Electronic Supplementary Information

A "turn-on" sensor based on MnO_2 coated UCNPs for detection of alkaline phosphatase and ascorbic acid

Mei-yu Liang, Bing Zhao, Yan Xiong, Wen-xin Chen, Jian-zhong Huo, Fei Zhang, Lu Wang, Yan Li*

Key Laboratory of Inorganic-Organic Hybrid Functional Material Chemistry (Tianjin Normal University), Ministry of Education, Tianjin Key Laboratory of Structure and Performance for Functional Molecule, College of Chemistry, Tianjin Normal University, 393 Binshui West Road, Tianjin 300387, PR China

* Corresponding authors. E-mail address: nkliyan398@gmail.com (Y. Li).

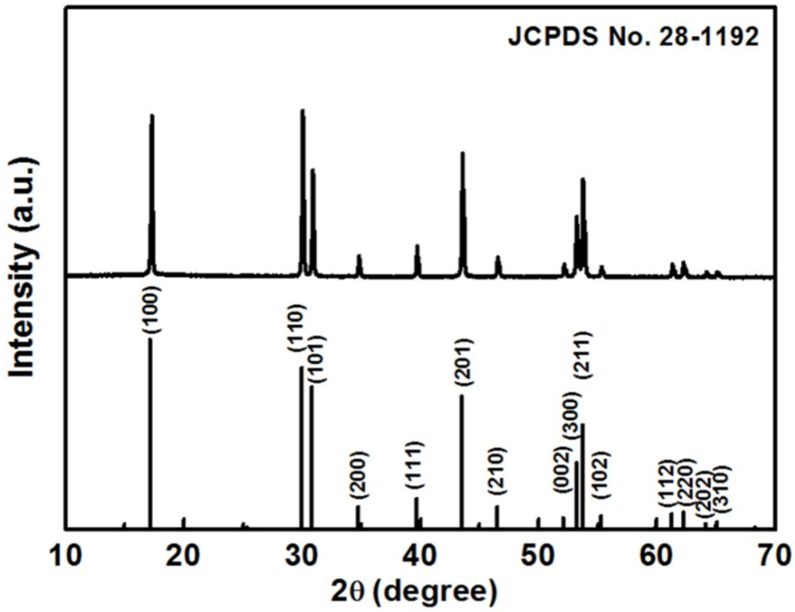

Fig. S1 XRD pattern of $NaYF_4$:Yb^{3+}, Tm^{3+} UCNPs which reflections were coincident with the diffraction peaks of the β-phase.

phase	ICP-MS tested result			The molar ratios of
	Y	Yb	Tm	Y: Yb: Tm
β	19.72%	8.04%	0.11%	77.54%: 16.27%: 0.22%

Table S1 ICP-MS quantitative analysis of molar ratios of Y: Yb: Tm in the sample.

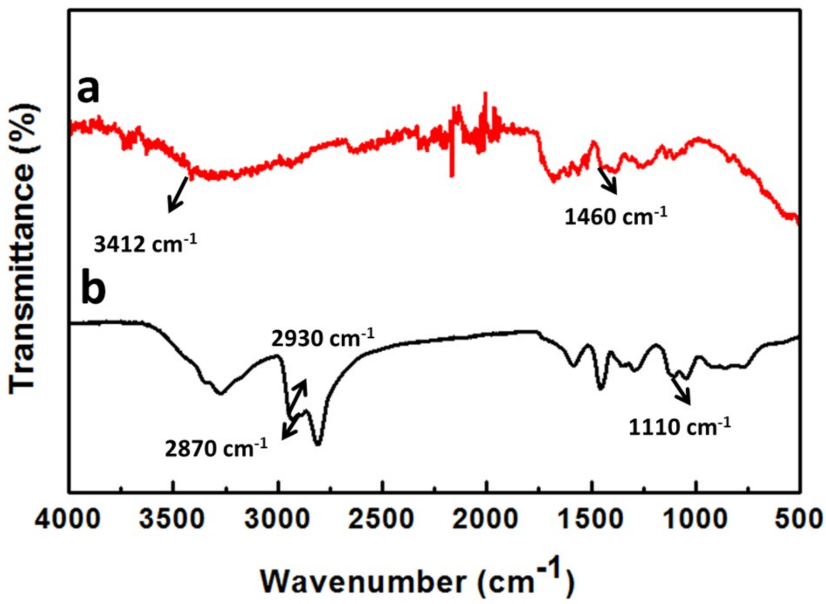

Fig. S2 FT-IR spectra of $NaYF_4$:Yb^{3+}, Tm^{3+} UCNPs (curve a) and pure PEI (curve b).

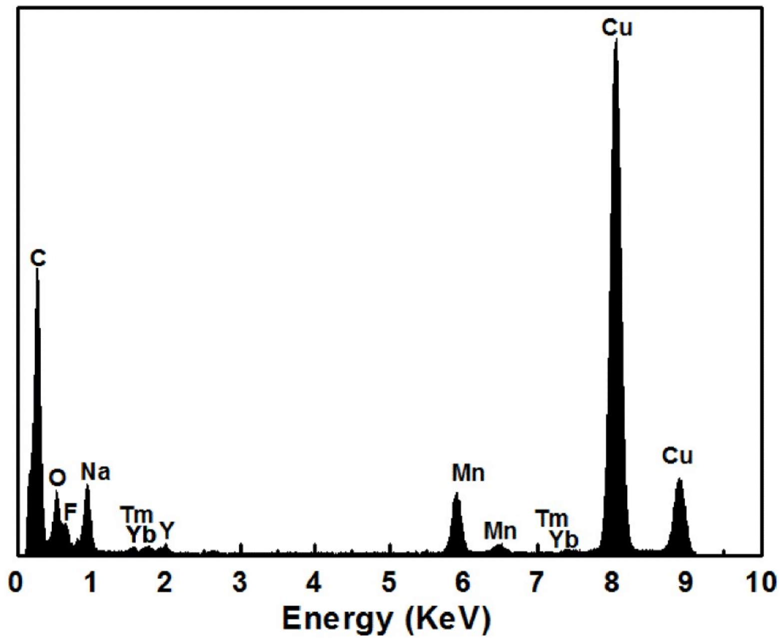

Fig. S3 Energy dispersive X-ray spectroscope (EDS) spectrum of MnO_2 coated UCNPs.

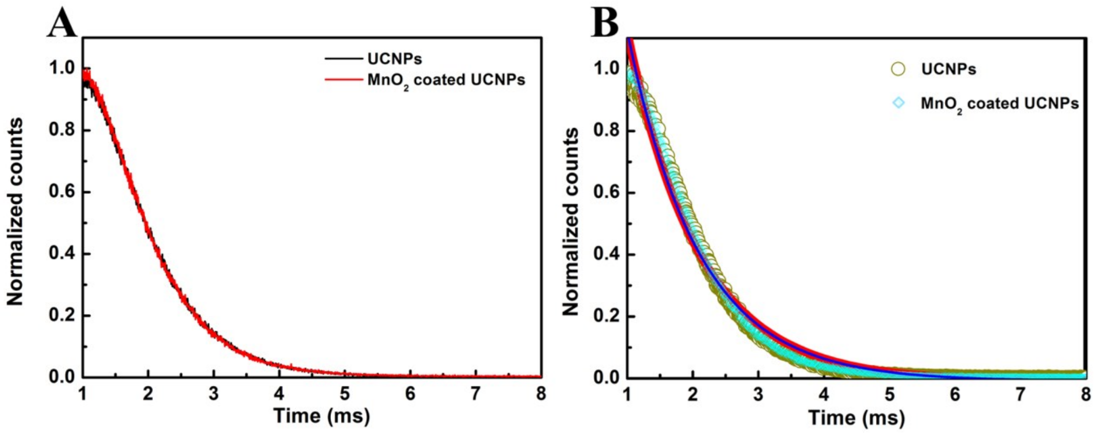

Fig. S4 (A) Luminescence decay curves of UCNPs (black line) and MnO_2 coated UCNPs (red line). (B) Luminescence decay curves of UCNPs and MnO_2 coated UCNPs and corresponding mono-exponential fitting based on $y=y_0+A_1*\exp[-(x-x_0)/\tau_1]$ (red line and blue line).

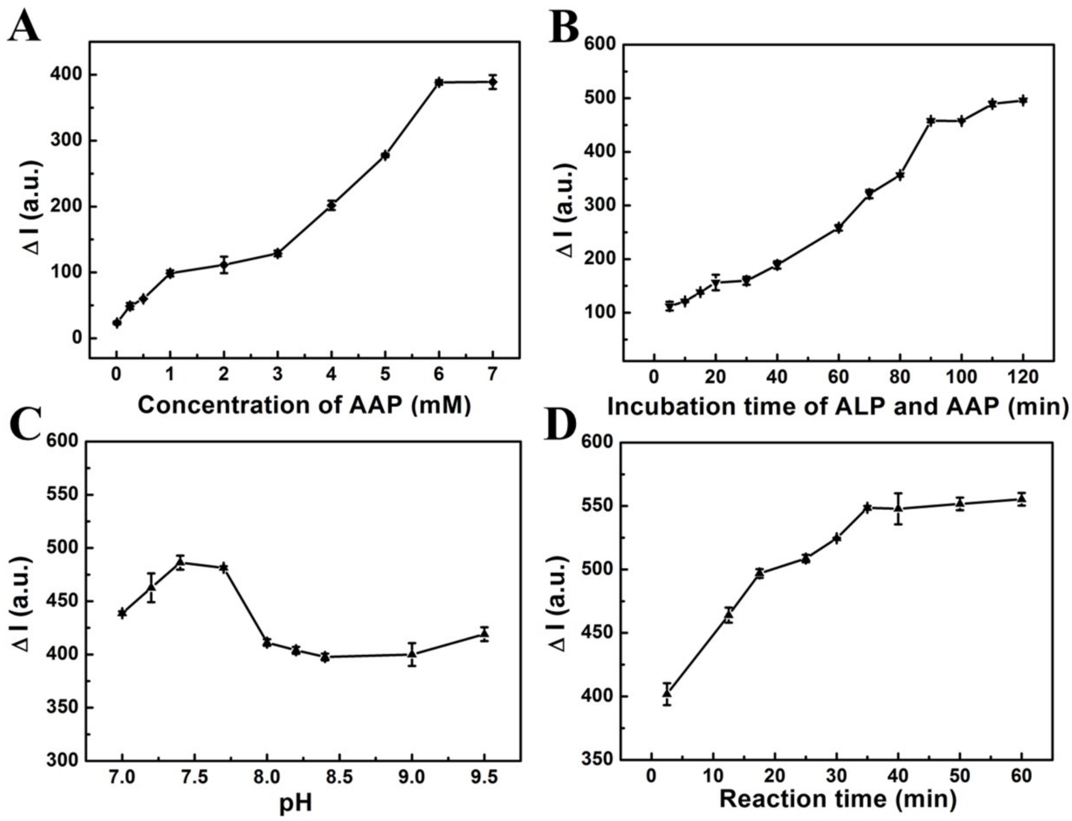

Fig. S5 (A) The restored luminescence intensity of the sensing system against the different concertrations of AAP in the presence of ALP (100 mU mL^{-1}). (B) The restored luminescence intensity of the sensing system against the incubation time of ALP (100 mU mL^{-1}) and AAP (6 mM). (C) The restored luminescence intensity of the sensing system against the varying pH of ALP (100 mU mL^{-1}) and AAP (6 mM). (D) The luminescence reaction time of the sensing system.

Table S2 Comparison of different detection methods of AA with the linear range and the detection limit

Assay method	Linear range	Detection limit	Ref.
Specific determination of ascorbic acid with high-performance liquid chromatography	0.1-100 μM	1 pM	1
Determination of ascorbic acid by capillary electrophoresis with electrochemical detection	1-1000 g mL^{-1}	2×10^{-7} g mL^{-1}	2
Bimodal electrochemiluminescence of G-CNQDs for ascorbic acid detection	3.5-330 nM	110 pM	3
Colorimetric detection of ascorbic acid using Pt/CeO_2 nanocomposites	0.5-30 μM	80 nM	4
A MnO_2 nanosheet-based ratiometric fluorescent nanosensor for detection of ascorbic acid	0.0 to 6.0 μM	10 nM	5
Graphene oxide nanosheets functionalized with poly(styrene sulfonate) for colorimetric assay for ascorbic of acid	0.8-60 μM	0.15 μM	6
An "on-off-on" fluorescent nanoprobe for recognition of ascorbic acid based on carbon quantum dot	5-200 μM	1.35 μM	7
Near-infrared quantum dots-gold nanoclusters nanohybrid for ratiometric fluorescent detection of ascorbic acid	3-40 μM	1.5 μM	8
Based on MnO_2 coated UCNPs for detection of alkaline phosphatase and ascorbic acid	0.5-250 μM	0.29 μM	This work

References

1 E. Kishida, Y. Nishimoto and S. Kojo, *Anal. Chem.*, 1992, **64**, 1505-1507.

2 Y. Peng, Y. Zhang and J. Ye, *J .Agr. Food Chem.,* 2008, **56**, 1838-1844.

3 H. Wang, G. Pu, S. Devaramani, Y. Wang, Z. Yang, L. Li, X. Ma and X. Lu, *Anal. Chem.*, 2018, **90**, 4871-4877.

4 X. Liu, X. Wang, C. Qi, Q. Han, W. Xiao, S. Cai, C. Wang and R. Yang, *Appl. Surf. Sci.*, 2019, **479**, 532-539.

5 Y. Lyu, Z. Tao, X. Lin, P. Qian, Y. Li, S. Wang and Y. Liu, *Anal. Bioanal. Chem.*, 2019, **411**, 4093-4101.

6 J. Chen, J. Ge, L. Zhang, Z. Li, J. Li, Y. Sun and L. Qu, *Microchim. Acta*, 2016, **183**, 1847-1853.

7 X. Gong, Y. Liu, Z. Yang, S. Shuang, Z. Zhang and C. Dong, *Anal. Chim. Acta*, 2017, **968**, 85-96.

8 P. Zhao, K. He, Y. Han, Z. Zhang, M. Yu, H. Wang, Y. Huang, Z. Nie and S. Yao, *Anal. Chem.*, 2015, **87**, 9998-10005.