Electronic Supplementary Information for Nanoscale

Rational morphology control of β-$NaYF_4$:Yb,Er/Tm upconversion nanophosphors using ligand, additive, and lanthanide doping

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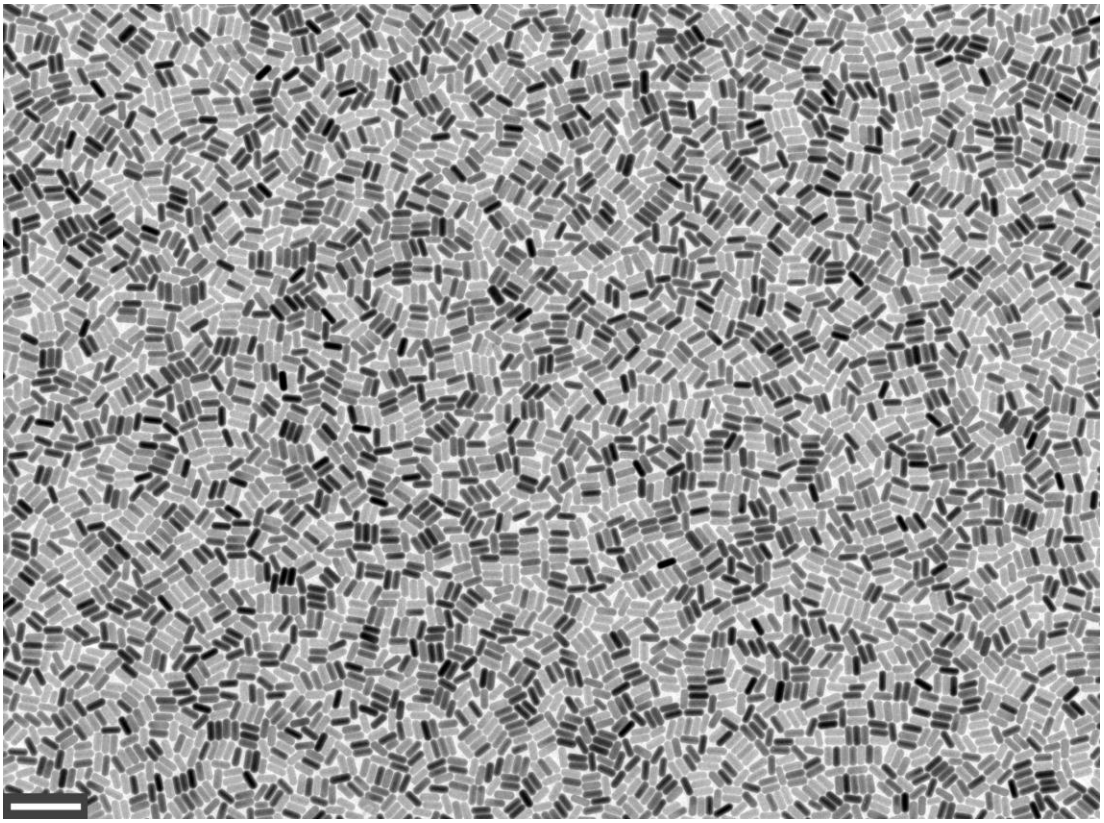

Figure S1. Large area TEM image of β-$NaYF_4$:Yb,Er UCNRs (Scale bar = 200 nm).

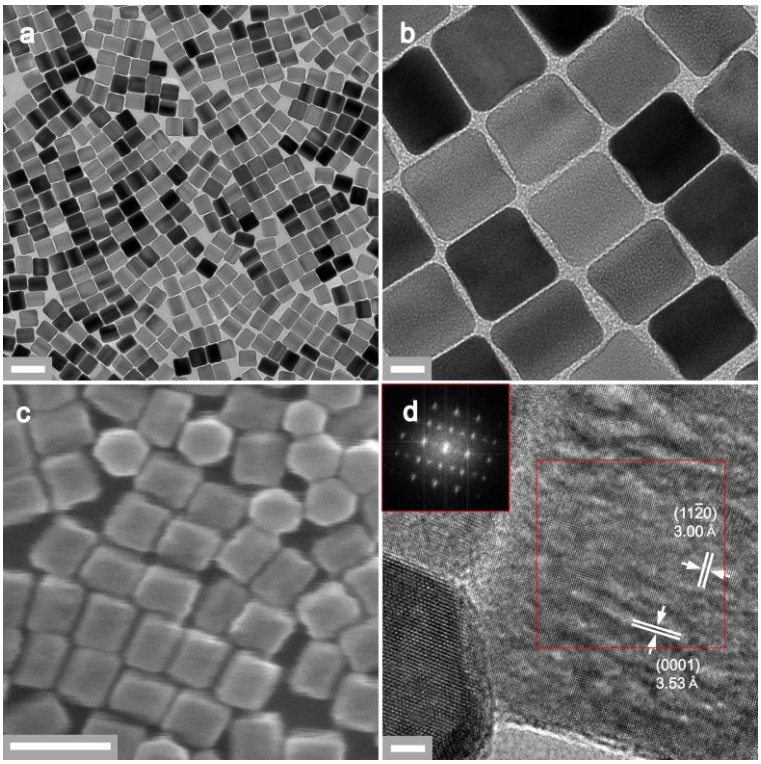

Figure S2. (a, b) TEM images and (c) scanning electron microscopy (SEM) image of β-$NaYF_4$:Yb,Er UCNPs synthesized with $LnCl_3$ instead of $Ln(oleate)_3$ as Ln precursors (Ln = Y, Yb, and Er). (d) HR-TEM image of the β-$NaYF_4$:Yb,Er UCNPs (Inset shows FFT diffractogram for red frame). Scale bars represent 100 nm for panels (a) and (c), 20 nm for panel (b), and 5 nm for panel (d), respectively.

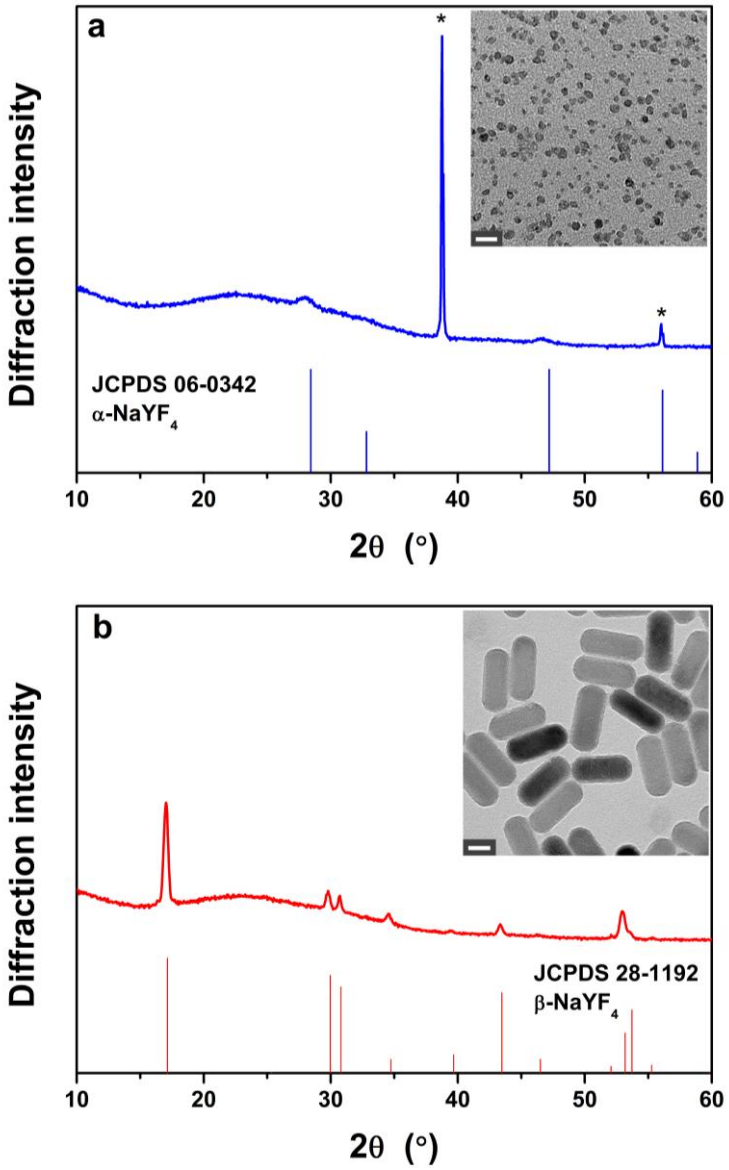

Figure S3. XRD patterns of β-$NaYF_4$:Yb,Er UCNPs synthesized in (a) an ODE solvent (OA:ODE = 0:21) and (b) an OA solvent (OA:ODE = 21:0), respectively. Insets show corresponding TEM images. Scale bars indicate 20 nm. (*: NaF)

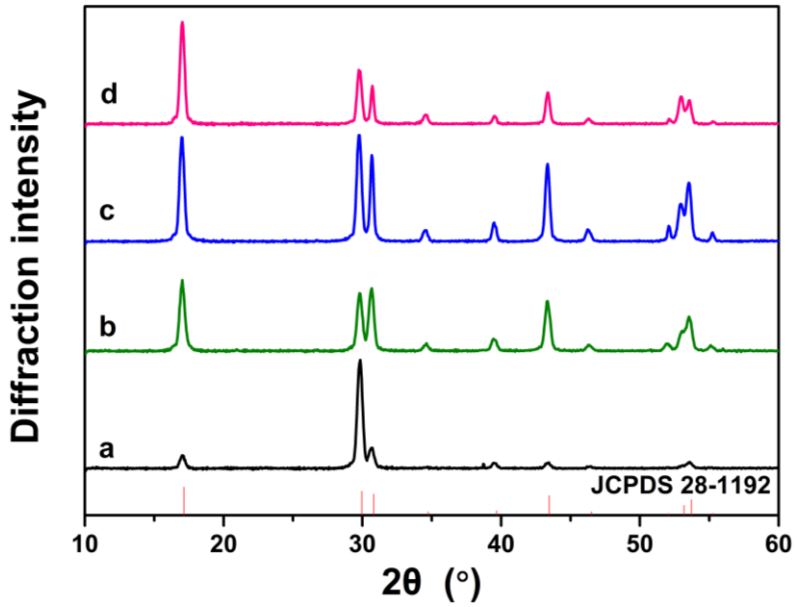

Figure S4. XRD patterns of $NaYF_4$:Yb,Tm UCNPs synthesized at various ratios of OA to ODE of (a) 2:19, (b) 6:15, (c) 15:6, and (d) 19:2, respectively.

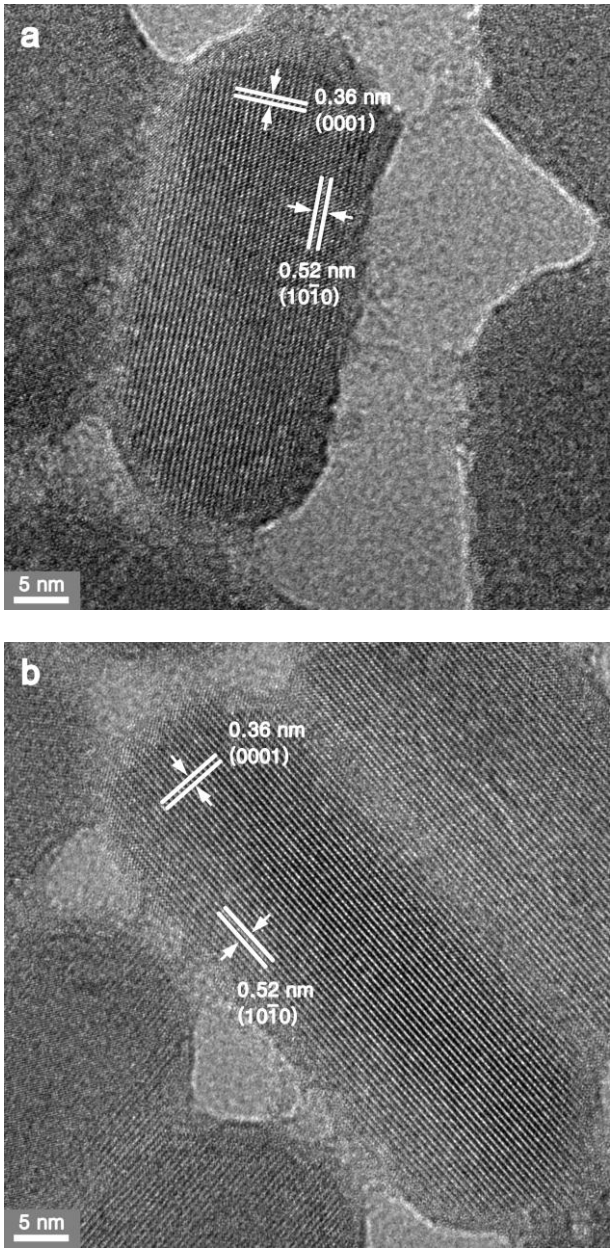

Figure S5. HR-TEM image of a β-$NaYF_4$:Yb,Tm UCNRs synthesized at various ratios of OA to ODE of (a) 15:6 and (b) 19:2.

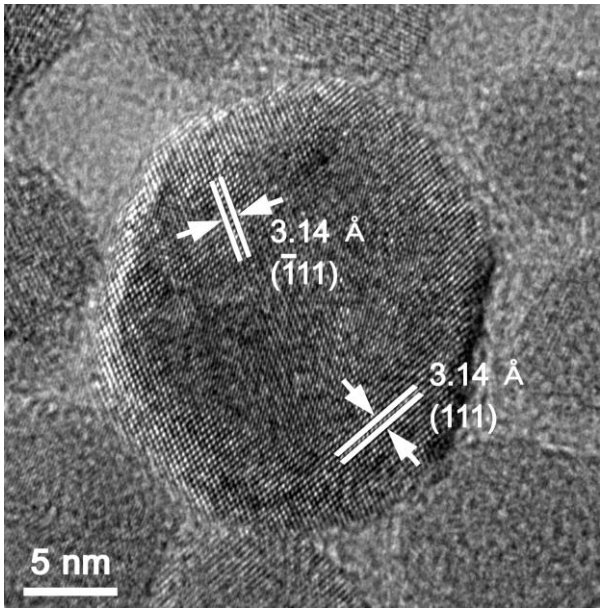

Figure S6. HR-TEM image of a $NaYF_4$:Yb,Er polyhedron synthesized with 3.0 mmol of Cl^- ions.

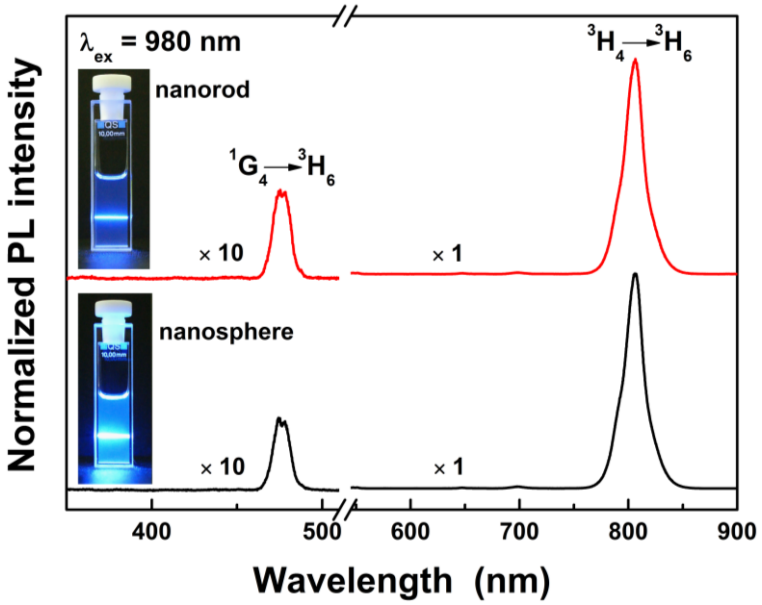

Figure S7. PL spectra of β-$NaYF_4$:Yb,Tm nanospheres and nanorods under the excitation of 980 nm. Insets show photographs showing upconversion blue luminescence from the β-$NaYF_4$:Yb,Tm nanospheres and nanorods.

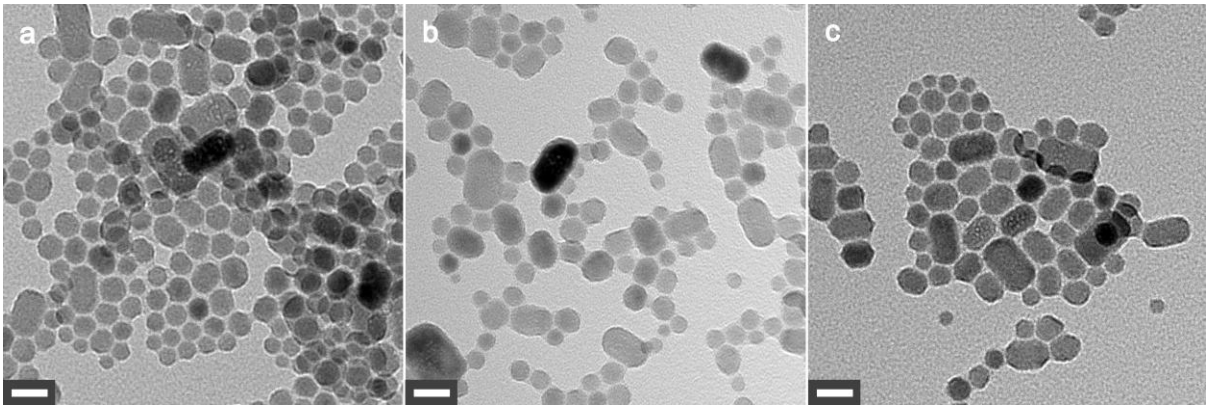

Figure S8. TEM images of β-$NaYF_4$:Yb,Er,Gd UCNPs with varying Gd amount of (a) 0.4 mmol, (b) 0.6 mmol, and (c) 0.8 mmol (that is β-$NaGdF_4$:Yb,Er), respectively. Scale bars represent 20 nm.

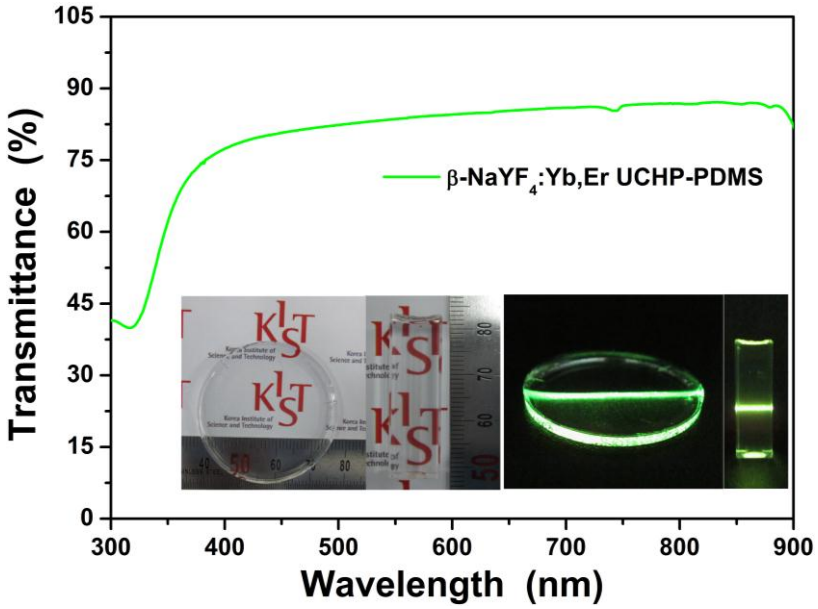

Figure S9. Transmittance spectrum of β-$NaYF_4$:Yb,Er upconversion hexagonal prism (UCHP)-PDMS composite. Inset shows prepared UCHP-PDMS disk and bar under room light (left) and under NIR laser (right).

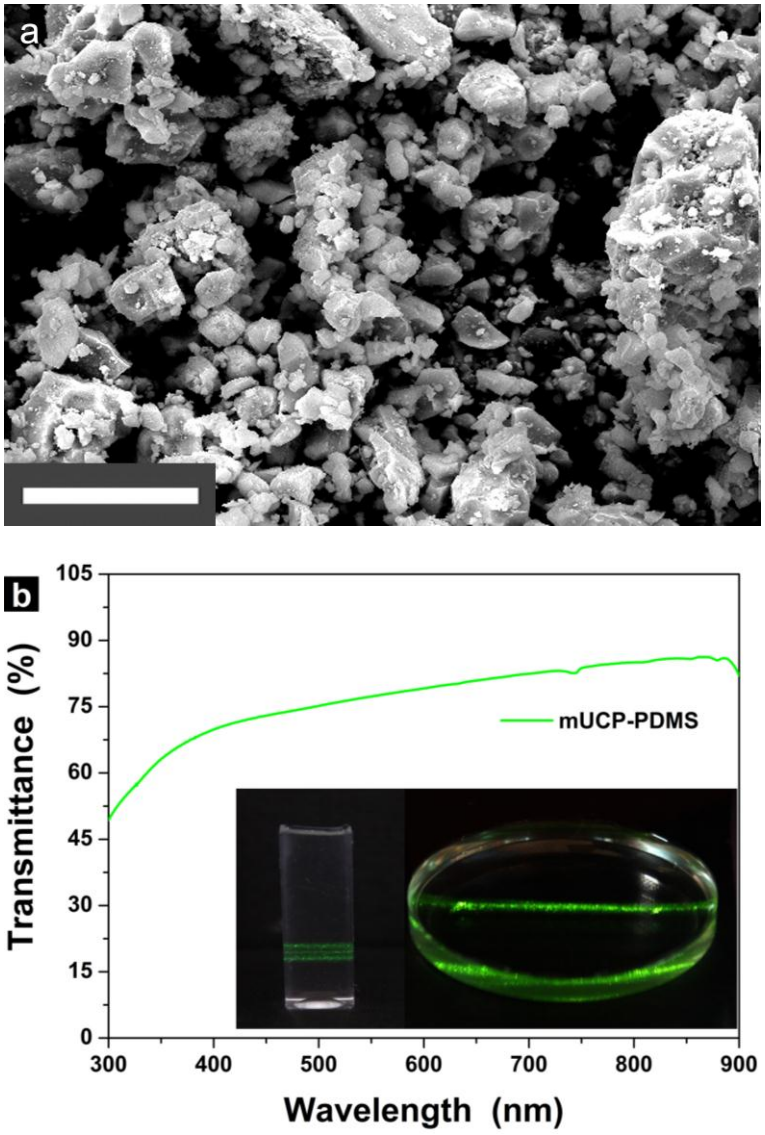

Figure S10. (a) Scanning electron microscopy image of micrometer-sized upconversion phosphor (mUCP) and (b) transmittance spectrum of mUCP-PDMS composite. Inset shows prepared mUCP-PDMS bar (left) and disk (right) under NIR laser. Scale bar represents 10 μm.

Table S1. Shape, size, and aspect ratio (AR) of β-$NaYF_4$:Yb,Tm UCNPs synthesized at various ratios of OA to ODE. (L: length and W: width)

OA:ODE	shape	size	AR
2:19	sphere	22.4 ± 0.9 nm	-
6:15	sphere	19.6 ± 0.7 nm	-
15:6	rod	L = 47.1 ± 1.0 nm W = 22.4 ± 0.9 nm	2.11 ± 0.09
19:2	rod	L = 58.7 ± 1.7 nm W = 23.8 ± 1.1 nm	2.47 ± 0.12

Table S2. Shape, size, and aspect ratio (AR) of β-$NaYF_4$:Yb,Er UCNPs with varying Cl^- amount. (L: length and W: width)

Cl^- amount (mmol)	shape	size	AR
0	rod	L = 60.1 ± 1.6 nm W = 21.5 ± 0.9 nm	2.80 ± 0.10
2.5	hexagonal prism	L = 52.9 ± 1.5 nm W = 35.1 ± 2.3 nm	1.51 ± 0.11
2.7	hexagonal prism	L = 48.8 ± 1.6 nm W = 44.0 ± 2.8 nm	1.11 ± 0.08
3.0	sphere/polyhedron	12.0 ± 4.9 nm	-

Table S3. Shape, size, and aspect ratio (AR) of β-$NaYF_4$:Yb,Er,Ce UCNRs with varying Ce amount. (L: length and W: width)

Ce amount (mmol)	shape	size	AR
0	rod	L = 60.1 ± 1.6 nm W = 21.5 ± 0.9 nm	2.80 ± 0.10
0.05	rod	L = 49.0 ± 1.7 nm W = 27.6 ± 1.4 nm	1.78 ± 0.09
0.1	rod	L = 42.3 ± 1.1 nm W = 29.8 ± 1.3 nm	1.42 ± 0.08
0.15	rod	L = 48.9 ± 1.7 nm W = 38.6 ± 1.8 nm	1.27 ± 0.07