Supporting Information

Super bright red upconversion in $NaErF_4$:0.5%Tm@$NaYF_4$:20%Yb nanoparticles for anti-counterfeit and bio-imaging applications

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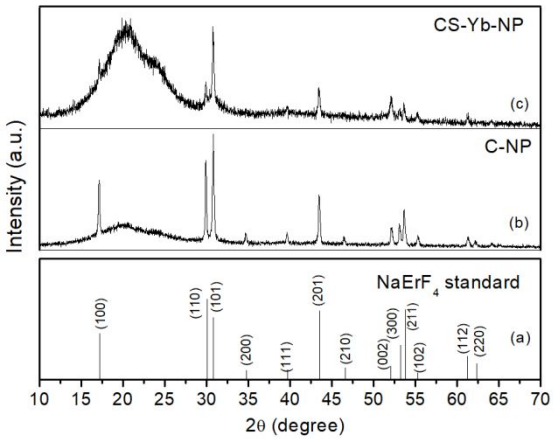

Figure S1. Typical XRD patterns of (a) $NaErF_4$ (standard JCPDS File No. 27-0689), (b) C-NPs, and (c) CS-Yb NPs.

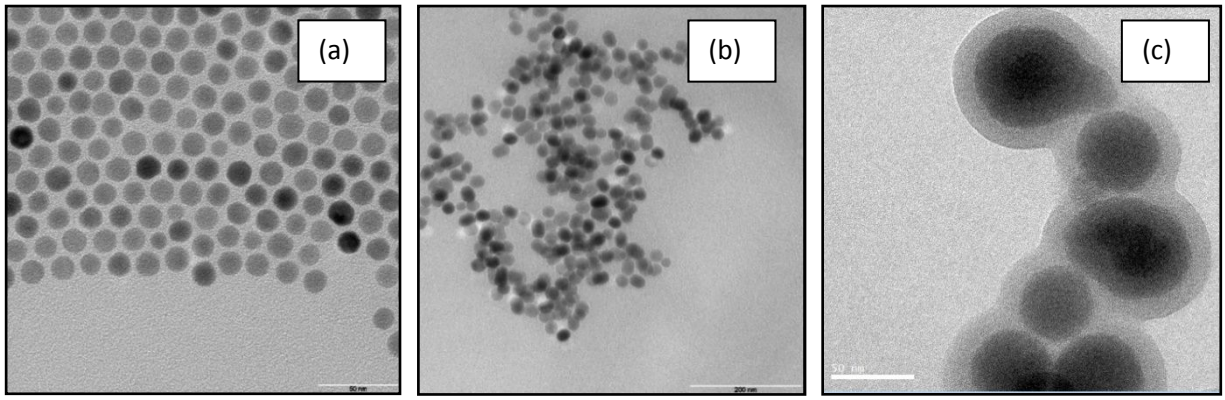

Figure S2. TEM micrographs of (a) C-NPs (scale bar 50 nm), (b) CS-Yb-NPs (scale bar 200 nm) and (c) CS-Yb-sil-NPs (scale bar 50 nm).

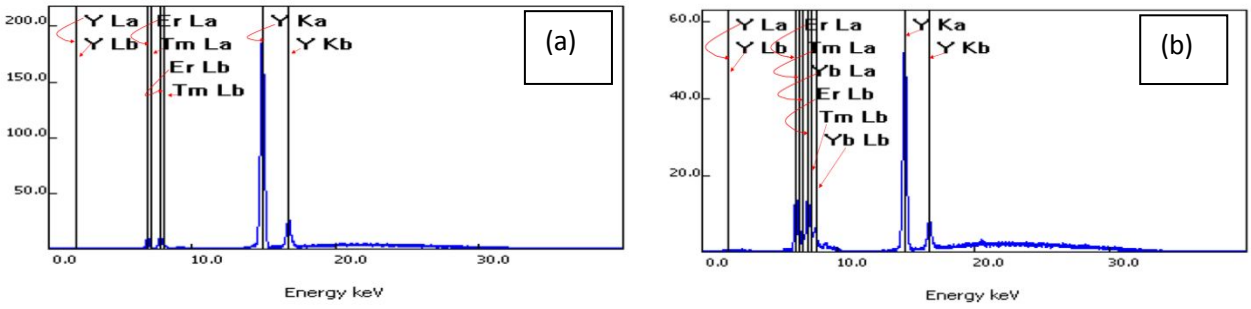

Figure S3. EDX spectra of (a) CS-Y-NPs and (b) CS-Yb-NPs.

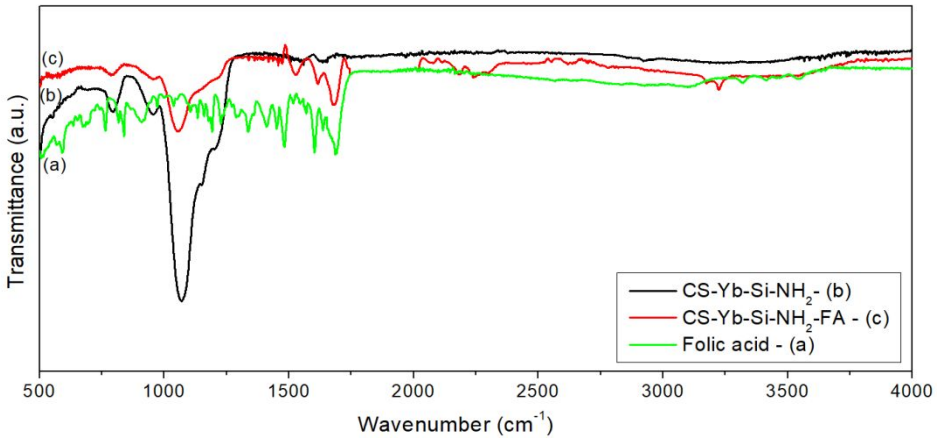

Figure S4. Representative IR spectra of (a) folic acid, (b) CS-Yb-Si-NH_2 and (c) CS-Yb-Si-NH_2-FA UCNPs.

Table S1. Assignments of different absorption peaks obtained in the IR spectra of amine coated (CS-Yb-Si-NH_2) and folic coated (CS-Yb-Si-NH_2-FA) upconversion nanoparticles.

S. No.	Folic acid (cm^{-1})	Amine coated UCNPs (cm^{-1})	Folic acid coated UCNPs (cm^{-1})	Assignment of peaks	References
1	3545	-	3537	O-H stretch	[1], [2]
2	3417	-	-	O-H stretch	[3]
3	3324	3250	3230	N-H stretch	[2]
4	2921	2930	2924	C-H stretch	[1]
5	1690	-	1681, 1690	C=O stretch from -COOH (FA) or C=O for amide I	[2]
6	1600	-	1610	C=C phenyl stretch	[4]
7	1516	1550	1521	N-H bend (amide II)	[2]
8	1480	-	1475	C-C aromatic stretch	[4]
9	1450	1455	1455	C-H bend	[4]
10	-	1055	1055	Si-O-Si stretch	[1], [3]
11	-	950	960	Si-OH stretch	[3]

References:

1. Ma, J.; Huang, P.; He, M.; Pan, L.; Zhou, Z.; Feng, L.; Gao, G.; Cui, D. Folic Acid-Conjugated LaF_3:Yb,Tm@SiO2 Nanoprobes for Targeting Dual-Modality Imaging of Upconversion Luminescence and X-ray Computed Tomography. *J. Phys. Chem. B*. **2012**, *116*, 14062–14070.

2. Mohapatra, S.; Mallick, S. K.; Maiti, T. K.; Ghosh, S. K.; Pramanik, P. Synthesis of Highly Stable Folic Acid Conjugated Magnetite Nanoparticles for Targeting Cancer Cells. *Nanotechnology* ***2007****, 18*, 385102.
3. Cheng, W.; Nie, J.; Xu, L.; Liang, C.; Peng, Y.; Liu, G.; Wang, T.; Mei, Lin.; Huang, L.; Zeng, X. pH-Sensitive Delivery Vehicle Based on Folic Acid-Conjugated Polydopamine-Modified Mesoporous Silica Nanoparticles for Targeted Cancer Therapy. *ACS Appl. Mater. Interfaces* **2017**, *9*, 18462–18473.
4. Sun, C.; Sze, R.; Zhang M. Folic Acid-PEG Conjugated Superparamagnetic Nanoparticles for Targeted Cellular Uptake and Detection by MRI. *J. Biomed. Mater. Res. A*. **2006,** *78*, 550-7.

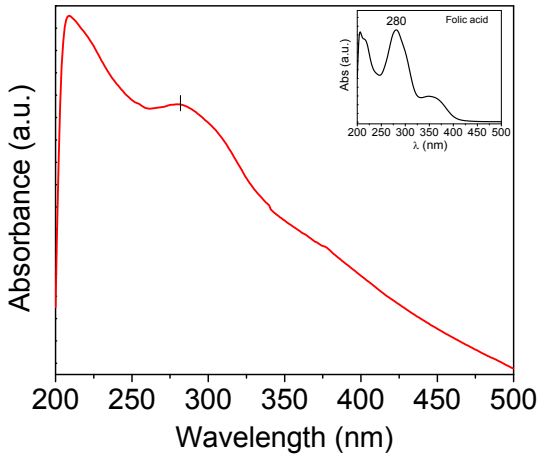

Figure S5. Representative UV-VIS spectrum of CS-Yb-Si-NH2-FA UCNPs. Inset: Absorption spectrum of pure folic acid for comparison.

This absorption peak obtained from folic acid is found to be at 280 nm in figure S5, which is matching with the reference [1] mentioned above. UV-VIS spectrum of CS-Yb-Si-NH2-FA UCNPs shows the similar peak confirming conjugation of folic acid over UCNPs particles.

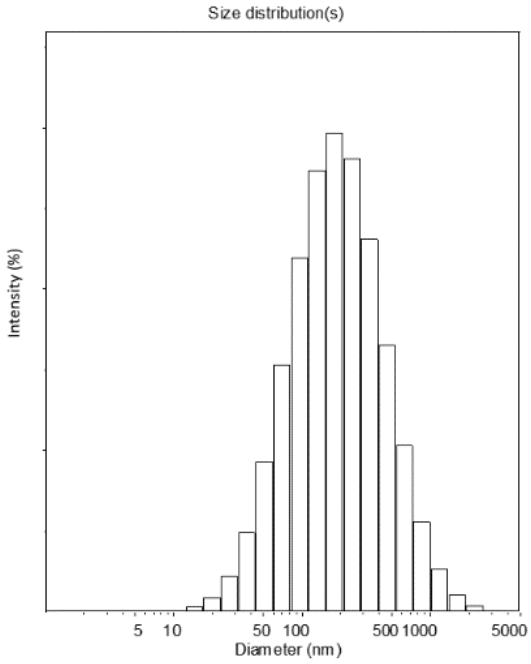

Figure S6. Dynamic light scattering measurement of CS-Yb-Si-FA UCNPs in water: hydrodynamic radius = 335 nm.

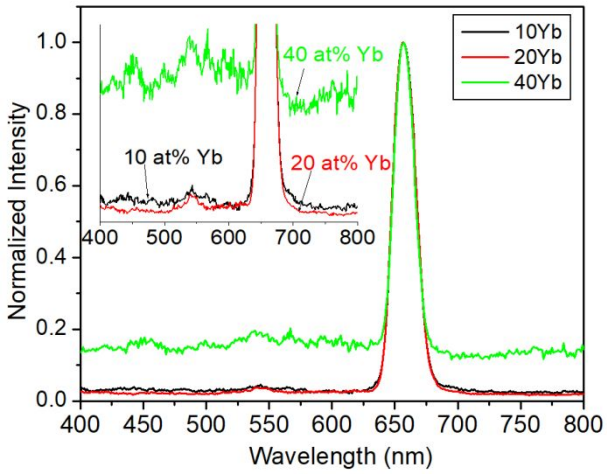

Figure S7. Upconversion spectra of CS-Yb-NPs for different amounts of Yb under 980 nm excitation (2W).