

A fluorescent aptasensor for highly sensitive and selective of carcinoembryonic antigen based on upconversion nanoparticles and WS₂ nanosheet

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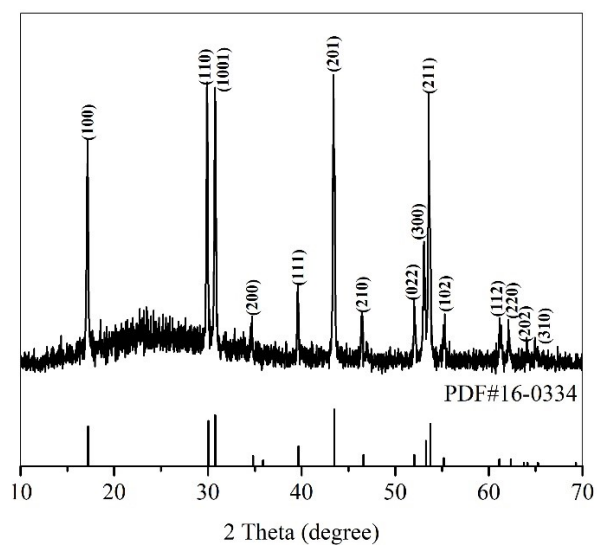


Fig. S1 XRD pattern of NaYF₄: Yb/Er upconversion nanoparticles and the standard pattern of hexagonal phase hexagonal phase (JCPDs card 16-0334).

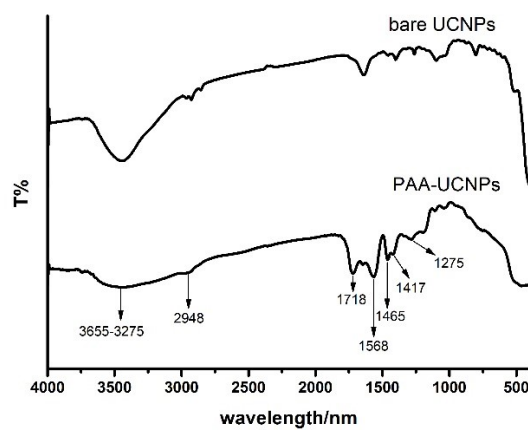


Fig. S2 FT-IR spectra of bare UCNPs and PAA modified UCNPs.

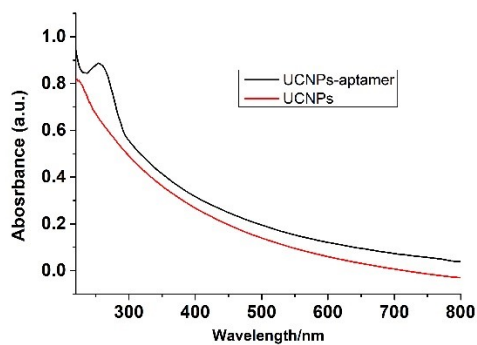


Fig. S3 The UV-vis absorption spectra of UCNPs-CEA aptamer complex (black line), UCNPs (red line).

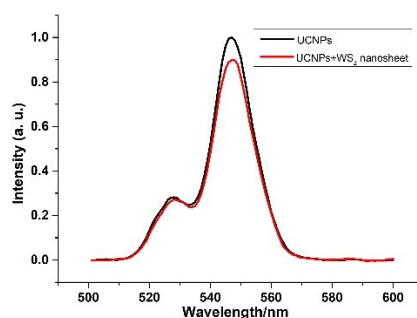


Fig. S4 The upconversion fluorescence spectra of PAA modified UCNPs (0.01mg/mL) in the absence (black line) and presence (red line) of WS₂ nanosheet (0.40mg/mL).

Table S1 Comparison of different methods for detection of CEA.

Methods	Materials	Detection range (ng/mL)	LOD (ng/mL)	Ref
FRET aptasensor	UCNPs, CNPs	0.1-40	0.1	1
FRET aptasensor	UCNPs, AuNPs	0.05-2.0	0.02	2
FRET aptasensor	UCNPs, AgNPs	0.1-200	0.09	3
Electrochemical aptasensor	Au-SiO ₂ Janus NPs	1-5000	0.21	4
SPR aptasensor	AgNCs, MOFs	1.0-2.5	0.3	5
Fluorescent aptasensor	Ag/AuNCs, GO	6.7-13300	3.18	6
Fluorescent aptasensor	Texas Red, MoS ₂ NSs	0.1-100	0.034	7
Colorimetric aptasensor	Magnetic beads, Hemin	0.1-8.0	0.06	8
FRET aptasensor	UCNPs, WS ₂ nanosheet	0.05-10	0.008	This work

Table S2 Recoveries of CEA in five human serum samples with the constructed aptasensor.

Sample (No.)	Added (ng/mL)	Found (ng/mL)	Recovery	RSD (n=3)
1	0.2	0.21	105%	6.0%
2	0.5	0.55	110%	2.4%
3	2	2.15	108%	1.4%
4	4	3.68	92.0%	5.8%
5	8	7.79	97.4%	5.2%

References

1. Z. Wu, H. Li and Z. Liu, Sensors and Actuators B: Chemical, 2015, 206, 531.

2. X.-H. Li, W.-M. Sun, J. Wu, Y. Gao, J.-H. Chen, M. Chen and Q.-S. Ou, *Analytical Methods*, 2018, **10**, 1552.
3. Y. Han, L. Shen, Z. Li and Z. Liu, *Analytical Methods*, 2018, **10**, 3933.
4. G. Paniagua, A. Villalonga, M. Eguílaz, B. Vegas, C. Parrado, G. Rivas, P. Díez and R. Villalonga, *Analytica Chimica Acta*, 2019, **1061**, 84.
5. C. Guo, F. Su, Y. Song, B. Hu, M. Wang, L. He, D. Peng and Z. Zhang, *ACS Applied Materials & Interfaces*, 2017, **9**, 41188.
6. Y. Wang, S. Wang, C. Lu and X. Yang, *Sensors and Actuators B: Chemical*, 2018, **262**, 9.
7. L. Zhao, M. Cheng, G. Liu, H. Lu, Y. Gao, X. Yan, F. Liu, P. Sun and G. Lu, *Sensors and Actuators B: Chemical*, 2018, **273**, 185.
8. M. Zou and S. Wang, *Bulletin of the Korean Chemical Society*, 2017, **38**, 1143.