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Supporting Information

Lutetium doping for making big core and core-shell upconversion nanoparticles

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$NaY_{1-x}Lu_xF_4$:Yb,Er		Y(%)	Lu(%)	Yb(%)	Er(%)	Tm(%)
x=0%	Concentration in raw materials	78	0	20	2	0
	ICP-OES measurement	79.73	0	18.06	2.21	0
x=10%	Concentration in raw materials	68	10	20	2	0
	ICP-OES measurement	70.45	9.53	17.90	2.12	0
x=20%	Concentration in raw materials	58	20	20	2	0
	ICP-OES measurement	61.03	18.85	18.01	2.11	0
x=30%	Concentration in raw materials	48	30	20	2	0
	ICP-OES measurement	51.58	27.92	18.37	2.13	0
x=50%	Concentration in raw materials	28	50	20	2	0
	ICP-OES measurement	33.75	44.43	19.50	2.32	0
$NaYF_4$:Yb,Er@ 5X($NaLuF_4$:Yb,Tm)	Concentration in raw materials	8	62.08	29.17	0.33	0.42
	ICP-OES measurement	8.91	62.25	28.03	0.36	0.45

Table S1. Element analysis through ICP-OES of the UCNs with different Lu^{3+} doping and with $NaLuF_4$ shell coating. The elemental content of the samples generally agree with the concentration of lanthanides in the raw materials.

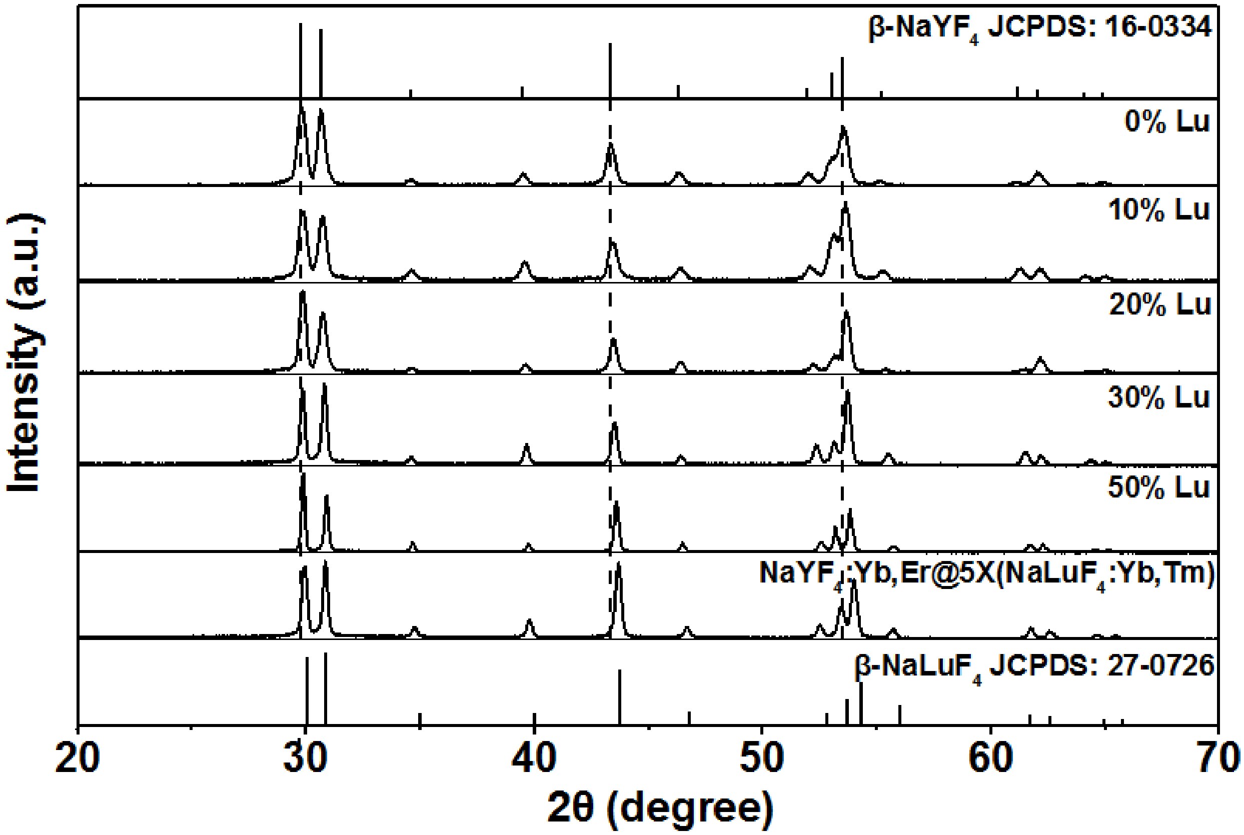

Figure S1. XRD patterns of NaY/LuF$_4$: Yb, Er UCNs doped with different concentrations of Lu^{3+} and core-shell UCNs of NaYF$_4$: Yb, Er@5X(NaLuF$_4$: Yb, Tm). Standard XRD patterns of β-NaYF$_4$ and β-NaLuF$_4$ are plotted as references.

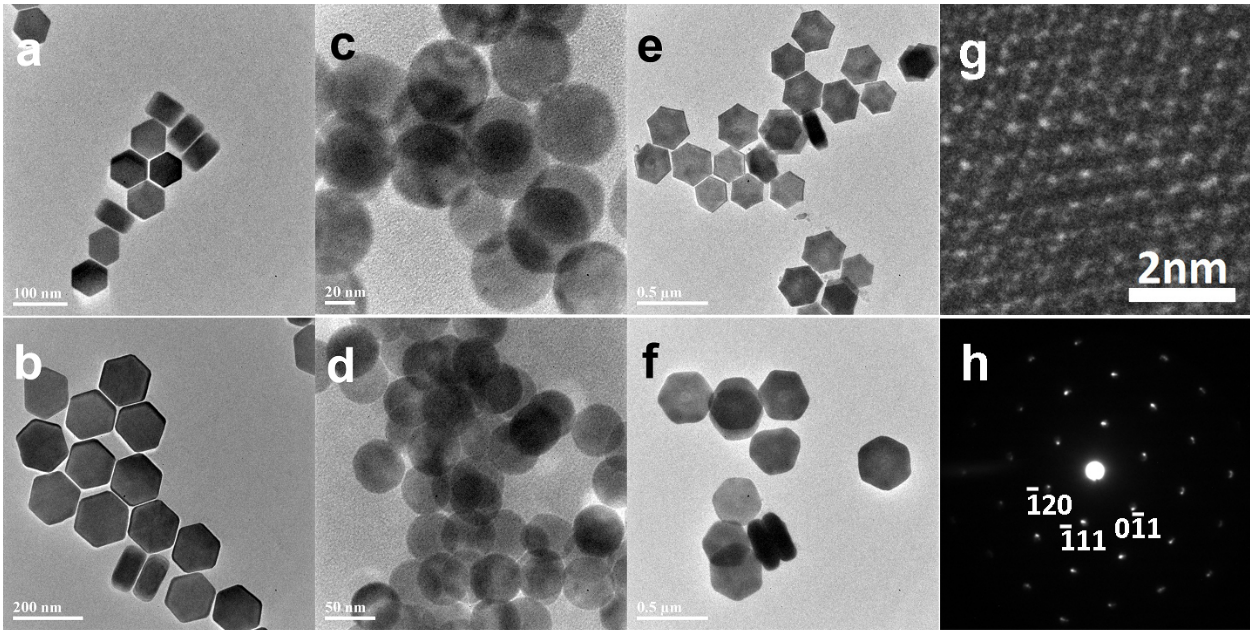

Figure S2. Low magnification TEM images of $NaYF_4$:Yb,Er UCNs doping with Lu^{3+} at the concentration of 30% (a) and 50% (b), and core-shell UCNs with $NaLuF_4$ shell at 1:5 (e) and 1:10 (f) core/shell ratio incubated for 4 hours. TEM images of core-shell UCNs with $NaLuF_4$ shell at 1:1 core/shell ratio incubated for 4 hours (c and d). High resolution TEM image (g) and its correspondence selected area electron diffraction (h) confirm the monocrystal of the synthesized UCNs.

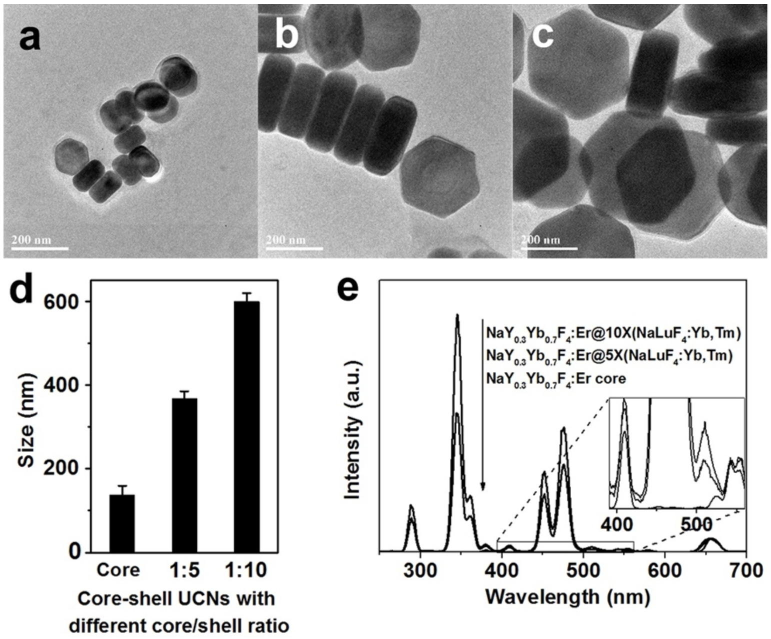

Figure S3. Coating $NaLuF_4$ shell onto bigger core UCNs. TEM image of core UCNs (a), core-shell UCNs with $NaLuF_4$ shell with 1:5 (b) and 1:10 (c) core/shell ratio; scale bar is 200 nm. d) Average size of the above samples measured by DLS. e) Luminescence spectra of the above samples; Er and Tm are doped in core and shell, respectively.

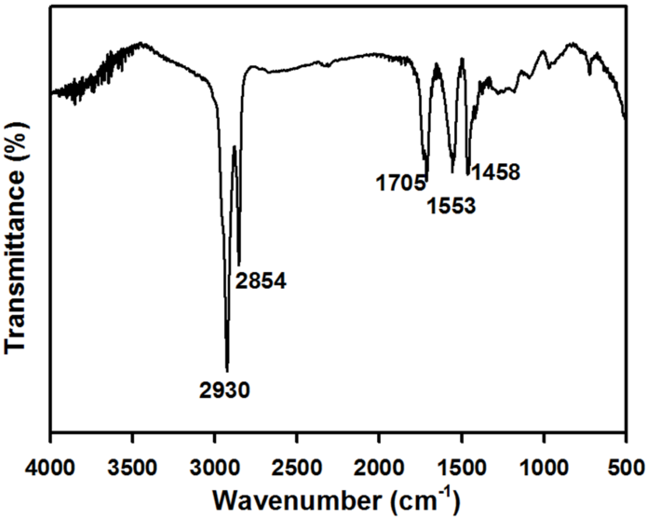

Figure S4. FTIR spectra of the core UCNs confirms the surface capping of oleic acid[1]. Band at 2930 and 2854 cm^{-1} are assigned to the asymmetric (ν_{as}) and symmetric (ν_s) stretching vibrations of methylene (CH_2) in the long alkyl chain of oleic acid, respectively. Bands at 1705, 1553 and

1458 cm^{-1}, are assigned to the stretching vibration of C=O of the carboxyl, the asymmetric (ν_{as}) and symmetric (ν_s) stretching vibrations of the carboxylic group of oleic acid, respectively.

References

1. T. Cao, T. Yang, Y. Gao, Y. Yang, H. Hu and F. Li, *Inorganic Chemistry Communications*, 2010, **13**, 392-394.