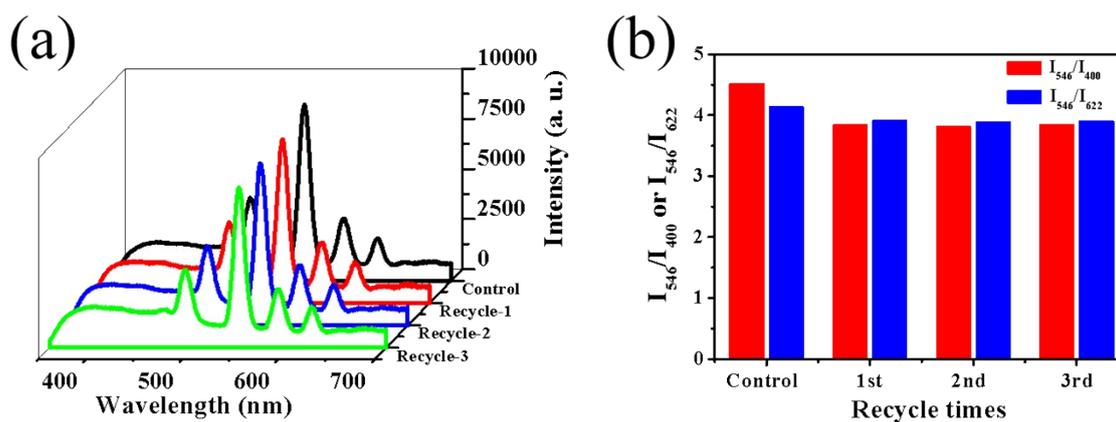
**Fig. S13** Anti-interference performance of the N-CDs@SiO<sub>2</sub>-Tb probe against Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> at low concentration: (a) Fluorescence emission spectra ( $\lambda_{\text{ex}} = 235$  nm) before and after adding MnO<sub>4</sub><sup>-</sup> (5 μM) and Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> (3 μM); (b) corresponding I<sub>546</sub>/I<sub>400</sub> and I<sub>546</sub>/I<sub>622</sub> ratios.



**Fig. S14** Anti-interference performance of the N-CDs@SiO<sub>2</sub>-Tb probe against Fe<sup>3+</sup> at low concentration: (a) Fluorescence emission spectra ( $\lambda_{\text{ex}} = 235$  nm) before and after adding MnO<sub>4</sub><sup>-</sup> (3 μM) and Fe<sup>3+</sup> (2 μM); (b) corresponding I<sub>546</sub>/I<sub>400</sub> and I<sub>546</sub>/I<sub>622</sub> ratios.



**Fig. S15** Emission spectra (a) and intensity ratios of  $I_{546}/I_{400}$  and  $I_{546}/I_{622}$  (b) of N-CDs@SiO<sub>2</sub>-Tb: fresh vs. recycled after MnO<sub>4</sub><sup>-</sup> treatment ( $\lambda_{ex} = 235$  nm).



**Fig. S16** (a) Fluorescence profiles of N-CDs@SiO<sub>2</sub>-Tb ( $\lambda_{ex} = 235$  nm) and (b) the corresponding ratios of  $I_{546}/I_{400}$  and  $I_{546}/I_{622}$  before and after treatment with MnO<sub>4</sub><sup>-</sup> (Conc. = 2.5  $\mu$ M) in recyclable experiments.

**Table S1** Sensitivity of various probes for detection of  $\text{MnO}_4^-$ .

	<b>Materials</b>	<b>Fluorescence emission</b>	<b>LOD</b>	<b>FL Ratios</b>	<b>Ref</b>
<b>1</b>	JXUST-9	single	1.23 $\mu\text{M}$	\	1
<b>2</b>	PP-TzDa	Dual	0.01 mM	$I_{595}/I_{520}$	2
<b>3</b>	$[\text{Tb}(\text{BCB})(\text{DMF})] \cdot (\text{DMF})_{1.5}(\text{H}_2\text{O})_2$	Dual	5.34 $\mu\text{M}$	$I_{548}/I_{622}$	3
<b>4</b>	$[\text{Tb}(\text{cpia})(\text{H}_2\text{O})_2]_n \cdot n\text{H}_2\text{O}$	Dual	1.17 $\mu\text{M}$	$I_{548}/I_{622}$	3
<b>5</b>	NCQDs@Cu	single	32.4 nM	\	4
<b>6</b>	SWU-4	single	5.19 $\mu\text{M}$	\	5
<b>7</b>	N/S-CDs	Dual	0.34 $\mu\text{M}$	\	6
<b>8</b>	<b>N-CDs@SiO<sub>2</sub>-Tb</b>	<b>Dual</b>	<b>0.12 <math>\mu\text{M}</math>, 0.13 <math>\mu\text{M}</math></b>	<b><math>I_{546}/I_{400}</math>, <math>I_{546}/I_{622}</math></b>	<b>This work</b>

## Reference

- [1] Q. Q. He, S. L. Yao, T. F. Zheng, H. Xu, S. J. Liu, J. L. Chen, N. Li and H. R. Wen, *CrystEngComm*, 2022, **24**, 1041–1048.
- [2] M. Huang, J. Chong, C. Hu and Y. Yang, *Inorg. Chem. Commun.*, 2020, **119**, 108094.
- [3] R. Huang, X. Shen, Q. Guo, J. Wu, J. Guo and H. Zheng, *Microchim. Acta*, 2026, **193**, 2.
- [4] H. Yu, H. Li and Y. Zhang, *Microchem. J.*, 2024, **206**, 111422.
- [5] Q. Li, X. Shen, Y. Deng, J. Zhang, T. Tian, S. Wang and X. Hang, *J. Mol. Struct.*, 2025, **1331**, 141588.
- [6] C. Ding, Z. Deng, J. Chen and Y. Jin, *Colloids Surf. B Biointerfaces*, 2020, **189**, 110838.